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USMMA Historic District Property Maintenance and Repair Manual

Volume 2 – Concrete Elements

Sunny E. Adams and Adam D. Smith

June 2018

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Cover Photo: Close-up of existing masonry repair at United States Merchant Marine Academy that should be corrected (ERDC-CERL, 2015).

USMMA Historic District Property Maintenance and Repair Manual

Volume 2 – Concrete 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.....	v
Preface	ix
Foreword	x
1 Concrete Elements	1
1.1 Concrete block	1
1.1.1 <i>Immediate concerns for concrete block</i>	1
1.1.2 <i>Guidelines, briefs, bulletins, and sources for concrete block</i>	20
1.1.2.1 Concrete block's characteristics, uses, and problems (GSA January 2017a).....	21
1.1.2.2 Preservation of concrete (Gaudette and Slaton 2007 – Preservation Brief #15).....	23
1.1.2.3 Dangers of abrasive cleaning (Grimmer 1979 – Preservation Brief #6)	38
1.1.2.4 Types of cracks and causes (GSA 2016a)	47
1.1.2.5 Repairing cracks with epoxy resin. (GSA 2016b)	50
1.1.2.6 Removing efflorescence (GSA 2016c).....	55
1.1.2.7 Patching spalls (GSA 2017b)	60
1.1.2.8 Patching scaling (GSA 2017c).....	63
1.1.2.9 Guidelines for cutting and patching (GSA 2016d)	66
1.1.2.10 Patching chips and cracks (GSA 2017d)	72
1.1.2.11 Removing bronze and copper stains (GSA 2016e).....	75
1.1.2.12 Removing surface dirt (GSA 2016f)	78
1.1.2.13 Removing mildew stains (GSA 2017e)	81
1.1.2.14 Removing moss stains (GSA 2016g)	84
1.1.2.15 Using substitute exterior materials (Park 1988 – Preservation Brief #16)	88
1.2 Precast concrete / cast stone.....	99
1.2.1 <i>Immediate concerns for precast concrete / cast stone</i>	99
1.2.2 <i>Guidelines, briefs, bulletins, and sources for precast concrete / cast stone</i>	106
1.2.2.1 Cast stone characteristics, uses, and problems (GSA 2016h).....	107
1.2.2.2 Maintenance, repair, and replacement of historic cast stone (Pieper 2001 – Preservation Brief #42)	109
1.3 Concrete – cast stone posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins	118
1.3.1 <i>Immediate concerns for concrete posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins</i>	118
1.3.2 <i>Guidelines, briefs, bulletins, and sources for cast posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins</i>	133
1.3.2.1 Maintenance, repair, and replacement of historic cast stone (Pieper 2001 – Preservation Brief #42)	134
1.3.2.2 Removing and replacing deteriorated cast stone balusters (GSA 2014).....	143
1.4 Preservation and rehabilitation guidelines for historic concrete.....	149
1.5 Maintenance / management for historic concrete.....	155
References.....	159

Report Documentation Page

Figures and Tables

Figures

Figure 1. Crack in mortar at the library needs to be examined by a structural engineer (ERDC-CERL, 2015).	4
Figure 2. Stair-step cracks and major cracks in concrete block walls need to be examined by a structural engineer (ERDC-CERL, 2015).	4
Figure 3. Close-up of stair-step crack that needs to be examined and patched with appropriate historic materials (ERDC-CERL, 2015).	5
Figure 4. Missing mortar and damaged concrete block needs to be addressed to stop water infiltration (ERDC-CERL, 2015).	5
Figure 5. Inappropriate replacement mortar on concrete block needs to be addressed and corrected for the concrete block to perform correctly and for visual appearances of the historic material (ERDC-CERL, 2015).	6
Figure 6. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).	6
Figure 7. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).	7
Figure 8. Inappropriate mortar on concrete block above cast-stone doorways needs to be addressed and corrected for the concrete block to perform correctly and for visual appearances of the historic material (ERDC-CERL, 2015).	7
Figure 9. Multiple issues regarding the concrete block including, inappropriate epoxy, missing mortar, moisture on concrete, and efflorescence on concrete (ERDC-CERL, 2015).	8
Figure 10. Inappropriate mortar and epoxy has been used to seal minor cracks. This needs to be addressed and corrected for the concrete block to perform correctly and for visual appearances of the historic material (EDRC-CERL, 2015).	8
Figure 11. Cracks and inappropriate mortar replacement on concrete block needs to be addressed (ERDC-CERL, 2015).	9
Figure 12. Walls show the presence of an inappropriate sealer that has stained and colored the concrete block; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).	9
Figure 13. Efflorescence covering the entire concrete block wall and a long vertical crack spanning the height of the wall (indicated by the red box) (ERDC-CERL, 2015).	10
Figure 14. Efflorescence on the concrete blocks should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).	10
Figure 15. Moisture infiltration from the roof has discolored the parapet wall, while water runoff from the metal windows has discolored the concrete block below the windows (ERDC-CERL, 2015).	11
Figure 16. Efflorescence on the concrete blocks should be removed with the gentlest cleaning method per guidelines, and the source of the water infiltration (leaking gutter in this case) needs to be addressed to correct this problem (ERDC-CERL, 2015).	11

Figure 17. Example of not in-kind colored and applied mortar on concrete block and painting of the concrete block in a nonhistoric manner (ERDC-CERL, 2015).	12
Figure 18. Inappropriate concrete block replacement is not in-kind to the original in color, texture, or mortar (ERDC-CERL, 2015).	12
Figure 19. Inappropriate replacement of the concrete block (ERDC-CERL, 2015).	13
Figure 20. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).	13
Figure 21. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).	14
Figure 22. Maintain the character of the randomly painted blocks and clean with the gentlest method provided in the guidelines (ERDC-CERL, 2015).	14
Figure 23. Inappropriate concrete block replacement is not in-kind to the original in color, texture, or mortar (ERDC-CERL, 2015).	15
Figure 24. Recently painted concrete block with peeling paint and damaged concrete block pieces, which should be replaced with material compatible with the original material (ERDC-CERL, 2015).	15
Figure 25. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).	16
Figure 26. Surface dirt and efflorescence is covering the entire concrete block wall (ERDC-CERL, 2015).	16
Figure 27. Cleaning the stains off the concrete block surface must be performed with the gentlest cleaning methods outlined in the guidelines (ERDC-CERL, 2015).	17
Figure 28. Staining of concrete block due to metal windows more than likely can only be remediated by replacing the windows (ERDC-CERL, 2015).	17
Figure 29. Inspect all gutters and downspouts and identify areas of moisture penetration (ERDC-CERL, 2015).	18
Figure 30. Inspect all gutters and downspouts to ensure they are working properly and not allowing water to stand on or penetrate historic materials (ERDC-CERL, 2015).	18
Figure 31. Efflorescence on the concrete blocks should be removed with the gentlest cleaning method per guidelines, and vegetation should be cleared from touching the historic material surface (ERDC-CERL, 2015).	19
Figure 32. Remove water-entrapping vegetation from or near concrete block walls (ERDC-CERL, 2015).	19
Figure 33. Inappropriate treatment on expansion joint leading to staining below on the library (ERDC-CERL, 2015).	100
Figure 34. Incorrect mortar or epoxy fill has been used for repairs (ERDC-CERL, 2015).	101
Figure 35. Cracks and flaking are apparent on the precast concrete/cast stone elements. Major cracks should be examined by a structural engineer (ERDC-CERL, 2015).	101
Figure 36. Walls show the presence of an inappropriate sealer that has stained and colored the precast concrete/cast stone panels; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).	102

Figure 37. Other walls also show the presence of an inappropriate sealer that has stained and colored the precast concrete/cast stone; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).....	102
Figure 38. Precast/cast stone panel walls show the presence of surface dirt and efflorescence; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).....	103
Figure 39. Surface dirt should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).	103
Figure 40. Surface dirt on precast concrete / cast stone architectural features should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).	104
Figure 41. Surface dirt and staining from metal handrail should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).....	104
Figure 42. Staining should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).....	105
Figure 43. Damaged mortar should be replaced with material compatible with the original material, and all natural growth should be removed (ERDC-CERL, 2015).....	105
Figure 44. Damaged precast concrete/cast stone elements should be replaced using materials compatible with original materials (ERDC-CERL, 2015).....	121
Figure 45. Damaged concrete should be patched with in-kind material and finished to match existing material (ERDC-CERL, 2015).	121
Figure 46. Damaged concrete should be patched with in-kind material finished to match the existing (ERDC-CERL, 2015).....	122
Figure 47. Spalling in precast concrete/cast stone should be repaired in accordance with the standards (ERDC-CERL, 2015).....	122
Figure 48. Formerly repaired spalls that do not meet the standards should be repaired in accordance with the standards (ERDC-CERL, 2015).....	123
Figure 49. Spalling in precast concrete/cast stone should be repaired in accordance with the standards (ERDC-CERL, 2015).....	123
Figure 50. Spalling concrete should be repaired in accordance with the standards (ERDC-CERL, 2015).	124
Figure 51. Inappropriate epoxy and mortar has been used to fill joints of precast concrete/cast stone elements (ERDC-CERL, 2015).	124
Figure 52. Improper patching material was used (ERDC-CERL, 2015).....	125
Figure 53. Visible sealant should be removed and replaced with appropriate epoxy resin (ERDC-CERL, 2015).	125
Figure 54. Cracks in cast concrete should be repaired (ERDC-CERL, 2015).....	126
Figure 55. Cracks should be patched by injecting epoxy resin according to the standards and guidelines (ERDC-CERL, 2015).	126
Figure 56. Missing stucco from precast concrete/cast stone should be repaired; however, the cause for it failing should be investigated since it might be a failure in the concrete system (ERDC-CERL, 2015).	127
Figure 57. Efflorescence and surface dirt should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).....	127

Figure 58. Efflorescence and surface dirt should be removed with the gentlest cleaning method per guidelines. [Note that the efflorescence on O'Hara is due to water pooling on the roof behind the parapet] (ERDC-CERL, 2015).	128
Figure 59. Efflorescence and surface dirt should be removed with the gentlest cleaning method per guidelines. [Note that the efflorescence on O'Hara is due to water pooling on the roof behind the parapet.] (ERDC-CERL, 2015).	128
Figure 60. Efflorescence and surface dirt on cornice and beltcourse should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).	129
Figure 61. Efflorescence on cornice should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).	129
Figure 62. Efflorescence on precast concrete/cast stone columns and capitals should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).	130
Figure 63. precast concrete/cast stone quoins show the presence of an inappropriate sealer that has stained and colored the concrete elements; the gentlest cleaning method per guidelines should be performed on these surfaces (ERDC-CERL, 2015).	130
Figure 64. Concrete block walls and precast concrete/cast stone beltcourse and cornice show the presence of an inappropriate sealer that has stained and colored the concrete elements, the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2013).	131
Figure 65. Surface dirt on precast concrete/cast stone elements such as the cornice should be removed with gentlest cleaning method per guidelines (ERDC-CERL, 2015).	131
Figure 66. Surface dirt on precast concrete/cast stone elements like the door pediments should be removed with gentlest cleaning method per guidelines (ERDC-CERL, 2015).	132
Figure 67. Moisture present on material (ERDC-CERL, 2015).	132
Figure 68. Biological growth should be removed the stairs using the gentlest cleaning method (ERDC-CERL, 2015).	133

Tables

Table 1. Preservation treatment for concrete (Grimmer 2017, 31–36).	150
Table 2. Rehabilitation as a treatment for concrete (Grimmer 2017, 80–87).	153

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 Dr. 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 2 of 8, and it covers guidance for proper maintenance and repair of historic concrete 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

1 Concrete 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 Concrete block

Several of the USMMAHD contributing buildings were constructed with a cast-in-place structure and buff-colored concrete block exterior walls in a distinctive stone-like pattern.

Major signs of concrete deterioration include cracking, spalling, deflection, stains, erosion, and corrosion. Whatever the causes of deterioration, careful analysis, supplemented by testing is vital to the success of any historic concrete repair project. Repair of historic concrete block may consist of either patching the historic material or filling in with new material worked to match the historic material. If replacement is necessary, duplication of historic materials and detailing should be as exact as possible to ensure a repair that is functionally and aesthetically acceptable.

1.1.1 Immediate concerns for concrete block

Deterioration of concrete can be caused by environmental factors, inferior materials, poor workmanship, inherent structural design defects, and inadequate maintenance. Environmental factors are a principal source of concrete deterioration. Concrete absorbs moisture readily, and this is particularly troublesome in regions of recurrent freeze-thaw cycles. Freezing water produces expansive pressure in the cement paste or in nondurable aggregates (Gaudette and Slaton 2007).

Improper maintenance of historic buildings can cause long-term deterioration of concrete. Water is a principal source of damage to historic concrete, and prolonged exposure to it can cause serious problems. Unrepaired roof and plumbing leaks, leaks through exterior cladding, and

unchecked absorption of water from damp earth are potential sources of building damage (Gaudette and Slaton 2007).

The following bullet points are examples with references to photographs of deterioration, damage, and other issues. Of course, it is possible for a building to exhibit more than one type of issue, but any one of these issues is cause for remediation.

- Walls have cracks that look like stair steps, (Figure 1 and Figure 2).
- Structural cracks should be examined a structural engineer (Figure 2, Figure 3, and Figure 13).
- Concrete blocks are cracked or broken; calculated maximum crack width for concrete should not exceed .3 mm (Figure 2, Figure 3, Figure 4, and Figure 5).
- Mortar is missing or crumbling between concrete block, which accelerates water infiltration (Figure 4 and Figure 5).
- Concrete blocks are showing signs of spalling (Figure 6 and Figure 7).
- Damaged concrete should be replaced with material compatible with the original material (Figure 6 and Figure 7).
- Incorrect mortar or epoxy fill has been used for inappropriate repairs (Figure 8–Figure 11, and Figure 17).
- Epoxy injection should be used for dormant cracks (i.e., cracks that remain unchanged). Dormant cracks generally pose little danger unless left unrepaired, in which case they will provide channels for moisture penetration.
- Walls show efflorescence, a white powdery substance leaching between the concrete blocks (Figure 9, Figure 13, Figure 14, Figure 15, Figure 16, and Figure 31).
- Inappropriate concrete block element replacement is not in-kind to the original and needs to be addressed (Figure 8, Figure 17, Figure 18, Figure 19, and Figure 23).
- Missing or severely damaged concrete blocks need to be replaced with in-kind materials and should not be left unfinished (Figure 20, Figure 21, Figure 24, and Figure 25).

- Painted concrete blocks need to be cleaned according to the guidelines by not damaging the painted blocks (Figure 22–Figure 25).
- Randomly painted concrete blocks need to be maintained around openings, corners, and within the wall (Figure 22, Figure 23, and Figure 25).
- When repainting is needed for concrete block, it must match the original (Figure 25).
- Peeling paint on concrete block surfaces needs to be addressed (Figure 24).
- Several types of stains and surface dirt were identified on the surface of the concrete blocks; cleaning should be performed using the gentlest methods outlined in the guidelines (Figure 12, Figure 26–Figure 27).
- Concrete blocks that appear wet, indicating a moisture problem within the wall and material and areas of moisture penetration (where concrete block appears to be wet) should be identified (Figure 28–Figure 30).
- Check to see that all gutters, downspouts, and other water run-off systems are in good repair and clear of debris (Figure 29 and Figure 30).
- Biological growth should be removed from the surface of concrete block walls (Figure 31 and Figure 32).
- Vegetation such as trees and shrubbery should be kept trimmed so that it is not touching concrete block, and/or (Figure 32).
- Water-entrapping vegetation from or near the concrete walls should be removed, and/or (Figure 31 and Figure 32).
- Any maintenance of the concrete block is to be executed by a qualified professional.
- Any existing condition with long-term impact (beyond 5 years) should be noted for repair.

Figure 1. Crack in mortar at the library needs to be examined by a structural engineer (ERDC-CERL, 2015).

Figure 2. Stair-step cracks and major cracks in concrete block walls need to be examined by a structural engineer (ERDC-CERL, 2015).

Figure 3. Close-up of stair-step crack that needs to be examined and patched with appropriate historic materials (ERDC-CERL, 2015).

Figure 4. Missing mortar and damaged concrete block needs to be addressed to stop water infiltration (ERDC-CERL, 2015).

Figure 5. Inappropriate replacement mortar on concrete block needs to be addressed and corrected for the concrete block to perform correctly and for visual appearances of the historic material (ERDC-CERL, 2015).

Figure 6. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).

Figure 7. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).

Figure 8. Inappropriate mortar on concrete block above cast-stone doorways needs to be addressed and corrected for the concrete block to perform correctly and for visual appearances of the historic material (ERDC-CERL, 2015).

Figure 9. Multiple issues regarding the concrete block including, inappropriate epoxy, missing mortar, moisture on concrete, and efflorescence on concrete (ERDC-CERL, 2015).

Figure 10. Inappropriate mortar and epoxy has been used to seal minor cracks. This needs to be addressed and corrected for the concrete block to perform correctly and for visual appearances of the historic material (EDRC-CERL, 2015).

Figure 11. Cracks and inappropriate mortar replacement on concrete block needs to be addressed (ERDC-CERL, 2015).

Figure 12. Walls show the presence of an inappropriate sealer that has stained and colored the concrete block; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).

Figure 13. Efflorescence covering the entire concrete block wall and a long vertical crack spanning the height of the wall (indicated by the red box) (ERDC-CERL, 2015).

Figure 14. Efflorescence on the concrete blocks should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 15. Moisture infiltration from the roof has discolored the parapet wall, while water runoff from the metal windows has discolored the concrete block below the windows (ERDC-CERL, 2015).

Figure 16. Efflorescence on the concrete blocks should be removed with the gentlest cleaning method per guidelines, and the source of the water infiltration (leaking gutter in this case) needs to be addressed to correct this problem (ERDC-CERL, 2015).

It appears that the multiple issues on the concrete block parapets and walls below the parapets are due to the issues regarding pooling water on the built-up roof behind the parapets. Please refer to the roofing volume for further information (Volume 6 of this report).

Figure 17. Example of not in-kind colored and applied mortar on concrete block and painting of the concrete block in a nonhistoric manner (ERDC-CERL, 2015).

Figure 18. Inappropriate concrete block replacement is not in-kind to the original in color, texture, or mortar (ERDC-CERL, 2015).

Figure 19. Inappropriate replacement of the concrete block (ERDC-CERL, 2015).

Figure 20. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).

Figure 21. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).

Figure 22. Maintain the character of the randomly painted blocks and clean with the gentlest method provided in the guidelines (ERDC-CERL, 2015).

Figure 23. Inappropriate concrete block replacement is not in-kind to the original in color, texture, or mortar (ERDC-CERL, 2015).

Figure 24. Recently painted concrete block with peeling paint and damaged concrete block pieces, which should be replaced with material compatible with the original material (ERDC-CERL, 2015).

Figure 25. Damaged concrete should be replaced with material compatible with the original material (ERDC-CERL, 2015).

Figure 26. Surface dirt and efflorescence is covering the entire concrete block wall (ERDC-CERL, 2015).

Figure 27. Cleaning the stains off the concrete block surface must be performed with the gentlest cleaning methods outlined in the guidelines (ERDC-CERL, 2015).

Figure 28. Staining of concrete block due to metal windows more than likely can only be remediated by replacing the windows (ERDC-CERL, 2015).

Figure 29. Inspect all gutters and downspouts and identify areas of moisture penetration (ERDC-CERL, 2015).

Figure 30. Inspect all gutters and downspouts to ensure they are working properly and not allowing water to stand on or penetrate historic materials (ERDC-CERL, 2015).

Figure 31. Efflorescence on the concrete blocks should be removed with the gentlest cleaning method per guidelines, and vegetation should be cleared from touching the historic material surface (ERDC-CERL, 2015).

Figure 32. Remove water-entrapping vegetation from or near concrete block walls (ERDC-CERL, 2015).

1.1.2 Guidelines, briefs, bulletins, and sources for concrete block

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 for caring for, preserving, and rehabilitating historic buildings, with emphasis on historic concrete block (see subsections 1.1.2.1–1.1.2.15).

1.1.2.1 Concrete block's characteristics, uses, and problems (GSA January 2017a)

Concrete Block: Characteristics, Uses And Problems

Procedure code:

422001G

Source:

20Th Century Building Materials (Ed. Tom Jester, Nps)

Division:

Masonry

Section:

Concrete Unit Masonry

Last Modified:

01/24/2017

This standard includes general information on the characteristics and common uses of concrete block and identifies typical problems associated with this material along with common causes of its deterioration.

Reference: National Park Service Preservation Brief #15: Preservation of Historic Concrete

<https://www.nps.gov/tps/how-to-preserve/briefs/15-concrete.htm>

Characteristics of Concrete Block:

- Made from a mixture of Portland cement, blended cement, various types of aggregates, and water.
- Also referred to as concrete masonry units (CMU).
- Advantages:
 - Inexpensive,
 - Lightweight
 - Durable,
 - Easy to install
 - Fireproof
 - Low maintenance
 - Could be ornamented
- Face plates were used to create a variety of surface finishes, including cobblestone, brick, ashlar and rockface (the most common type); more decorative finishes included designs of scrolls, wreaths and roping.
- Typical size manufactured is nominally for a stretcher block 8 by 8 by 16 inches; this was the standard size manufactured by 1930 (actual dimensions 8 by 7 3/4 by 15 3/4 inches).

- Typical size manufactured is nominally for a stretcher block 8 by 8 by 16 inches; this was the standard size manufactured by 1930 (actual dimensions 8 by 7 3/4 by 15 3/4 inches).
- They may be solid or hollow with two or three cores for such stretcher blocks; various other types of standard shapes are also often available and one should consult the local market to determine availability. Block ends may be flat or flanged.
- Compressive strength and fire resistance of the each block is dependent upon the block's configuration.
- Lightweight aggregates were introduced around 1917 and cinder blocks were patented.
- Advantages of using cinder blocks included its strength, ability to receive nails and ease of installation.
- Lightweight aggregates were either natural materials, by-products or manufactured.
- Natural aggregate materials included pumice.
- By-products aggregate materials included cinders and slag; Pottscor or Celocrete is one example of slag product used around 1930 in the manufacture of blocks; Waylite is another example introduced in the late 1930s.
- Manufactured aggregate materials included expanded shale, clay and slate; Haydite is one example of an expanded shale product used in the early 1920s in the manufacture of blocks.

Typical Uses

- Typical historical uses for concrete block include:
- Foundation walls - typically rockfaced.
- Basement walls.
- Partition walls - usually plainfaced.
- Exterior walls - usually plainfaced and then often covered with stucco.
- Most concrete block was used as a back-up material or for cavity wall construction.
- Coatings are often applied to concrete block in order to prevent water penetration; some of these include Portland cement paints, latex paints, oil- and rubber-based coatings, epoxy coatings, alkyd paints, urethanes and silicones; a single type may be selected for a specific function including its water resistance; other factors to consider might also include its resistance to ultraviolet rays, its breathability, its resistance to alkalis, and its coloration or visual appearance when applied to the block.

Natural or Inherent Problems

- Cracking: Often due to shrinkage of the concrete or movement of the wall.
- Efflorescence: Occurs when accumulations of salt are carried to the surface by water migrating through the masonry.
- Staining: Staining may appear in many forms, including dirt build-up, metallic staining or painted Rising Damp: When ground water enters the wall from the base and migrates upward.

Vandalism and other Human-induced Problems

- Spalling: May be caused by the composition of the concrete mixture, prolonged exposure to water which has infiltrated the wall, or mechanical failure.

1.1.2.2 Preservation of concrete (Gaudette and Slaton 2007 – Preservation Brief #15)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 15 Concrete

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PRESERVATION BRIEFS

15

Preservation of Historic Concrete

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[Introduction to Historic Concrete](#)

[History of Use and Manufacture](#)

[Historic Interiors](#)

[Concrete Characteristics](#)

[Modes of Deterioration](#)

[Concrete Preservation](#)

[Maintenance and Repair](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)

Introduction to Historic Concrete

Concrete is an extraordinarily versatile building material used for utilitarian, ornamental, and monumental structures since ancient times. Composed of a mixture of sand, gravel, crushed stone, or other coarse material, bound together with lime or cement, concrete undergoes a chemical reaction and hardens when water is added. Inserting reinforcement adds tensile strength to structural concrete elements. The use of reinforcement contributes significantly to the range and size of building and structure types that can be constructed with concrete.

While early twentieth century proponents of modern concrete often considered it to be permanent, it is, like all materials, subject to deterioration. This Brief provides an overview of the history of concrete and its popularization in the United States, surveys the principal causes and modes of concrete deterioration, and outlines approaches to repair and protection that are appropriate to historic concrete. In the context of this Brief, historic concrete is considered to be concrete used in construction of structures of historical, architectural, or engineering interest, whether those structures are old or relatively new.

Brief History of Use and Manufacture

The ancient Romans found that a mixture of lime putty and pozzolana, a fine volcanic ash, would harden under water. The resulting hydraulic cement became a major feature of Roman building practice, and was used in many buildings and engineering projects such as bridges and aqueducts. Concrete technology was kept alive during the Middle Ages in Spain and Africa. The Spanish introduced a form of concrete to the New World in the first decades of the sixteenth century, referred to as “tapia” or “tabby.” This material, a mixture of lime, sand, and shell or stone aggregate mixed with water, was placed between wooden forms, tamped, and allowed to dry in successive layers. Tabby was later used by the English settlers in the coastal southeastern United States.

Figure 1. The Sebastopol House in Seguin, Texas, is an 1856 Greek Revival-style house constructed of lime concrete. Lime concrete or "limecrete" was a popular construction material, as it could be made inexpensively from local materials. By 1900, the town had approximately ninety limecrete structures, twenty of which remain. Photo: Texas Parks and Wildlife Department.

The early history of concrete was fragmented, with developments in materials and construction techniques occurring on different continents and in various countries. In the United States, concrete was slow in achieving widespread acceptance in building construction and did not begin to gain popularity until the late nineteenth century. It was more readily accepted for use in transportation and infrastructure systems.

The Erie Canal in New York is an example of the early use of concrete in transportation in the United States. The natural hydraulic cement used in the canal construction was processed from a deposit of limestone found in 1818 near Chittenango, southeast of Syracuse. The use of concrete in residential construction was publicized in the second edition of Orson S. Fowler's *A Home for All* (1853) which described the advantages of "gravel wall" construction to a wide audience. The town of Seguin, Texas, thirty-five miles east of San Antonio, already had a number of concrete buildings by the 1850s and came to be called "The Mother of Concrete Cities," with approximately ninety concrete buildings made from local "lime water" and gravel (Figure 1).

Impressed by the economic advantages of poured gravel wall or "lime-grout" construction, the Quartermaster General's Office of the War Department embarked on a campaign to improve the quality of building for frontier military posts. As a result, lime-grout structures were constructed at several western posts soon after the Civil War, including Fort Fred Steele and Fort Laramie, both in Wyoming (Figure 2). By the 1880s, sufficient experience had been gained with unreinforced concrete to permit construction of much larger buildings. A notable example from this period is the Ponce de Leon Hotel in St. Augustine, Florida.

Figure 2. Chatterton House was the home of the post trader at Fort Fred Steele in Wyoming, one of several forts established in the 1860s to protect the Union Pacific Railroad. The walls of the post trader's house were built using stone aggregate and lime, without cement. The use of this material presents special preservation challenges.

Figure 3. The Lincoln Highway Association promoted construction of a high quality continuous hard surface roadway across the country. The Boys Scouts of America installed concrete road markers along the Lincoln Highway in 1928.

Extensive construction in concrete also occurred through the system of coastal fortifications commissioned by the federal government in the 1890s for the Atlantic, Pacific, and Gulf coasts. Unlike most concrete construction to that time, the special requirements of coastal fortifications called for concrete walls as much as 20 feet thick, often at sites that were difficult to access. Major structures in the coastal defenses of the 1890s were built of mass concrete with no internal reinforcing, a practice that was replaced by the use of reinforcing bars in fortifications constructed after about 1905.

The use of reinforced concrete in the United States dates from 1860, when S.T. Fowler obtained a patent for a reinforced concrete wall. In the early 1870s, William E. Ward built his own house in Port Chester, New York, using concrete reinforced with iron rods for all structural elements. Despite these developments, such

construction remained a novelty until after 1880, when innovations introduced by Ernest L. Ransome made the use of reinforced concrete more practicable. Ransome made many contributions to the development of concrete construction technology, including the use of twisted reinforcing bars to improve bond between the concrete and the steel, which he patented in 1884. Two years later, Ransome introduced the rotary kiln to United States cement production. The new kiln had greater capacity and burned more thoroughly and uniformly, allowing development of a less expensive, more uniform, and more reliable manufactured cement. Improvements in concrete production initiated by Ransom led to a much greater acceptance of concrete after 1900.

The Lincoln Highway Association, incorporated in 1913, promoted the use of concrete in construction of a coast-to-coast roadway system. The goal of the Lincoln Highway Association and highway advocate Henry B. Joy was to educate the country in the need for good roads made of concrete, with an improved Lincoln Highway as an example. Concrete "seedling miles" were constructed in remote areas to emphasize the superiority of concrete over unimproved dirt. The Association believed that as people learned about concrete, they would press the government to construct good roads throughout their states. Americans' enthusiasm for good roads led to the involvement of the federal government in road-building and the creation of numbered U.S. routes in the 1920s (Figure 3).

During the early twentieth century, Ernest Ransome in Beverly, Massachusetts, Albert

Figure 5. Following World War II, architects and engineers took advantage of improvements in concrete production, quality control, and advances in precast concrete to design structures such as the Police Headquarters building in Philadelphia, Pennsylvania, constructed in 1961. Photo: Courtesy of the Philadelphia Police Department.

Figure 4. The highly ornamental concrete panels on the exterior facade of the Baha'i House of Worship in Wilmette, Illinois, illustrate the work of fabricator John J. Earley, known as "the man who made concrete beautiful."

Kahn in Detroit, and Richard E. Schmidt in Chicago, promoted concrete for use in "Factory Style" utilitarian buildings with an exposed concrete frame infilled with expanses of glass. Thomas Edison's cast-in-place reinforced concrete homes in Union Township, New Jersey (1908), proclaimed a similarly functional emphasis in residential construction. From the 1920s onward, concrete began to be used with spectacular design results: examples include John J. Earley's Meridian Hill Park in Washington, D.C.; Louis Bourgeois' exuberant, graceful Baha'i Temple in Wilmette, Illinois (1920

–1953), for which Earley fabricated the concrete (Figure 4); and Frank Lloyd Wright's Fallingwater near Bear Run, Pennsylvania (1934). Continuing improvements in quality control and development of innovative fabrication processes, such as the Shockbeton method for precast concrete, provided increasing opportunities for architects and engineers. Wright's Guggenheim Museum in New York City (1959); Geddes Brecher Qualls & Cunningham's Police Headquarters building in Philadelphia, Pennsylvania (1961); and Eero Saarinen's soaring terminal building at Dulles International Airport outside Washington, D.C., and the TWA terminal at Kennedy Airport in New York (1962), exemplify the masterful use of concrete achieved in the modern era (Figure 5).

Throughout the twentieth century, a wide range of architectural and engineering structures were built using concrete as a practical and cost-effective choice—and concrete also became valued for its aesthetic qualities. Cast in place and precast concrete were readily adapted to the Streamlined Moderne style, as exemplified by the Bailey Magnet School in Jackson, Mississippi, designed as the Jackson Junior High School by N. W. Overstreet & Town in 1936 (Figs. 6 and 7). The school is one of many concrete buildings designed and constructed under the auspices of the Public Works Administration. Recreational structures and landscape features also utilized the structural range and unique character of exposed concrete to advantage, as seen in Chicago's Lincoln Park Chess Pavilion, designed by Morris Webster in 1956 (Figure 8), and the Ira C. Keller Fountain in Portland Oregon, designed by Lawrence Halprin in 1969 (Figure 9). Concrete was also popular for building interiors, with ornamental features and exposed structural elements recognized as part of the design aesthetic (See Figs. 10 and 11).

Figure 7. Detailed bas-reliefs as well as sculptures, such as this lion at the Bailey Magnet School, could be used as ornamentation on concrete buildings. Sculptural concrete elements were typically cast in molds.

Figure 6. The Bailey Magnet School in Jackson, Mississippi, was designed as the Jackson Junior High School by the firm of N. W. Overstreet & Town in 1936. The streamlined building exemplifies the applicability of concrete to creating a modern architectural aesthetic. Photo: Bill Burris, Burris/Wagnon Architects, P.A.

Historic Interiors

Figure 10. The Berkeley City Club has significant interior spaces and features of concrete construction, including the lobby and pool. Photos: Una Gilmartin (left) and Brian Kehoe (right), Wiss, Janney, Elstner Associates, Inc.

The expanded use of concrete provided new opportunities to create dramatic spaces and ornate architectural detail on the interiors of buildings, at a significant cost savings over traditional construction practices. The architectural design of the Berkeley City Club in Berkeley, California, expressed Moorish and Gothic elements in concrete on the interior of the building (Figure 10). Used as a woman's social club, the building was designed by noted California architect Julia Morgan and constructed in 1929. The vaulted ceilings, columns, and ornamental capitals of the lobby and the ornamental arches and beamed ceiling of the "plunge" are all constructed of concrete.

The historic character of a building's interior can also be conveyed in a more utilitarian

manner in terms of concrete features and finishes (Figure 11). The exposed concrete structure—columns, capitals, and drop panels—is an integral part of the character of this old commercial building in Minneapolis. In concrete warehouse and factory buildings of the early twentieth century, exposed concrete columns and formboard finish concrete slab ceilings are common features as seen in this warehouse, now converted for use as a parking garage and shops.

Figure 11. Whether in a circa 1925 office (left) or in a parking garage and retail facility (right), exposed concrete structures help characterize these building interiors. Photo: Minnesota Historical Society (left).

Concrete Characteristics

Concrete is composed of fine (sand) and coarse (crushed stone or gravel) aggregates and paste made of portland cement and water. The predominant material in terms of bulk is the aggregate. Portland cement is the binder most commonly used in modern concrete. It is commercially manufactured by blending limestone or chalk with clays that contain alumina, silica, lime, iron oxide and magnesia, and heating the compounds together to high temperatures. The hydration process that occurs between the portland cement and water results in formation of an alkali paste that surrounds and binds the aggregate together as a solid mass.

The quality of the concrete is dependent on the ratio of water to the binder; binder content; sound, durable, and well-graded aggregates; compaction during placement; and proper curing. The amount of water used in the mix affects the concrete permeability and strength. The use of excess water beyond that required in the hydration process results in more permeable concrete, which is more susceptible to weathering and deterioration. Admixtures are commonly added to concrete to adjust concrete properties such as setting or hardening time, requirements for water, workability, and other characteristics. For example, the advent of air entraining agents in the 1930s provided enhanced durability for concrete.

Figure 8. The Chess Pavilion in Chicago's Lincoln Park was designed by architect Morris Webster and constructed in 1956. The pavilion is a distinctive landscape feature, with its reinforced concrete cantilevered slab that provides cover for chess players.

Figure 9. The Ira C. Keller Fountain in Portland, Oregon, was designed by Lawrence Halprin and constructed in 1969. The fountain is constructed primarily of concrete pillars with formboard textures and surrounding elements, patterned with geometric lines, which facilitate the path of water. Photo: Anita Washko, Wiss, Janney, Elstner Associates, Inc.

During the twentieth century, there was a steady rise in the strength of ordinary concrete as chemical processes became better understood and quality control measures improved. In addition, the need to protect embedded reinforcement against corrosion was acknowledged. Requirements for concrete cover over reinforcing steel, increased cement content, decreased water-cement ratio, and air entrainment all contributed to greater concrete strength and improved durability.

Mechanisms and Modes of Deterioration

Causes of Deterioration

Concrete deterioration occurs primarily because of corrosion of the embedded steel, degradation of the concrete itself, use of improper techniques or materials in construction, or structural problems. The causes of concrete deterioration must be understood in order to select an appropriate repair and protection system.

While reinforcing steel has played a pivotal role in expanding the applications of concrete in twentieth century architecture, corrosion of this steel has also caused deterioration in many historic structures. Reinforcing steel embedded in the concrete is normally surrounded by a passivating oxide layer that, when present, protects the steel from corrosion and aids in bonding the steel and concrete. When the concrete's normal alkaline environment (above a pH of 10) is compromised and the steel is exposed to water, water vapor, or high relative humidity, corrosion of the steel reinforcing takes place. A reduction in alkalinity results from carbonation, a process that occurs when the carbon dioxide in the atmosphere reacts with calcium hydroxide and moisture in the concrete. Carbonation starts at the concrete's exposed surface but may extend to the reinforcing steel over time. When carbonation reaches the metal reinforcement, the concrete no longer protects the steel from corrosion.

Corrosion of embedded reinforcing steel may be initiated and accelerated if calcium chloride was added to the concrete as a set accelerator during original construction to promote more rapid curing. It may also take place if the concrete is later exposed to deicing salts, as may occur during the winter in northern climates. Seawater or other marine environments can also provide large amounts of chloride, either from inadequately washed original aggregate or from exposure of the concrete to seawater.

Corrosion-related damage to reinforced concrete is the result of rust, a product of the corrosion process of steel, which expands and thus requires more space in the concrete than the steel did at the time of installation. This change in volume of the steel results in expansive forces, which cause cracking and spalling of the adjacent concrete (Figure 12). Other signs of corrosion of embedded steel include delamination of the concrete (planar separations parallel to the surface) and rust staining (often a precursor to spalling) on the concrete near the steel.

Lack of proper maintenance of building elements such as roofs and drainage systems can contribute to water-related deterioration of the adjacent concrete, particularly when concrete is saturated with water and then exposed to freezing temperatures. As water within the concrete freezes, it expands and exerts forces on the adjacent concrete. Repeated freezing and thawing can result in the concrete cracking and delaminating. Such damage appears as surface degradation, including severe scaling and micro-cracking that extends into the concrete. The condition is most often observed near the surface of the concrete but can also eventually occur deep within the concrete. This type of deterioration is usually most severe at joints, architectural details, and other areas with more surface exposure to weather. In the second half of the twentieth century, concrete has utilized entrained air (the incorporation of microscopic air bubbles) to provide enhanced protection against damage due to cyclic freezing of saturated concrete.

The use of certain aggregates can also result in deterioration of the concrete. Alkali-aggregate reactions—in some cases alkali-silica reaction (ASR)—occur when alkalis normally present in cement react with certain aggregates, leading to the development of an expansive crystalline gel. When this gel is exposed to moisture, it expands and causes cracking of the aggregate and concrete matrix. Deleterious aggregates are typically found only in certain areas of the country and can be detected through analysis by an experienced petrographer. Low-alkali cements as well as fly ash are used today in new construction to prevent such reactions where this problem may occur.

Problems Specifically Encountered with Historic Concrete

Materials and workmanship used in the construction of historic concrete structures, particularly those built before the First World War, sometimes present potential sources of problems. For example, where the aggregate consisted of cinder from burned coal or crushed brick, the concrete tends to be weak and porous because these aggregates absorb water. Some of these aggregates can be extremely susceptible to deterioration when exposed to moisture and cyclic freezing and thawing. Concrete was sometimes compromised by inclusion of seawater or beach sand that was not thoroughly washed with fresh water, a condition more common with coastal fortifications built prior to 1900. The sodium chloride present in seawater and beach sand accelerates the rate of corrosion of the reinforced concrete.

Another problem encountered with historic concrete is related to poor consolidation of the concrete during its placement in forms, or in molds in the case of precasting. This problem is especially prevalent in highly ornamental units. Early twentieth century concrete was often tamped or rodded into place, similar to techniques used in forming cast stone. Poorly consolidated concrete often contains voids (“bugholes” or “honeycombs”), which can reduce the protective concrete cover over the embedded reinforcing bars, entrap water, and, if sufficiently large and strategically numerous, reduce localized concrete strength. Vibration technology has improved over time and flowability agents are also used today to address this problem.

A common type of deterioration observed in concrete is the effect of weathering from exposure to wind, rain, snow, and salt water or spray. Weathering appears as erosion of the cement paste, a condition more prevalent in northern regions where precipitation can be highly acidic. This results in the exposure of the aggregate particles on the exposed concrete surface. Variations may occur in the aggregate exposure due to differential erosion or dissolution of exposed cement paste. Erosion can also be caused by the mechanical action of water channeled over concrete, such as by the lack of drip grooves

Figure 12. The concrete lighthouse at the Kilauea Point Light Station, Kilauea, Kauai, Hawaii, was constructed circa 1913. The concrete, which was a good quality, high strength mix for its day, is in good condition after almost one hundred years in service. Deterioration in the form of spalling related to corrosion of embedded reinforcing steel has occurred primarily in areas of higher ornamentation such as projecting bands and brackets (see close-up photo).

in belt courses and sills, and by inadequate drainage. In addition, high-pressure water when used for cleaning can also erode the concrete surface.

In concrete structures built prior to the First World War, concrete was often placed into forms in relatively short vertical lifts due to limitations in lifting and pouring techniques available at the time. Joints between different concrete placements (often termed cold joints or lift lines) may sometimes be considered an important part of the character of a concrete element (Figure 13). However, wide joints may permit water to infiltrate the concrete, resulting in more rapid paste erosion or freeze-thaw deterioration of adjacent concrete in cold climates.

In the early twentieth century, concrete was sometimes placed in several layers parallel to the exterior surface. A base concrete was first created with formwork and then a more cement rich mortar layer was applied to the exposed vertical face of the base concrete. The higher cement content in the facing concrete provided a more water-resistant outer layer and finished surface. The application of a cement-rich top layer, referred to in some early concrete publications as “waterproofing,” was also used on top surfaces of concrete walls, or as the top layer in sidewalks. With this type of concrete construction, deterioration can occur over time as a result of debonding between layers, and can proceed very rapidly once the protective cement-rich layer begins to break down.

It is common for historic concrete to have a highly variable appearance, including color and finish texture. Different levels of aggregate exposure due to paste erosion are often found in exposed aggregate concrete. This variability in the appearance of historic concrete increases the level of difficulty in assessing and repairing weathered concrete.

Figure 13. Fort Casey on Admiralty Head, Fort Casey, Washington, was constructed in 1898. The lift lines from placement of concrete are clearly visible on the exterior walls and characterize the finished appearance.

Signs of Distress and Deterioration

Characteristic signs of failure in concrete include cracking, spalling, staining, and deflection. Cracking occurs in most concrete but will vary in depth, width, direction, pattern, and location, and can be either active or dormant (inactive). Active cracks can widen, deepen, or migrate through the concrete, while dormant cracks remain relatively unchanged in size. Some dormant cracks, such as those caused by early age shrinkage of the concrete during curing, are not a structural concern but when left unrepaired, can provide convenient channels for moisture penetration and subsequent damage. Random surface cracks, also called map cracks due to their resemblance to lines on a map, are usually related to early-age shrinkage but may also indicate other types of deterioration such as alkali-silica reaction.

Structural cracks can be caused by temporary or continued overloads, uneven foundation settling, seismic forces, or original design inadequacies. Structural cracks are active if excessive loads are applied to a structure, if the overload is continuing, or if settlement is ongoing. These cracks are dormant if the temporary overloads have been removed or if differential settlement has stabilized. Thermally-induced cracks result from stresses produced by the expansion and contraction of the concrete during temperature changes. These cracks frequently occur at the ends or re-entrant corners of older concrete structures that were built without expansion joints to relieve such stress.

Spalling (the loss of surface material) is often associated with freezing and thawing as well as cracking and delamination of the concrete cover over embedded reinforcing steel. Spalling occurs when reinforcing bars corrode and the corrosion by-products expand, creating high stresses on the adjacent concrete, which cracks and is displaced. Spalling can also occur when water absorbed by the concrete freezes and thaws (Figure 14). In addition, surface spalling or scaling may result from the improper finishing, forming, or other surface phenomena when water-rich cement paste (laitance) rises to the surface. The resulting weak material is vulnerable to spalling of thin layers, or scaling. In some cases, spalling of the concrete can diminish the load-carrying capacity of the structure.

Deflection is the bending or sagging of structural beams, joists, or slabs, and can be an indication of deficiencies in the strength and structural soundness of concrete. This condition can be produced by overloading, corrosion of embedded reinforcing, or inadequate design or construction, such as use of low-strength concrete or undersized reinforcing bars.

Staining of the concrete surface can be related to soiling from atmospheric pollutants or other contaminants, dirt accumulation, and the presence of organic growth. However, stains can also indicate more serious underlying problems, such

Figures 14. Layers of architectural concrete that have debonded (spalled) from the surface were removed from a historic water tank during

as corrosion of embedded reinforcing steel, improper previous surface treatments, alkali-aggregate reaction, or efflorescence, the deposition of soluble salts on the surface of the concrete as a result of water migration (Figure 15).

the investigation performed to assess existing conditions. Photos: Anita Washko, Wiss, Janney, Elstner Associates, Inc.

Planning for Concrete Preservation

The significance of a historic concrete building or structure—including whether it is important for its architectural or engineering design, for its materials and construction techniques, or both—guides decision making about repair and, if needed, replacement methods. Determining the causes of deterioration is also central to the development of a conservation and repair plan. With historic concrete buildings, one of the more difficult challenges is allowing for sufficient time during the planning phase to analyze the concrete, develop mixes, and provide time for adequate aging of mock-ups for matching to the original concrete.

An understanding of the original construction techniques (cement characteristics, mix design, original intent of assembly, type of placement, precast versus cast in place, etc.) and previous repair work performed on the concrete is important in determining causes of existing deterioration and the susceptibility of the structure to potential other types of deterioration. For example, concrete placed in short lifts (individual concrete placements) or constructed in precast segments will have numerous joints that can provide entry points for water infiltration. Inappropriate prior repairs, such as installation of patches using an incompatible material, can affect the future performance of the concrete. Such prior repairs may require corrective work.

As with other preservation projects, three primary approaches are usually considered for historic concrete structures: **maintenance, repair, or replacement**. Maintenance and repair best achieve the preservation goal of minimal intervention and the greatest retention of existing historic fabric. However, where elements of the building are severely deteriorated or where inherent problems with the material lead to ongoing failures, replacement may be necessary.

During planning, information is gathered through research, visual survey, inspection openings, and laboratory studies. The material should then be reviewed by professionals experienced in concrete deterioration to help evaluate the nature and causes of the concrete problems, to assess both the short-term and long-term effects of the deterioration, and to formulate proper repair approaches.

Condition Assessment

A condition assessment of a concrete building or structure should begin with a review of all available documents related to original construction and prior repairs. While plans and specifications for older concrete buildings are not always available, they can be an invaluable resource and every attempt should be made to find them. They may provide information on the composition of the concrete mix or on the type and location of reinforcing bars. If available, documents related to past repairs should also be reviewed to understand how the repairs were made and to help evaluate their anticipated performance and service life. Archival photographs can also provide a valuable source of information about original construction.

A visual condition survey will help identify and evaluate the extent, types, and patterns of distress and deterioration. The American Concrete Institute offers several useful guides on how to perform a visual condition survey of concrete. Generally, the condition assessment begins with an overall visual survey, followed by a close-up investigation of representative areas to obtain more detailed information about modes of deterioration.

A number of nondestructive testing methods can be used in the field to evaluate concealed conditions. Basic techniques include sounding with a hand-held hammer (or for horizontal surfaces, a chain) to help identify areas of delamination. More sophisticated techniques include impact-echo testing (Figure 16), ground penetrating radar, pulse velocity, and other methods that characterize concrete thickness and locate voids or delaminations. Magnetic detection instruments are used to locate embedded reinforcing steel and can be calibrated to identify the size and depth of reinforcement. Corrosion measurements can be taken using copper-copper sulfate half-cell tests or linear polarization techniques to determine the probability or rate of active corrosion of the reinforcing steel.

To further evaluate the condition of the concrete, samples may be removed for laboratory study to determine material components and composition, and causes of deterioration. Samples need to be representative of existing conditions but should be taken from unobtrusive locations. Laboratory studies of the concrete may include petrographic evaluation following ASTM C856, *Practice for Petrographic Examination of Hardened Concrete*. Petrographic examination, consisting of microscopical studies performed by a geologist specializing in the evaluation of construction materials, is performed to determine air content, water-cement ratio, cement content, and general aggregate characteristics. Laboratory studies can

Figure 15. Evidence of moisture movement through concrete is apparent in the form of mineral deposits on the concrete surface. Cyclic freezing and thawing of entrapped moisture, and corrosion of embedded reinforcement, have also contributed to deterioration of the concrete column on this fence at Crocker Field in Fitchburg, Massachusetts, designed by the Olmsted Brothers.

also include chemical analyses to determine chloride content, sulfate content, and alkali levels of the concrete; identification of deleterious aggregates; and determination of depth of carbonation. Compressive strength studies can be conducted to evaluate the strength of the existing concrete and provide information for repair work. The laboratory studies provide a general identification of the original concrete's components and aggregates, and evidence of damage due to various mechanisms including cyclic freezing and thawing, alkali-aggregate reactivity, or sulfate attack. Information gathered through laboratory studies can also be used to help develop a mix design for the repair concrete.

Cleaning

As with other historic structures, concrete structures are cleaned for several reasons: to improve the appearance of the concrete, as a cyclical maintenance measure, or in preparation for repairs. Consideration should first be given to whether the historic concrete structure needs to be cleaned at all. If cleaning is required, then the gentlest system that will be effective should be selected.

Three primary methods are used for cleaning concrete: water methods, abrasive surface treatments, and chemical surface treatments. Low-pressure water (less than 200 psi) or steam cleaning can effectively remove surface soiling from sound concrete; however, care is required on fragile or deteriorated surfaces. In addition, water and steam methods are typically not effective in removing staining or severe soiling. Power washing with high-pressure water is sometimes used to clean or remove coatings from sound, high-strength concrete, but high-pressure water washing is generally damaging to and not appropriate for concrete on historic structures.

When used with proper controls and at very low pressures (typically 35 to 75 psi), microabrasive surface treatments using very fine particulates, such as dolomitic limestone powder, can sometimes clean effectively. However, microabrasive cleaning may alter the texture and surface reflectivity of concrete. Some concrete can be damaged even by fine particulates applied at very low pressures.

Chemical surface treatments can clean effectively but may also alter the appearance of the concrete by bleaching the concrete, removing the paste, etching the aggregate, or otherwise altering the surface. Detergent cleaners or mild, diluted acid cleaners may be appropriate for removal of staining or severe soiling. Cleaning products that contain strong acids such as hydrochloric (muriatic) or hydrofluoric acid, which will damage concrete and are harmful to persons, animals, site features, and the environment, should not be used.

For any cleaning process, trial samples should be performed prior to full-scale implementation. The intent of the cleaning program should not be to return the structure to a like new appearance. Concrete can age gracefully, and as long as soiling is not severe or deleterious, many structures can still be appreciated without extensive cleaning.

Figure 16. Impact echo testing is performed on a concrete structural slab to help determine depth of deterioration. In this method, a short pulse of energy is introduced into the structure and a transducer mounted on the impacted surface of the structure receives the reflected input waves or echoes. These waves are analyzed to help identify flaws and deterioration within the concrete.

Methods of Maintenance and Repair

The maintenance of historic concrete often is thought of in terms of appropriate cleaning to remove unattractive dirt or soiling materials. However, the implementation of an overall maintenance plan for a historic structure is the most effective way to help protect historic concrete. For examples, the lack of maintenance to roofs and drainage systems can promote water related damage to adjacent concrete features. The repeated use of deicing salts in winter climates can pit the surface of old concrete and also may promote decay in embedded steel reinforcements. Inadequate protection of concrete walls adjacent to driveways and parking areas can result in the need for repair work later on.

The maintenance of historic concrete involves the regular inspection of concrete to establish baseline conditions and identify needed repairs. Inspection tasks involve monitoring protection systems, including sealant joints, expansion joints, and protective coatings; reviewing existing conditions for development of distress such as cracking and delaminations; documenting conditions observed; and developing and implementing a cyclical repair program.

Figure 17. (a) The 63rd Street Beach House was constructed on the shoreline of Chicago in 1919. The highly exposed aggregate concrete of the exterior walls of the beach house was used for many buildings in the Chicago parks as an alternative to more expensive stone construction. Photo: Leslie Schwartz Photography. (b) Concrete deterioration included cracking, spalling, and delamination caused by corrosion of embedded reinforcing steel and concrete damage due to cyclic freezing and thawing. (c) Various sizes and types of aggregates were reviewed for matching to the original concrete materials. (d) Mock-ups of the concrete repair mix were prepared for comparison to the original concrete. Considerations included aggregate type and size, cement color, proportions, aggregate exposure, and surface finish. (e) The craftsman finished the surface to replicate the original appearance in a mock-up on the structure. Here, he used a nylon bristle brush to remove loose paste and expose the aggregate, creating a variable surface to match the adjacent original concrete.

Sealants are an important part of maintenance of historic concrete structures. Elastomeric sealants, which have replaced traditional oil-resin based caulks for many applications, are used to seal cracks and joints to keep out moisture and reduce air infiltration. Sealants are commonly used at windows and door perimeters, at interfaces between concrete and other materials, and at attachments to or through walls or roofs, such as with lamps, signs, or exterior plumbing fixtures.

When used for crack repairs on historic facades, the finished appearance of the sealant application must be considered, as it may be visually intrusive. In some cases, sand can be broadcast onto the surface of the sealant to help conceal the repair.

Urethane and polyurethane sealants are often used to seal joints and cracks in concrete structures, paving, and walkways; these sealants provide a service life of up to ten years. High-performance silicone sealants also are often used with concrete, as they provide a range of movement capabilities and a service life of twenty years or more. Some silicone sealants may stain adjacent materials, which may be a problem with more porous concrete, and may also tend to accumulate dust and dirt. The effectiveness of sealants for sealing joints and cracks depends on numerous factors including proper surface preparation and application. Sealants should be examined as part of routine maintenance inspections, as these materials deteriorate faster than their substrates and must be replaced periodically as a part of cyclical maintenance.

Repair of historic concrete may be required to address deterioration because the original design and construction did not provide for long-term durability, or to facilitate a change in use of the structure. Examples include increasing concrete cover to protect reinforcing steel and reducing water infiltration into the structure by repair of joints. Any such improvements must be thoroughly evaluated for compatibility with the original design and appearance. Care is required in all aspects of historic concrete repair, including surface preparation; installation of formwork; development of the concrete mix design; and concrete placement, consolidation, and curing.

An appropriate repair program addresses existing distress and reduces the rate of future deterioration, which in many cases involves moisture-related issues. The repair program should incorporate materials and methods that are sympathetic to the existing materials in character and appearance, and which provide good long-term performance. In addition, repair materials should age and weather similarly to the original materials. In order to best achieve these goals, concrete repair projects should be divided into three phases: development of trial repair procedures, trial repairs and evaluation, and production repair work.

For any concrete repair project, the process of investigation, laboratory analysis, trial samples, mock-ups, and full-scale repairs allows ongoing refinement of the repair work as well as implementation of quality-control measures. The trial repair process provides an opportunity for the owner, architect, engineer, and contractor to evaluate the concrete mix design and the installation and finishing techniques for the repairs from both technical and aesthetic standpoints. The final repair materials and procedures should match the original concrete in appearance while meeting the established criteria for durability. Information gathered through trial repairs and mock-ups is invaluable in refining the construction documents prior to the start of the overall repair project (Figure 17).

Surface Preparation

In undertaking surface preparation for historic concrete repair, care must be taken to limit removal of existing material while still providing an appropriate substrate for repairs. This is particularly important where ornamentation and fine details are involved. Preparation for localized repairs usually begins with removal of the loose concrete to determine the general extent of the repair, followed by saw-cutting the perimeter of the repair area. The repair area should extend beyond the area of concrete deterioration to a sufficient extent to provide a sound substrate. When repairing concrete with an exposed aggregate or other special surface texture, a sawcut edge may be too visually evident. To hide the repair edge, techniques such as lightly hand-chipping the edge of the patch may be used to conceal the joint between the original concrete and the new repair material. The depth to which the concrete needs to be removed may be difficult to determine without invasive probing in the repair area. Removal of concrete should typically extend beyond the level of the reinforcing steel, if present, so that the patch encapsulates the reinforcing steel, which provides mechanical attachment for the repair.

If the concrete was originally of lower strength and quality, the assessment of present soundness is more difficult. Deteriorated and unsound concrete is typically removed using pneumatic chipping hammers. Removal of concrete in historic structures is better controlled by using smaller chipping hammers or hand tools. The area of the concrete to be repaired and the exposed reinforcing steel are then cleaned, usually by careful sandblast and air blast procedures applied only within the repair area. Adjacent original concrete surfaces should be protected during this work. In some cases, project constraints such as dust control may limit the ability to thoroughly clean the concrete and steel. For example, it may be necessary to use needle scaling (a small pneumatic impact device) and wire brushing instead of sandblasting.

Supplemental steel may be needed when existing reinforcing steel is severely deteriorated, or if reinforcing steel is not present in repair areas. Exposed existing reinforcing and other embedded steel elements should be cleaned, primed, and painted with a corrosion-inhibiting coating. The patching material should be reinforced and mechanically attached to the existing concrete. Reinforcement materials used in repairs most often include mild steel, epoxy-coated steel, or stainless steel, depending on existing conditions.

Formwork and Molds

Special formwork is needed to recreate ornamental concrete features—which may be complex, in high relief, or architecturally detailed—and to provide special surface finishes such as wood form board textures. Construction of the formwork itself requires particular skill and craftsmanship. Reusable forms can be used for concrete ornamentation that is repeated across a building facade, or precast concrete elements may be used to replace missing or unrepairable architectural features. Formwork for ornamental concrete is often created using a four-step process: a casting of the original concrete is taken; a plaster replica of the unit is prepared; a mold or form is made from the plaster replica; and a new concrete unit is cast. Custom formwork and molds are often the work of specialty companies, such as precasters and cast stone fabricators.

The process of forming architectural features or special surface textures is particularly challenging if early age stripping (removal of formwork early in the concrete curing process) is needed to perform surface treatment on the concrete. Timing for formwork removal is related to strength gain, which in turn is partly dependent on temperature and weather conditions. Early age removal of formwork in highly detailed concrete can lead to damage of the new concrete that has not yet gained sufficient strength through curing.

Selection of Repair Materials and Mix Design

Selection and design of proper repair materials is a critical component of the repair project. This process requires evaluation of the performance, characteristics, and limitations of the repair materials, and may involve laboratory testing of proposed materials and trial repairs. The materials should be selected to address the specific type of repair required and to be compatible with special characteristics of the original concrete. Some modern repair materials are designed to have a high compressive strength and to be impermeable. Even though inherently durable, these newer materials may not be appropriate for use in repairing a low strength historic concrete.

The concrete's durability, or resistance to deterioration, and the materials and methods selected for repair depend on its composition, design, and quality of workmanship. In most cases, a mix design for durable

replacement concrete should use materials similar to those of the original concrete mix. Prepackaged materials are often not appropriate for repair of historic concrete. The concrete patching material can be air entrained or polymer-modified if subject to exterior exposure, and should incorporate an appropriate selection of aggregate and cement type, and proper water content and water to cement ratio. Some admixtures, including polymer modifiers, may change the appearance of the concrete mix. Design of the concrete patching material should address characteristics required for durability, workability, strength gain, compressive strength, and other performance attributes. During installation of the repair, skilled workmanship is required to ensure proper mixing procedures, placement, consolidation, and curing.

Matching and Repair Techniques for Historic Concrete

Repair measures should be selected that retain as much of the original material as possible, while providing for removal of an adequate amount of deteriorated concrete to provide a sound substrate for a durable repair. The installed repair must visually match the existing concrete as closely as possible and should be similar in other aspects such as compressive strength, permeability, and other characteristics important in the mix design of the concrete (Figure 18).

Understanding the original construction techniques often provides opportunities in the design of repairs. For example, joints between the new and old concrete can be hidden in changes in surface profile and cold joints. The required patching mix for the concrete to be used in the repair will likely need to be specially designed to replicate the appearance of the adjacent historic concrete. A high level of craftsmanship is required for finishing of historic concrete, in particular to create the sometimes inconsistent finish and variation in the original concrete in contrast to the more even appearance required for most non-historic repairs.

To match the various characteristics of the original concrete, trial mixes should be developed. These mixes need to take into account the types and colors of aggregates and paste present in the original concrete. Different mixes may be needed because of variations in the appearance and composition of the historic concrete. The trials should utilize different forming and finishing techniques to achieve the best possible match to the original concrete. Initial trials should first take place on site but off the structure. The mix designs providing the best match are then installed as trial repairs on the structure, and assessed after they have cured.

Achieving compatibility between repair work and original concrete may be difficult, especially given the variability often present in historic concrete materials and finishes. Formed rather than trowel-applied patch repairs are recommended for durability, as forming permits better ranges of mix ingredients (such as coarse aggregates) and improved consolidation as compared to trowel-applied repairs. Parge coatings usually are not recommended as they do not provide as durable repair as formed concrete. However, in some cases parge coatings may be appropriate to match an original parged surface treatment. Proper placement and finishing of the repair are important to obtain a match with the original concrete. To minimize problems associated with rapid curing of concrete, such as surface cracking, it is important to use proper curing methods and to allow for sufficient time.

Hairline cracks that show no sign of increasing in size may often be left unrepaired. The width of the crack and the amount of movement usually limits the selection of crack repair techniques that are available. Although it is difficult to determine whether cracks are moving or non-moving, and therefore most cracks should be assumed to be moving, it is possible to repair non-moving cracks by installation of a cementitious repair mortar matching the adjacent concrete. It is generally desirable not to widen cracks prior to the mortar application. Repair mortar containing sand in the mix may be used for wider cracks; unsanded repair mortar may be used for narrower cracks.

Figure 18. (a) Exposed aggregate precast concrete is sounded with a hammer to detect areas of deterioration. Corrosion of the exposed reinforcing steel bar has led to spalling of the adjacent concrete. (b) Samples of aggregate considered for use in repair concrete are compared to the original concrete materials in terms of size, color, texture, and reflectance. (c) Various sample panels are made using the selected concrete repair mix design for comparison to the original concrete on the building, and the mix design is adjusted based on review of the samples. (d) After removal of the spall, the concrete surface is prepared for installation of a formed patch. (e) Prior to placement of the concrete, a retarding agent is brush-applied to the inside face of the formwork to slow curing at the surface. After the concrete is partially cured, the forms are removed and the surface of the concrete is rubbed to remove some of the paste and expose the aggregate to match the original concrete.

When it is desirable to re-establish the structural integrity of a concrete structure involving dormant cracks, epoxy injection repair has proven to be an effective procedure. Such a repair is made by first sealing the crack on both sides of a wall or structural member with epoxy, polyester, wax, tape, or cement slurry, and then injecting epoxy through small holes or ports drilled in the concrete. Once the epoxy in the crack has hardened, the surface sealing material may be removed; however, this type of repair is usually quite apparent. Although it may be possible to inject epoxy without leaving noticeable residue, this process is difficult and, in general, the use of epoxy repairs in visible areas of concrete on historic structures is not recommended.

Active structural cracks (which move as loads are added or removed) and thermal cracks (which move as temperatures fluctuate) must be repaired in a manner that will accommodate the anticipated movement. In some more extreme cases, expansion joints may have to be introduced before crack repairs are undertaken. Active cracks may be filled with sealants that will adhere to the sides of the cracks and will compress or expand during crack movement. The design, detailing, and execution of sealant repairs require considerable attention, or they will detract from the appearance of the historic building. The routing and cleaning of a crack, and installation of an elastomeric sealant to prevent water penetration, is used to address cracks where movement is anticipated. However, unless located in a concealed area of the concrete, this technique is often not acceptable for historic structures because the repair will be visually intrusive (Figure 19). Other approaches, such as installation of a cementitious crack repair, may need to be considered even though this type of repair may be less effective or have a shorter service life than a sealant repair.

Replacement

If specific components of historic concrete structures are beyond repair, replacement components can be cast to match historic ones. Replacement of original concrete should be carefully considered and viewed as a method of last resort. In some cases, such as for repeated ornamental units, it may be more cost-effective to fabricate precast concrete units to replace missing elements. The forms created for precast or cast-in-place units can then be used again during future repair projects.

Careful mix formulation, placement, and finishing are required to ensure that replacement concrete units will match the historic concrete. There is often a tendency to make replacement concrete more consistent in appearance than the original concrete. The consistency can be in stark contrast with the variability of the original concrete due to original construction techniques, architectural design, or differential exposure to weather. Trial repairs and mock-ups are used to evaluate the proposed replacement concrete work and to refine construction techniques (Fig 20).

Protection Systems

Coatings and Penetrating Sealers. Protection systems such as a penetrating sealers or film forming coating are often used with non-historic structures to protect the concrete and increase the length of the service life of concrete repairs. However, film-forming coatings are often inappropriate for use on a historic structure, unless the structure was coated historically. Film-forming coatings will often change the color and appearance of a surface, and higher build coatings can also mask architectural finishes and ornamental details. For example, the application of a coating on concrete having a formboard finish may hide the wood texture of the surface. Pigmented film-forming coatings are also typically not appropriate for use over exposed aggregate concrete, where the uncoated exposed surface contributes significantly to the historic character of the facade. In cases where the color of a substrate needs to be changed, such as to modify the appearance of existing repairs, an alternative to pigmented film-forming coatings is the use of pigmented stains.

Many proprietary clear, penetrating sealers are currently available to protect concrete substrates. These products render fine cracks and pores within the concrete hydrophobic; however, they do not bridge or fill cracks. Clear sealers may change the appearance of the concrete in that treated areas become more visible after rain in contrast to the more absorptive areas of original concrete. Once applied, penetrating sealers cannot be effectively removed and are therefore considered irreversible. They should not be used on historic concrete without thorough prior consideration. However, clear penetrating sealers provide an important means of protection for historic concrete that is not of good quality and can help to avoid more extensive future repairs or replacement. Thus they are sometimes appropriate for use on historic concrete. Once applied, these sealers will require periodic re-application.

Figure 19. A high-speed grinder is used to widen a crack in preparation for installation of a sealant. This process is called "routing." After the crack is prepared, the sealant is installed to prevent moisture infiltration through the crack. Although sealant repairs can provide a durable, watertight repair for moving cracks, they tend to be very visible.

Waterproofing membranes are systems used to protect concrete surfaces such as roofs, terraces, plazas, or balconies, as well as surfaces below grade. Systems range from coal tar pitch membranes used on older buildings, to asphalt or urethane-based systems. On historic buildings, membrane systems are typically used only on surfaces that were originally protected by a similar system and surfaces that are not visible from grade. Waterproofing membranes may be covered by roofing, paving, or other architectural finishes.

Laboratory and field testing is recommended prior to application of a protection system or treatment on any concrete structure; testing is even more critical for historic structures because many such treatments are not reversible. As with other repairs, trial samples are important to evaluate the effectiveness of the treatment and to determine whether it will harm the concrete or affect its appearance.

Figure 20. (a) The Jefferson Davis Memorial in Fairview, Kentucky, constructed from 1917-1924, is 351 feet tall and constructed of unreinforced concrete. The walls of the memorial are 8 feet thick at the base and 2 feet thick at the top of the wall. Access to the monument for investigation was provided by rappelling techniques, while ground supported and suspended scaffolding was used to access the exterior during repairs. (b) The concrete was severely deteriorated at isolated locations, with spalling and damage from cyclic freezing and thawing of entrapped water. In addition, previous repairs were at the end of their service life and removal of deteriorated concrete and failed previous repairs was required. Light duty chipping hammers were used to avoid damage to adjacent material when removing deteriorated concrete to the level of sound concrete. (c) Field samples were performed to match the color, finish, and texture of the original concrete. A challenge in matching of historic concrete is achieving variability of appearance. (d) The completed surface after repairs exhibits intentional variability of the concrete surface to match the appearance of the original concrete. Some formwork imperfections that would normally be removed by finishing were intentionally left in place, to replicate the highly variable finish of the original concrete. (e) The Jefferson Davis Memorial after completion of repairs in 2004. Photo e: Joseph Lenzi, Senler, Campbell & Associates, Inc.

Cathodic Protection. Corrosion is an electrochemical process in which electrons flow between cathodic (positively charged) and anodic (negatively charged) areas on a metal surface; corrosion occurs at the anodes. Cathodic protection is a technique used to control the corrosion of metal by making the whole metal surface the cathode of an electrochemical cell. This technique is used to protect metal structures from corrosion and is also sometimes used to protect steel reinforcement embedded in concrete. For reinforced concrete, cathodic protection is typically accomplished by connecting an auxiliary anode to the reinforcing so that the entire reinforcing bar becomes a cathode. In sacrificial anode (passive) systems, current flows naturally by galvanic action between the less noble anode (such as zinc) and the cathode. In impressed-current (active) systems, current is impressed between an inert anode (such as titanium) and the cathode. Cathodic protection is intended to reduce the rate of corrosion of embedded steel in concrete, which in turn reduces overall deterioration. Protecting embedded steel from corrosion helps to prevent concrete cracking and spalling.

Impressed-current cathodic protection is the most effective means of mitigating steel corrosion and has been used in practical structural applications since the 1970s. However, impressed-current cathodic protection systems are typically the most costly to install and require substantial ongoing monitoring, adjustment, and maintenance to ensure a proper voltage output (protection current) over time. Sacrificial anode cathodic protection dates back to the 1800s, when the hulls of ships were protected using this technology. Today many industries utilize the concept of sacrificial anode cathodic protection for the protection of steel exposed to corrosive environments. It is less costly than an impressed-current system, but is somewhat less effective and requires reapplication of the anode when it becomes depleted.

Re-alkalization. Another technique currently available to protect concrete is realkalization, which is a process to restore the alkalinity of carbonated concrete. The treatment involves soaking the concrete with an alkaline solution, in some cases forcing it into the concrete to the level of the reinforcing steel by passage of direct current. These actions increase the alkalinity of the concrete around the reinforcement, thus restoring the protective alkaline environment for the reinforcement. Re-alkalization has been used in the United States for a little more than a decade. Like impressed-current cathodic protection methods, it is costly. However, it is a one-time operation and therefore does not require periodic reapplication.

Careful evaluation of existing conditions, the causes and nature of distress, and environmental factors is essential before a protection method is selected and implemented. Not every protection system will be effective on each structure. In

addition, the level of intrusion caused by the protection system must be carefully evaluated before it is used on a historic concrete structure.

Summary and References

In the United States, concrete has been a popular construction material since the late nineteenth century and recently has gained greater recognition as a historic material. Preservation of historic concrete requires a thorough understanding of the causes and types of deterioration, as well as of repair and replacement materials and methods. It is important that adequate time is allotted during the planning phase of a project to provide for trial repairs and mock-ups in order to evaluate the effectiveness and aesthetics of the repairs. Careful design is essential and, as with other preservation efforts, the skill of those performing the work is critical to the success of the repairs. The successful repair of many historic concrete structures in recent years demonstrates that the techniques and materials now available can extend the life of such structures and help ensure their preservation.

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2007

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1.1.2.3 Dangers of abrasive cleaning (Grimmer 1979 – Preservation Brief #6)

Technical Preservation Services

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[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 6 Dangers of Abrasive Cleaning

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PRESERVATION BRIEFS

6

Dangers of Abrasive Cleaning to Historic Buildings

Anne E. Grimmer

[What is Abrasive Cleaning?](#)

[Why are Abrasive Cleaning Methods Used?](#)

[Problems of Abrasive Cleaning](#)

[How Building Materials React to Abrasive Cleaning](#)

[When is Abrasive Cleaning Permissible?](#)

[Do Not Abrasively Clean these Historic Interiors](#)

[Mitigating the Effects of Abrasive Cleaning](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#) ^(b)

Undamaged historic brick (above).
Sandblasted brick (below). Photo:
Courtesy, Illinois Historic Preservation
Agency.

"Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible." —**The Secretary of the Interior's Standards for Rehabilitation.**

Abrasive cleaning methods are responsible for causing a great deal of damage to historic building materials. To prevent indiscriminate use of these potentially harmful techniques, this brief has been prepared to explain abrasive cleaning methods, how they can be physically and aesthetically destructive to historic building materials, and why they generally are not acceptable preservation treatments for historic structures. There are alternative, less harsh means of cleaning and removing paint and stains from historic buildings. However, careful testing should precede general cleaning to assure that the method selected will not have an adverse effect on the building materials. A historic building is irreplaceable, and should be cleaned using only the "gentlest means possible" to best preserve it.

What is Abrasive Cleaning?

Abrasive cleaning methods include all techniques that physically abrade the building surface to remove soils, discolorations or coatings. Such techniques involve the use of certain *materials* which impact or abrade the surface under pressure, or abrasive *tools and equipment*. Sand, because it is readily available, is probably the most commonly used type of grit material. However, any of the following materials may be substituted for sand, and all can be classified as abrasive substances: ground slag or volcanic ash, crushed (pulverized) walnut or almond shells, rice husks, ground corncobs, ground coconut shells, crushed eggshells, silica flour, synthetic

particles, glass beads and micro-balloons. Even *water* under pressure can be an abrasive substance. Tools and equipment that are abrasive to historic building materials include wire brushes, rotary wheels, power sanding disks and belt sanders.

The use of water in combination with grit may also be classified as an abrasive cleaning method. Depending on the manner in which it is applied, water may soften the impact of the grit, but water that is too highly pressurized can be very abrasive. There are basically two different methods which can be referred to as "wet grit," and it is important to differentiate between the two. One technique involves the addition of a stream of water to a regular sandblasting nozzle. This is done primarily to cut down dust, and has very little, if any, effect on reducing the aggressiveness, or cutting action of the grit particles. With the second technique, a very small amount of grit is added to a pressurized water stream. This method may be controlled by regulating the amount of grit fed into the water stream, as well as the pressure of the water.

Abrasive cleaning can cause permanent damage to historic fabric, such as this brick wall. Photo: NPS files.

Why Are Abrasive Cleaning Methods Used?

Usually, an abrasive cleaning method is selected as an expeditious means of quickly removing years of dirt accumulation, unsightly stains, or deteriorating building fabric or finishes, such as stucco or paint.

Brick molding next to the window has been severely abraded by sandblasting to remove paint. Photo: NPS files.

The fact that sandblasting is one of the best known and most readily available building cleaning treatments is probably the major reason for its frequent use.

Many mid-19th century brick buildings were painted immediately or soon after completion to protect poor quality brick or to imitate another material, such as stone. Sometimes brick buildings were painted in an effort to produce what was considered a more harmonious relationship between a building and its natural surroundings. By the 1870s, brick buildings were often left unpainted as mechanization in the brick industry brought a cheaper pressed brick and fashion decreed a sudden preference for dark colors. However, it was still customary to paint brick of poorer quality for the additional protection the paint afforded.

It is a common 20th century misconception that all historic masonry buildings were initially unpainted. If the intent of a modern restoration is to return a building to its original appearance, removal of the paint not only may be historically inaccurate, but also harmful. Many older buildings were painted or stuccoed at some point to correct recurring maintenance problems caused by faulty construction techniques, to hide alterations, or in an attempt to solve moisture problems. If this is the case, removal of paint or stucco may cause these problems to reoccur.

Another reason for paint removal, particularly in rehabilitation projects, is to give the building a "new image" in response to contemporary design trends and to attract investors or tenants. Thus, it is necessary to consider the purpose of the intended cleaning. While it is clearly important to remove unsightly stains, heavy encrustations of dirt, peeling paint or other surface coatings, it may not be equally desirable to remove paint from a building which originally was painted. Many historic buildings which show only a slight amount of soil or discoloration are much better left as they are.

A thin layer of soil is more often protective of the building fabric than it is harmful, and seldom detracts from the building's architectural and/or historic character. Too thorough cleaning of a historic building may not only sacrifice some of the building's character, but also, misguided cleaning efforts can cause a great deal of damage to historic building fabric. Unless there are stains, graffiti or dirt and pollution deposits which are destroying the building fabric, it is generally preferable to do as little cleaning as possible, or to repaint where necessary. It is important to remember that a historic building does not have to look as if it were newly constructed to be an attractive or successful restoration or rehabilitation project.

Problems of Abrasive Cleaning

The crux of the problem is that abrasive cleaning is just that--abrasive. An abrasively cleaned historic structure may be physically as well as aesthetically damaged. Abrasive methods "clean" by eroding dirt or paint, but at the same time they also tend to erode the surface of the building material. In this way, abrasive cleaning is destructive and causes irreversible harm to the historic building fabric. If the fabric is brick, abrasive methods remove the hard, outer protective surface, and therefore make the brick more susceptible to rapid weathering and deterioration.

Grit blasting may also increase the water permeability of a brick wall. The impact of the grit particles tends to erode the bond between the mortar and the brick, leaving cracks or enlarging existing cracks where water can enter. Some types of stone develop a protective

patina or "quarry crust" parallel to the worked surface (created by the movement of moisture towards the outer edge), which also may be damaged by abrasive cleaning. The rate at which the material subsequently weathers depends on the quality of the inner surface that is exposed.

Abrasive cleaning can destroy, or substantially diminish, decorative detailing on buildings such as a molded brickwork or architectural terra-cotta, ornamental carving on wood or stone, and evidence of historic craft techniques, such as tool marks and other surface textures.

In addition, perfectly sound and/or "tooled" mortar joints can be worn away by abrasive techniques. This not only results in the loss of historic craft detailing but also requires repointing, a step involving considerable time, skill and expense, and which might not have been necessary had a gentler method been chosen. Erosion and pitting of the building material by abrasive cleaning creates a greater surface area on which dirt and pollutants collect. In this sense, the building fabric "attracts" more dirt, and will require more frequent cleaning in the future.

In addition to causing physical and aesthetic harm to the historic fabric, there are several adverse environmental effects of dry abrasive cleaning methods. Because of the friction caused by the abrasive medium hitting the building fabric, these techniques usually create a considerable amount of dust, which is unhealthy, particularly to the operators of the abrasive equipment. It further pollutes the environment around the job site, and deposits dust on neighboring buildings, parked vehicles and nearby trees and shrubbery. Some adjacent materials not intended for abrasive treatment such as wood or glass, may also be damaged because the equipment may be difficult to regulate.

Wet grit methods, while eliminating dust, deposit a messy slurry on the ground or other objects surrounding the base of the building. In colder climates where there is the threat of frost, any wet cleaning process applied to historic masonry structures must be done in warm weather, allowing ample time for the wall to dry out thoroughly before cold weather sets in. Water which remains and freezes in cracks and openings of the masonry surface eventually may lead to spalling. High-pressure wet cleaning may force an inordinate amount of water into the walls, affecting interior materials such as plaster or joist ends, as well as metal building components within the walls.

On the left, grit blasting has obliterated the vertical tooling marks from granite, a very dense stone. Photo: NPS files.

Variable Factors

The greatest problem in developing practical guidelines for cleaning any historic building is the large number of variable and unpredictable factors involved. Because these variables make each cleaning project unique, it is difficult to establish specific standards at this time. This is particularly true of abrasive cleaning methods because their inherent potential for causing damage is multiplied by the following factors:

- the type and condition of the material being cleaned
- the size and sharpness of the grit particles or the mechanical equipment
- the pressure with which the abrasive grit or equipment is applied to the building surface
- the skill and care of the operator, and
- the constancy of the pressure on all surfaces during the cleaning process.

Pressure: The damaging effects of most of the variable factors involved in abrasive cleaning are self evident. However, the matter of pressure requires further explanation. In cleaning specifications, pressure is generally abbreviated as "psi" (pounds per square inch), which technically refers to the "tip" pressure, or the amount of pressure at the nozzle of the blasting apparatus. Sometimes "psig," or pressure at the gauge (which may be many feet away, at the other end of the hose), is used in place of "psi." These terms are often incorrectly used interchangeably.

Despite the apparent care taken by most architects and building cleaning contractors to prepare specifications for pressure cleaning which will not cause harm to the delicate fabric of a historic building, it is very difficult to ensure that the same amount of pressure is applied to all parts of the building. For example, if the operator of the pressure equipment stands on the ground while cleaning a two-story structure, the amount of force reaching the first story will be greater than that hitting the second story, even if the operator stands on scaffolding or in a cherry picker, because of the "line drop" in the distance from the pressure source to the nozzle. Although technically it may be possible to prepare cleaning specifications with tight controls that would eliminate all but a small margin of error, it may not be easy to find professional cleaning firms willing to work under such restrictive conditions. The fact is that many professional building cleaning firms do not really understand the extreme delicacy of historic building fabric, and how it differs from modern construction materials. Consequently, they may accept building cleaning projects for which they have no experience.

Bronze statuary may be cleaned gently using crushed walnut shells. Photo: NPS files.

The amount of pressure used in any kind of cleaning treatment which involves pressure, whether it is dry or wet grit, chemicals or just plain water, is crucial to the outcome of the cleaning project. Unfortunately, no standards have been established for determining the correct pressure for cleaning each of the many historic building materials which would not cause harm. The considerable discrepancy between the way the building cleaning industry and architectural conservators define "high" and "low" pressure cleaning plays a significant role in the difficulty of creating standards.

Non-historic/Industrial: A representative of the building cleaning industry might consider "high" pressure water cleaning to be anything over 5,000 psi, or even as high as 10,000 to 15,000 psi! Water under this much pressure may be necessary to clean industrial structures or machinery, but would destroy most historic building materials. Industrial chemical cleaning commonly utilizes pressures between 1,000 and 2,500 psi.

Historic: By contrast, conscientious dry or wet abrasive cleaning of a historic structure would be conducted within the range of 20 to 100 psi at a range of 3 to 12 inches. Cleaning at this low pressure requires the use of a very fine 00 or 0 mesh grit forced through a nozzle with a 1/4-inch opening. A similar, even more delicate method being adopted by architectural conservators uses a micro-abrasive grit on small, hard-to-clean areas of carved, cut or molded ornament on a building facade. Originally developed by museum conservators for cleaning sculpture, this technique may employ glass beads, micro-balloons, or another type of micro-abrasive gently powered at approximately 40 psi by a very small, almost pencil-like pressure instrument. Although a slightly larger pressure instrument may be used on historic buildings, this technique still has limited practical applicability on a large scale building cleaning project because of the cost and the relatively few technicians competent to handle the task. In general, architectural conservators have determined that only through very controlled conditions can most historic building material be abrasively cleaned of soil or paint without measurable damage to the surface or profile of the substrate.

Yet some professional cleaning companies which specialize in cleaning historic masonry buildings use chemicals and water at a pressure of approximately 1,500 psi, while other cleaning firms recommend lower pressures ranging from 200 to 800 psi for a similar project. An architectural conservator might decide, after testing, that some historic structures could be cleaned properly using a moderate pressure (200-600 psi), or even a high pressure (600-1800 psi) water rinse. However, cleaning historic buildings under such high pressure should be considered an exception rather than the rule, and would require *very careful* testing and supervision to assure that the historic surface materials could withstand the pressure without gouging, pitting or loosening.

These differences in the amount of pressure used by commercial or industrial building cleaners and architectural conservators point to one of the main problems in using abrasive means to clean historic buildings: misunderstanding of the potentially fragile nature of historic building materials. There is no one cleaning formula or pressure suitable for all situations. Decisions regarding the proper cleaning process for historic structures can be made only after careful analysis of the building fabric, and testing.

How Building Materials React to Abrasive Cleaning

Brick and Architectural Terra-cotta: Abrasive blasting does not affect all building materials to the same degree. Such techniques quite logically cause greater damage to softer and more porous materials, such as brick or architectural terra-cotta. When these materials are cleaned abrasively, the hard, outer layer (closest to the heat of the kiln) is eroded, leaving the soft, inner core exposed and susceptible to accelerated weathering. Glazed architectural terra-cotta and ceramic veneer have a baked on glaze which is also easily damaged by abrasive cleaning. Glazed architectural terra-cotta was designed for easy maintenance, and generally can be cleaned using detergent and water; but chemicals or steam may be needed to remove more persistent stains. Large areas of brick or architectural terra-cotta which have been painted are best left painted, or repainted if necessary.

Plaster and Stucco: Plaster and stucco are types of masonry finish materials that are softer than brick or terra-cotta; if treated abrasively these materials will simply disintegrate. Indeed, when plaster or stucco is treated abrasively it is usually with the intention of removing the plaster or stucco from whatever base material or substrate it is covering. Obviously, such abrasive techniques should not be applied to clean sound plaster or stuccoed walls, or decorative plaster wall surfaces.

Building Stones: Building stones are cut from the three main categories of natural rock: dense, igneous rock such as granite; sandy, sedimentary rock such as limestone or sandstone; and crystalline, metamorphic rock such as marble. As opposed to kiln-dried masonry materials such as brick and architectural terra-cotta, building stones are generally homogeneous in character at the time of a building's construction. However, as the stone is exposed to weathering and

environmental pollutants, the surface may become friable, or may develop a protective skin or patina. These outer surfaces are very susceptible to damage by abrasive or improper chemical cleaning.

Building stones are frequently cut into ashlar blocks or "dressed" with tool marks that give the building surface a specific texture and contribute to its historic character as much as ornately carved decorative stonework. Such detailing is easily damaged by abrasive cleaning techniques; the pattern of tooling or cutting is erased, and the crisp lines of moldings or carving are worn or pitted.

Occasionally, it may be possible to clean small areas of rough-cut granite, limestone or sandstone having a heavy dirt encrustation by using the "wet grit" method, whereby a small amount of abrasive material is injected into a controlled, pressurized water stream. However, this technique requires very careful supervision in order to prevent damage to the stone. Polished or honed marble or granite should never be treated abrasively, as the abrasion would remove the finish in much the way glass would be etched or "frosted" by such a process. It is generally preferable to underclean, as too strong a cleaning procedure will erode the stone, exposing a new and increased surface area to collect atmospheric moisture and dirt. Removing paint, stains or graffiti from most types of stone may be accomplished by a chemical treatment carefully selected to best handle the removal of the particular type of paint or stain without damaging the stone. (See section on the "Gentlest Means Possible.")

Very high-pressure water has scarred this granite.
Photo: NPS files.

Wood: Most types of wood used for buildings are soft, fibrous and porous, and are particularly susceptible to damage by abrasive cleaning. Because the summer wood between the lines of the grain is softer than the grain itself, it will be worn away by abrasive blasting or power tools, leaving an uneven surface with the grain raised and often frayed or "fuzzy." Once this has occurred, it is almost impossible to achieve a smooth surface again except by extensive hand sanding, which is expensive and will quickly negate any costs saved earlier by sandblasting. Such harsh cleaning treatment also obliterates historic tool marks, fine carving and detailing, which precludes its use on any interior or exterior woodwork which has been hand planed, milled or carved.

Metals: Like stone, metals are another group of building materials which vary considerably in hardness and durability. Softer metals which are used architecturally, such as tin, zinc, lead, copper or aluminum, generally should not be cleaned abrasively as the process deforms and destroys the original surface texture and appearance, as well as the acquired patina.

Decorative pressed metal interior or exterior features should not be cleaned abrasively. Photo: NPS files.

Much applied architectural metal work used on historic buildings--tin, zinc, lead and copper--is often quite thin and soft, and therefore susceptible to denting and pitting. Galvanized sheet metal is especially vulnerable, as abrasive treatment would wear away the protective galvanized layer.

In the late 19th and early 20th centuries, these metals were often cut, pressed or otherwise shaped from sheets of metal into a wide variety of practical uses such as roofs, gutters and flashing, and facade ornamentation such as cornices, friezes, dormers, panels, cupolas, oriel windows, etc. The architecture of the 1920s and 1930s made use of metals such as chrome, nickel alloys, aluminum and stainless steel in decorative exterior panels, window frames, and doorways. Harsh abrasive blasting would destroy the original surface finish of most of these metals, and would increase the possibility of corrosion.

However, conservation specialists are now employing a sensitive technique of glass bead peening to clean some of the harder metals, in particular large bronze outdoor sculpture. Very fine (75125 micron) glass beads are used at a low pressure of 60 to 80 psi. Because these glass beads are completely spherical, there are no sharp edges to cut the surface of the metal. After cleaning, these

statues undergo a lengthy process of polishing. Coatings are applied which protect the surface from corrosion, but they must be renewed every 3 to 5 years. A similarly delicate cleaning technique employing glass beads has been used in Europe to clean historic masonry structures without causing damage. But at this time the process has not been tested sufficiently in the United States to recommend it as a building conservation measure.

Sometimes a very fine smooth sand is used at a low pressure to clean or remove paint and corrosion from copper flashing and other metal building components. Restoration architects recently found that a mixture of crushed walnut shells and copper slag at a pressure of approximately 200 psi was the only way to remove corrosion successfully from a mid-19th century terne-coated iron roof. Metal cleaned in this manner must be painted immediately to prevent rapid recurrence of corrosion. It is thought that these methods "work harden" the surface by compressing the outer layer, and actually may be good for the surface of the metal. But the extremely complex nature and the time required by such processes make it very expensive and impractical for large-scale use at this time.

Cast and wrought iron architectural elements may be gently sandblasted or abrasively cleaned using a wire brush to remove layers of paint, rust and corrosion. Sandblasting was, in fact, developed originally as an efficient maintenance procedure for engineering and industrial structures and heavy machinery--iron and steel bridges, machine tool frames, engine frames, and railroad rolling stock--in order to clean and prepare them for repainting. Because iron is hard, its surface, which is naturally somewhat uneven, will not be noticeably damaged by controlled abrasion. Such treatment will, however, result in a small amount of pitting. But this slight abrasion creates a good surface for paint, since the iron must be repainted immediately to prevent corrosion. Any abrasive cleaning of metal building components will also remove the caulking from joints and around other openings. Such areas must be recaulked quickly to prevent moisture from entering and rusting the metal, or causing deterioration of other building fabric inside the structure.

Cast iron may be abrasively cleaned, but must be painted immediately to prevent rust. Photo: NPS files.

When is Abrasive Cleaning Permissible?

For the most part, abrasive cleaning is destructive to historic building materials. A limited number of special cases have been explained when it may be appropriate, if supervised by a skilled conservator, to use a delicate abrasive technique on some historic building materials. The type of "wet grit" cleaning which involves a small amount of grit injected into a stream of low pressure water may be used on small areas of stone masonry (i.e., rough cut limestone, sandstone or unpolished granite), where milder cleaning methods have not been totally successful in removing harmful deposits of dirt and pollutants. Such areas may include stone window sills, the tops of cornices or column capitals, or other detailed areas of the facade.

This is still an abrasive technique, and without proper caution in handling, it can be *just as harmful to the building surface as any other abrasive cleaning method*. Thus, the decision to use this type of "wet grit" process should be made only after consultation with an experienced building conservator.

Remember that it is very time consuming and expensive to use any abrasive technique on a historic building in such a manner that it does not cause harm to the often fragile and friable building materials.

At this time, and only under certain circumstances, abrasive cleaning methods may be used in the rehabilitation of interior spaces of warehouse or industrial buildings for contemporary uses.

Interior spaces of factories or warehouse structures in which the masonry or plaster surfaces do not have significant design, detailing, tooling or finish, and in which wooden architectural features are not finished, molded, beaded or worked by hand, may be cleaned abrasively in order to remove layers of paint and industrial discolorations such as smoke, soot, etc. It is expected after such treatment that brick surfaces will be rough and pitted, and wood will be somewhat frayed or "fuzzy" with raised wood grain. These nonsignificant surfaces will be damaged and have a roughened texture, but because they are interior elements, they will not be subject to further deterioration caused by weathering.

Industrial interiors that are not finely milled may be abrasively cleaned, in some instances. Photo: NPS files.

Historic Interiors That Should Not Be Cleaned Abrasively

Those instances (generally industrial and some commercial properties), when it may be acceptable to use an abrasive treatment on the interior of historic structures have been described. But for the majority of historic buildings, the Secretary of the Interior's *Guidelines for Rehabilitation* do not recommend "changing the texture of exposed wooden architectural features (including structural members) and masonry surfaces through sandblasting or use of other abrasive techniques to remove paint, discolorations and plaster.

Thus, it is not acceptable to clean abrasively interiors of historic residential and commercial properties which have *finished* interior spaces featuring milled woodwork such as doors, window and door moldings, wainscoting, stair balustrades and mantelpieces. Even the most modest historic house interior, although it may not feature elaborate detailing, contains plaster and woodwork that is architecturally significant to the original design and function of the house. Abrasive cleaning of such an interior would be destructive to the historic integrity of the building.

Decorative wood exterior or interior features should not be cleaned abrasively. Photo: NPS files.

Abrasive cleaning is also impractical. Rough surfaces of abrasively cleaned wooden elements are hard to keep clean. It is also difficult to seal, paint or maintain these surfaces which can be splintery and a problem to the building's occupants. The force of abrasive blasting may cause grit particles to lodge in cracks of wooden elements, which will be a nuisance as the grit is loosened by vibrations and gradually sifts out. Removal of plaster will reduce the thermal and insulating value of the walls. Interior brick is usually softer than exterior brick, and generally of a poorer quality. Removing surface plaster from such brick by abrasive means often exposes gaping mortar joints and mismatched or repaired brickwork which was never intended to show. The resulting bare brick wall may require repointing, often difficult to match. It also may be necessary to apply a transparent surface coating (or sealer) in order to prevent the mortar and brick from "dusting." However, a sealer may not only change the color of the brick, but may also compound any existing moisture problems by restricting the normal evaporation of water vapor from the masonry surface.

"Gentlest Means Possible"

There are alternative means of removing dirt, stains and paint from historic building surfaces that can be recommended as more efficient and less destructive than abrasive techniques. The "gentlest means possible" of removing dirt from a building surface can be achieved by using a low-pressure water wash, scrubbing areas of more persistent grime with a natural bristle (never metal) brush. Steam cleaning can also be used effectively to clean some historic building fabric. Low-pressure water or steam will soften the dirt and cause the deposits to rise to the surface, where they can be washed away.

A third cleaning technique which may be recommended to remove dirt, as well as stains, graffiti or paint, involves the use of commercially available chemical cleaners or paint removers, which, when applied to masonry, loosen or dissolve the dirt or stains. These cleaning agents may be used in combination with water or steam, followed by a clear water wash to remove the residue of dirt and the chemical cleaners from the masonry. A natural bristle brush may also facilitate this type of chemically assisted cleaning, particularly in areas of heavy dirt deposits or stains, and a wooden scraper can be useful in removing thick encrustations of soot. A limewash or absorbent talc, whitening or clay poultice with a solvent can be used effectively to draw out salts or stains from the surface of the selected areas of a building facade. It is almost impossible to remove paint from masonry surfaces without causing some damage to the masonry, and it is best to leave the surfaces as they are or repaint them if necessary.

Some physicists are experimenting with the use of pulsed laser beams and xenon flash lamps for cleaning historic masonry surfaces. At this time it is a slow, expensive cleaning method, but its initial success indicates that it may have an increasingly important role in the future.

There are many chemical paint removers which, when applied to painted wood, soften and dissolve the paint so that it can be scraped off by hand. Peeling paint can be removed from wood by hand scraping and sanding. Particularly thick layers of paint may be softened with a heat gun or heat plate, providing appropriate precautions are taken, and the paint film scraped off by hand. Too much heat applied to the same spot can burn the wood, and the fumes caused by burning paint are dangerous to inhale, and can be explosive. Furthermore, the hot air from heat guns can start fires in the building cavity. Thus, adequate ventilation is important when using a heat gun or heat plate, as well as when using a chemical stripper. A torch or open flame should never be used.

Preparations for Cleaning: It cannot be overemphasized that all of these cleaning methods must be approached with caution. When using any of these procedures which involve water or other liquid cleaning agents on masonry, it is imperative that all openings be tightly covered, and all cracks or joints be well pointed in order to avoid the danger of water penetrating the building's facade, a circumstance which might result in serious moisture related problems such as efflorescence and/or subflorescence. Any time water is used on masonry as a cleaning agent, either in its pure state or in combination with chemical cleaners, it is very important that the work be done in warm weather when there is no danger of frost for several months. Otherwise water which has penetrated the masonry may freeze, eventually causing the surface of the building to crack and spall, which may create another conservation problem more serious to the health of the building than dirt.

Each kind of masonry has a unique composition and reacts differently with various chemical cleaning substances. Water and/or chemicals may interact with minerals in stone and cause new types of stains to leach out to the surface immediately, or more gradually in a delayed reaction. What may be a safe and effective cleaner for certain stain on one type of stone, may leave unattractive discolorations on another stone, or totally dissolve a third type.

Testing: Cleaning historic building materials, particularly masonry, is a technically complex subject, and thus, should never be done without expert consultation and testing. No cleaning project should be undertaken without first applying the intended cleaning agent to a representative test patch area in an inconspicuous location on the building surface. The test patch or patches should be allowed to weather for a period of time, preferably through a complete seasonal cycle, in order to determine that the cleaned area will not be adversely affected by wet or freezing weather or any by-products of the cleaning process.

Mitigating the Effects of Abrasive Cleaning

There are certain restoration measures which can be adopted to help preserve a historic building exterior which has been damaged by abrasive methods. Wood that has been sandblasted will exhibit a frayed or "fuzzed" surface, or a harder wood will have an exaggerated raised grain. The only way to remove this rough surface or to smooth the grain is by laborious sanding. Sandblasted wood, unless it has been extensively sanded, serves as a dustcatcher, will weather faster, and will present a continuing and ever worsening maintenance problem. Such wood, after sanding, should be painted or given a clear surface coating to protect the wood, and allow for somewhat easier maintenance.

There are few successful preservative treatments that may be applied to grit-blasted exterior masonry. Harder, denser stone may have suffered only a loss of crisp edges or tool marks, or other indications of craft technique. If the stone has a compact and uniform composition, it should continue to weather with little additional deterioration. But some types of sandstone, marble and limestone will weather at an accelerated rate once their protective "quarry crust" or patina has been removed.

Softer types of masonry, particularly brick and architectural terra-cotta, are the most likely to require some remedial treatment if they have been abrasively cleaned. Old brick, being essentially a soft, baked clay product, is greatly susceptible to increased deterioration when its hard, outer skin is removed through abrasive techniques. This problem can be minimized by painting the brick. An alternative is to treat it with a clear sealer or surface coating but this will give the masonry a glossy, or shiny look. It is usually preferable to paint the brick rather than to apply a transparent sealer since sealers reduce the transpiration of moisture, allowing salts to crystallize as subflorescence that eventually spalls the brick. If a brick surface has been so extensively damaged by abrasive cleaning and weathering that spalling has already begun, it may be necessary to cover the walls with stucco, if it will adhere.

Of course, the application of paint, a clear surface coating (sealer), or stucco to deteriorating masonry means that the historical appearance will be sacrificed in an attempt to conserve the historic building materials. However, the original color and texture will have been changed already by the abrasive treatment. At this point it is more important to try to preserve the brick, and there is little choice but to protect it from "dusting" or spalling too rapidly. As a last resort, in the case of severely spalling brick, there may be no option but to replace the brick--a difficult, expensive (particularly if custom-made reproduction brick is used), and lengthy process. As described earlier, sandblasted interior brick work, while not subject to change of weather, may require the application of a transparent surface coating or painting as a maintenance procedure to contain loose mortar and brick dust. (See [Preservation Briefs No. 1](#) for a more thorough discussion of coatings.)

Metals, other than cast or wrought iron, that have been pitted and dented by harsh abrasive blasting usually cannot be smoothed out. Although fillers may be satisfactory for smoothing a painted surface, exposed metal that has been damaged usually will have to be replaced.

Summary and References

Sandblasting or other abrasive methods of cleaning or paint removal are by their nature destructive to historic building materials and should not be used on historic buildings except in a few well-monitored instances. There are exceptions when certain types of abrasive cleaning may be permissible, but only if conducted by a trained conservator, and if cleaning is necessary for the preservation of the historic structure.

There is no one formula that will be suitable for cleaning all historic building surfaces. Although there are many commercial cleaning products and methods available, it is impossible to state definitively which of these will be the most effective without causing harm to the building fabric. It is often difficult to identify ingredients or their proportions contained in cleaning products; consequently it is hard to predict how a product will react to the building materials to be cleaned. Similar uncertainties affect the outcome of other cleaning methods as they are applied to historic building materials. Further advances in understanding the complex nature of the many variables of the cleaning techniques may someday provide a better and simpler solution to the problems. But until that time, the process of cleaning historic buildings must be approached with caution through trial and error.

It is important to remember that historic building materials are neither indestructible, nor are they renewable. They must be treated in a responsible manner, which may mean little or no cleaning at all if they are to be preserved for future generations to enjoy. If it is in the best interest of the building to clean it, then it should be done "using the gentlest means possible."

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June 1979

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1.1.2.4 Types of cracks and causes (GSA 2016a)

Types of Cracks in Concrete and Typical Causes

Procedure code:

373202G

Division:

Concrete

Section:

Concrete Repair

Last Modified:

08/08/2016

Introduction

Cracks can be broadly classified as either active or dormant. Active cracks show some change in direction, width or depth over a measured period of time while dormant cracks remain unchanged. If left unrepaired, both active and dormant cracks provide channels for moisture penetration, which can lead to future damage. For guidance on patching dormant cracks, see "Repairing Cracks in Concrete by Injecting Epoxy Resin".

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Types of Cracks

The severity of a crack can be characterized in terms of its direction, width, and depth; cracks may be longitudinal, transverse, vertical, diagonal or random. Different risks for cracking exist for cured versus uncured concrete, and for reinforced concrete. Breakages occur through thermal, chemical or mechanical processes causing shrinkage, expansion or flexural stress. Below is a list of types of concrete cracks, and some of their possible causes:

- A. Plastic-shrinkage cracking: Cracks that run to the mid-depth of the concrete, are distributed across the surface unevenly, and are usually short in length.

- Most often occurs while concrete is curing, due to the surface of the concrete drying too rapidly relative to the concrete below.
- B. **Crazing/Map cracking/Checking:** A web of fine, shallow cracks across the surface of the concrete.
- Also occur during curing due to the surface of concrete drying faster than the interior concrete, but the surface drying occurs at a lesser depth.
 - Because this type of cracking is limited to the surface, it does not usually pose serious structural problems.
- C. **Hairline cracking:** Very thin but deep cracks.
- Due to settlement of the concrete while it is curing.
 - Due to their depth, these cracks can allow for more serious cracking once the concrete is hardened.
- D. **Pop-Outs:** Conical depressions in the concrete surface
- Occurs when a piece of aggregate near the concrete surface is particularly absorbent, causing it to expand and pop out of the surface of the concrete.
- E. **Scaling:** Small pock marks in the concrete surface, exposing aggregate underneath.
- Once cured, if concrete does have an adequate finish to prevent water penetration, water that seeps into the concrete will expand when it freezes, pushing off pieces of the concrete surface.
 - Scaling can also be caused by delamination, which occurs when too much water (due to insufficient curing) or air (due to insufficient vibrating) remains in the concrete when it is finished. The water and air rise to the top and form pockets below the surface. These pockets may form blisters or which may break open to create scaling.
- F. **Spalling:** Surface depressions that are larger and deeper than scaling, often linear when following the length of a rebar.
- Also caused by pressure from under the surface of the concrete.
 - Most often occur due to improperly constructed joints or the corrosion of rebar in the concrete
 - Corrosion creates pressure as rust forms, which can push away large chunks of concrete, and expose the corroded metal below.
 - Spalling that exposes corroded metal can be particularly problematic because the corrosion is likely to accelerate due to exposure to air and water.
- G. **D-Cracking:** Cracks that runs roughly parallel or stem from a concrete joint and are deeper than surface cracks.
- Due to moisture infiltration at the joint.
- H. **Offset cracking:** Cracks where the concrete on one side of the crack is lower than the concrete on the other side.
- Due to uneven surfaces below the concrete, such as subgrade settlement or pressure from objects such as tree roots, previously-placed concrete, or rebar.
- I. **Diagonal corner cracking:** Cracks that run from one joint to its perpendicular joint at the corner of a slab

- The corners of concrete slabs can be prone to curling(due to differences in temperature at different depths in the curing concrete) or warping (due to differences in moisture evaporation at different depths in the curing concrete). The dryer or colder level of concrete will shrink more and create cracks as the concrete dries.
- Because the warped or curled-up corners often have some empty space below them, they are also prone to cracking after curing due to weight overload causing the corner to snap downward into the empty space.

1.1.2.5 Repairing cracks with epoxy resin. (GSA 2016b)

Repairing Cracks in Concrete by Injecting Epoxy Resin

Procedure code:

373201S

Division:

Concrete

Section:

Concrete Repair

Last Modified:

08/10/2016

PART 1---GENERAL

1.01 SUMMARY

- A. This specification provides guidance on patching cracks in concrete by injecting an epoxy adhesive.
- B. Epoxy Injection should be used for dormant cracks, i.e., cracks that remain unchanged. Dormant cracks generally pose little danger. However, if left unrepaired, they will provide channels for moisture penetration.
- C. The calculated maximum crack width for concrete should not exceed 0.3 mm. Consult a professional to determine the cause for cracking and its source, as superficial repairs can aggravate the problem.
- D. Read "General Project Guidelines" along with this specification. 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). The 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)
- E. For guidance in monitoring cracks, see "Monitoring and Evaluating Cracks in Masonry".

1.02 REFERENCES

American Society for Testing and Materials (ASTM)

PART 2---PRODUCTS

2.01 MATERIALS

A. Epoxy Resin (Abatron, Inc., Sika Corp. or approved equal).

1. For Fine Cracks:

- a. Epoxy shall be a two-part type, low viscosity epoxy adhesive material containing 100% solids and shall meet or exceed the following characteristics when tested in accordance with the standards specified.
 - b. Characteristics of Components:
 - Component A - shall be a blend of modified epoxy resins.
 - Component B - shall be a blend of modified amine curing agents.
 - c. Test Method Requirements:
 - Component A - Brookfield RVT, 700 maximum; Viscosity @ 77 +/- 3 degrees Fahrenheit, cps; Spindle No. 2 @ 20 rpm.
 - Component B - Brookfield RVT, 240 maximum; Viscosity @ 77 +/- 3 degrees Fahrenheit, cps; Spindle No. 2.
 - d. Properties of Combined Components: When mixed in the ratio of two parts Component A to one part Component B by volume; or 100 parts Component A to 44 parts Component B by weight, properties shall be:
 - Potlife, 60g @ 77 +/- 3 degrees Fahrenheit, minutes; 25 minutes maximum.
 - e. Properties of the Cured Adhesive: When cured for seven days @ 77 +/- 3 degrees Fahrenheit, unless otherwise specified, properties shall be:
 - Ultimate Tensile Strength: ASTM D638; 8000 minimum.
 - Compressive Yield Strength, psi: ASTM D695*; 15,000 minimum.
 - Heat Deflection Temperature: ASTM D648*; 130 Fahrenheit minimum.
- NOTE: Test specimens must be cured in a manner such that the peak exothermic temperature of the adhesive does not exceed 77 degrees Fahrenheit.

2. For Wide Cracks:

- a. Epoxy shall be a two-part gel epoxy adhesive material containing 100% solids and shall meet or exceed the following characteristics when tested in accordance with the standards specified.
- b. Properties of Combined Components: When mixed in the ratio of two parts Component A to one part Component B by volume; or 100 parts Component A to 34 parts Component B by weight, properties shall be:
 - Potlife, 200g @ 77 +/- 3 degrees Fahrenheit, minutes.

c. Properties of the Cured Adhesive: When cured for seven days @ 77 +/- 3 degrees Fahrenheit, unless otherwise specified, properties shall be:

- Ultimate Tensile Strength: ASTM D638; 1,500 psi minimum. 2) Compressive Yield Strength: ASTM D695; 6,000 psi minimum.
- Heat Deflection Temperature: ASTM D648; 105 Fahrenheit minimum.

B. Surface Seal: (Epoxy Mortar or Oil-Free Clay)

1. Description: The surface seal material is that material used to confine the injection adhesive in the joints or cracks during injection and cure.
2. Properties: The surface seal material shall have adequate strength to hold injection fittings firmly in place and to resist injection pressures adequately to prevent leakage during injection. The material shall not leave a residue upon removal.
3. NOTE: Provide adhesive crack fillers and other related materials that are compatible with one another and with substrates under conditions of severe weather, demonstrated by sealant manufacturer based on testing and field experience.

2.03 EQUIPMENT

Equipment for Injection:

- A. Type: The equipment used to meter and mix the two injection adhesive components and inject the mixed adhesive into the crack shall be portable, positive displacement type pumps with interlock to provide positive ratio control of exact proportions of the two components at the nozzle. The pumps shall be electric or air powered and shall provide in-line metering and mixing.
- B. Discharge Pressure: The injection equipment shall have automatic pressure control capable of discharging the mixed adhesive at any pre-set pressure up to 200 psi + 5 psi and shall be equipped with a manual pressure control override. For injection of the gel epoxy, the equipment shall be equipped with the above features and be able to pump at up to 5,000 psi.
- C. Ratio Tolerance: The equipment shall have the capability of maintaining the volume ratio for the injection adhesive prescribed by the manufacturer of the adhesive within a tolerance of + 5% by volume at any discharge pressure up to 200 psi. For gel epoxies, the ratio will be checked by weight at up to 5,000 psi.
- D. Automatic Shut-Off Control: The injection equipment shall be equipped with sensors on both the Component A and B reservoirs that will automatically stop the machine when only one component is being pumped to the mixing head.
- E. The manufacturer of the injection equipment and the manufacturer of the epoxy resin adhesive for injection shall be one and the same.

PART 3---EXECUTION

3.01 EXAMINATION

- A. Examine the nature and severity of the crack:
 1. Note directions and widest point of cracks.
 2. Note sloped floors, bulging walls and doors that do not fit.

B. Determine the probable cause of cracks:

1. Foundation erosion.
2. Decay of materials.
3. Structural failure.
4. Change in materials or geometry.
5. Thermal and moisture changes.

C. Determine possible consequences if cracks are left unrepaired.

D. Evaluate alternative methods of repair.

E. For cracks associated with thermal movement, look for:

1. Horizontal or diagonal cracks near the ground at piers in long walls, due to horizontal shearing stresses between the upper wall and the wall where it enters the ground.
2. Vertical cracks near the ends of walls.
3. Vertical cracks near the top and ends of the facade.
4. Cracks around stone sills or lintel, due to expansion of the masonry against both ends of the tight fitting stone piece that cannot be compressed.

3.02 PREPARATION

Surface Preparation:

- A. Do not proceed with installation of joint sealers until contaminants capable of interfering with their adhesion are removed from joint substrates.
- B. Surfaces adjacent to joints or other areas of application shall be cleaned of dirt, dust, grease, oil or other foreign matter detrimental to bond of epoxy injection surface seal system.
- C. Entry ports shall be provided along the crack at intervals of not less than the thickness of the concrete member at that location.
- D. Surface seal material shall be applied to the face of the crack or end. For through cracks, surface seal shall be applied to both faces.
- E. Allow enough time for the surface seal material to gain adequate strength before proceeding with the injection.

3.03 ERECTION, INSTALLATION, APPLICATION

- A. If the crack is still damp when repairs are going to be made, be sure to use an epoxy appropriate for damp conditions.
- B. Seal both sides of cracks with an epoxy mortar or oil-free clay, leaving small holes through which epoxy resin will be injected. 1/8" to 1/4" diameter tubing can be used to form holes. Holes should be 2"-4" long and roughly 8" apart.
- C. Inject two-component epoxy using device as provided by manufacturer.

- D. Injection of epoxy adhesive shall begin at lower entry port and continue until there is an appearance of epoxy adhesive at the next entry port adjacent to the entry port being pumped.
- E. When epoxy adhesive travel is indicated by appearance at the adjacent port, injection shall be discontinued on the entry port being pumped, and epoxy injection shall be transferred to next adjacent port where epoxy adhesive has appeared.
- F. Perform epoxy adhesive injection continuously until cracks are completely filled.
- G. If port-to-port travel of epoxy adhesive is not indicated, the work shall be stopped immediately and the engineer notified.
- H. When cracks or joints are completely filled, epoxy adhesive shall be cured for sufficient time to allow removal of injection or port sealing devices.
- I. The outermost quarter inch of the crack shall be filled with a colored epoxy material of the installers choice subject to prior approval of the RHPO. The colored epoxy filler shall match the existing material which it is filling and shall not be discernible from a distance of 15 feet.

3.04 ADJUSTING/CLEANING

Upon completion of work, remove all seal material and other residue from site. Remove and clean exposed surfaces of residue or staining resulting from this work.

1.1.2.6 Removing efflorescence (GSA 2016c).

Removing Efflorescence from Concrete

Procedure code:

371016S

Source:

Historic Concrete: Investigation & Repair - Pre-Conference Training Course, APT Annual Meeting, 1989.

Division:

Concrete

Section:

Concrete Cleaning

Last Modified:

08/10/2016

PREFACE

The cleaning or removal of stains from concrete may involve the use of liquids, detergents or solvents which may run off on adjacent material, discolor the concrete or drive the stains deeper into porous concrete. Use the products and techniques described here only for the combinations of dirt/stain and concrete specified.

PART 1---GENERAL

1.01 SUMMARY

- A. This specification provides guidance on removing efflorescence from concrete using chemical solvents.
- B. Efflorescence is a condition wherein white deposits form on the surface of the concrete. These deposits often contain calcium, sodium and potassium hydroxides or carbonates, bicarbonates, chlorides and sulfates of calcium and magnesium.
- C. The surface deposits may originate as soluble compounds within the concrete or in the soil. These compounds combine with water and gradually migrate in solution to the wall surface, where they remain when the water evaporates. Surface deposits may also result from acid etching with hydrochloric acid, which is sometimes applied to roughen the concrete surface.
- D. Surface deposits originating from within the concrete are usually soluble and may be removed by scrubbing with water alone or hosing with water under high pressure.
- E. Surface deposits composed mainly of calcium acid carbonate and magnesium acid carbonate from the soil or of calcium hydroxide should be washed off with water as soon as possible. These deposits are water-soluble for only a brief period of time after reaching the atmosphere, after which the carbon dioxide converts them to water-insoluble calcium carbonate and magnesium carbonate, which are impossible to remove without the use of acids.
- F. Safety Precautions:

1. DO NOT save unused portions of stain-removal materials.
2. DO NOT store any chemicals in unmarked containers.
3. NOTE: EXCELLENT VENTILATION MUST BE PROVIDED WHEREVER ANY SOLVENT IS USED. USE RESPIRATORS WITH SOLVENT FILTERS.
4. No use of organic solvents indoors should be allowed without substantial air movement. Use only spark-proof fans near operations involving flammable liquids.
5. Provide adequate clothing and protective gear where the chemicals are indicated to be dangerous.
6. Have antidote and accident treatment chemicals readily available where noted.

G. Read "General Project Guidelines" along with this specification. 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). The 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)

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. Use one of the following solvents (see Section 3.02 A. below for mixing proportions):

Acetic Acid (C₂H₄O₂):

1. A colorless pungent liquid acid that is the chief acid of vinegar and that is used especially in synthesis (as of plastics).
2. Other chemical or common names include Vinegar acid*. (Vinegar itself, which contains about 4% acetic acid, may be suitable for some purposes requiring acetic acid.)
3. Potential hazards: CAUSTIC TO FLESH; CORROSIVE TO CONCRETE, STEEL, WOOD AND GLASS.
4. Available from chemical supply house (both commercial and scientific), drugstore or pharmaceutical supply distributor, grocery store or supermarket, or hardware store.

-OR-

Hydrochloric Acid (30-35%):

1. A strong corrosive irritating acid.
2. Other chemical or common names include Chlorhydric acid; Hydrogen chloride; Muriatic acid* (generally available in 18 degree and 20 degree Baume solutions); Marine acid*; Spirit of salt*; Spirit of sea salt*.
3. Potential Hazards: TOXIC, CAUSTIC TO FLESH; CORROSIVE TO CONCRETE, STEEL, WOOD AND GLASS; FLAMMABLE.
4. Available from chemical supply house, drugstore or pharmaceutical supply distributor, or hardware store.

OR-

Phosphoric Acid (H₃PO₄):

1. A syrupy or deliquescent tribasic acid used especially in preparing phosphates (as for fertilizers), in rust-proofing metals, and as a flavoring in soft drinks.
2. Other chemical or common names include Orthophosphoric acid.
3. Potential Hazards: CAUSTIC TO FLESH; CORROSIVE TO CONCRETE, STEEL, WOOD AND GLASS.
4. Available from chemical supply house or hardware store.

B. Calcium Hydroxide:

1. Other chemical or common names include Calcium hydrate*; Hydrated lime*; Lime hydrate*; Slaked lime*.
2. Potential Hazards: SKIN IRRITANT; AVOID INHALATION OF THE DRY POWDER.
3. Available from chemical supply house, construction materials yard, construction specialties distributor, garden and lawn supply center, or hardware store.

C. Filler material such as paper pulp.

D. Mineral water.

E. Plastic sheeting.

F. Clean dry towels for blotting the area after treatment.

G. Masking tape.

H. Accessible source of water, soap and towels for washing and rinsing in case of emergencies associated with the use of chemicals.

2.02 EQUIPMENT

A. Glass or ceramic container for mixing the poultice solution.

B. Rubber or plastic pale for mixing the acid and water solution.

C. Wooden utensil for stirring the ingredients.

D. Wood or plastic spatula.

PART 3---EXECUTION

3.01 PREPARATION

Protection:

- A. Provide adequate wash solutions (i.e. water, soap and towels) before starting the job.
- B. Whenever acid is used, the surface should be thoroughly rinsed with water as soon as its action has been adequate. Otherwise it will continue etching the concrete even though the stain is gone.

3.02 ERECTION, INSTALLATION, APPLICATION

NOTE: DO NOT TRY MORE THAN ONE TREATMENT ON A GIVEN AREA UNLESS THE CHEMICALS USED FROM PRIOR TREATMENT HAVE BEEN WASHED AWAY.

A. Mix in a glass or ceramic bowl one of the following combinations:

1. 1 part hydrochloric acid in 9 to 19 parts water, OR
2. 1 part phosphoric acid in 9 parts water, OR
3. 1 part phosphoric acid plus 1 part acetic acid in 19 parts water.

CAUTION: ALWAYS ADD ACID TO WATER RATHER THAN VICE-VERSA. ADDING WATER TO CONCENTRATED ACID CAN CAUSE THE WATER TO BECOME SUPER-HEATED AND TURN TO STEAM, WHICH CAN RESULT IN ACID SPLASHING ON THE USER.

- B. Saturate the concrete with clean, clear water.
- C. Begin by using the first mixture listed above and apply to the affected concrete surface with a stiff, non-metallic bristle brush.
- D. Thoroughly rinse the area with clean, clear water and allow to dry.
- E. If the first mixture is unsuccessful in adequately removing the efflorescence, repeat the treatment using the other mixtures listed in the order displayed until successful results are achieved.
- F. For concrete heavily laden with potential efflorescence:
 1. Remove all visible surface salts, following Steps A-E directly above.
 2. Follow by applying a poultice of paper pulp saturated in water and allow to dry.
 3. Remove the dried poultice using a wood or plastic spatula.
 4. Thoroughly rinse the surface with clean, clear water and allow to dry.
 5. Repeat as necessary to achieve the desired level of cleanliness.

3.03 ADJUSTING/CLEANING

If there is a supply of dilute acid to be disposed of when work is complete, neutralize it by stirring in 3 pounds of powdered calcium hydroxide for every gallon of the dilute (1-3) acid. The resulting solution is a harmless mixture of calcium hydroxide and calcium fluoride.

1.1.2.7 Patching spalls (GSA 2017b)

Patching Spalled Concrete

Procedure code:

373204S

Source:

National Capitol Region Specification - Agriculture Building

Division:

Concrete

Section:

Concrete Repair

Last Modified:

07/07/2017

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on patching spalls and holes in concrete with a cementitious patching material.
- 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).

1.02 QUALITY ASSURANCE

- A. Masonry and Concrete Repair: Prepare sample panels of size indicated for each type of masonry material indicated to be patched, rebuilt or replaced.

PART 2---PRODUCTS

2.01 MANUFACTURERS

- A. Sika Corporation usa.skie.com
- B. General Polymers, www.generalpolymers.com
- C. BASF Master Builders Solutions, www.master-builders-solutions-basf.us
- D. Euclid Chemical, www.euclidchemical.com

2.02 MATERIALS

- A. Concrete Patching Material: One component, early strength, cementitious patching material "Sika Repair 222" (Sika Corporation); "TPM 723" (General Polymers); (Master Builders), or approved equal.
- B. Water: Clean, free of oils, acids, alkalis and organic matter.

2.03 EQUIPMENT

- A. Trowels
- B. Chisels
- C. Stiff bristle brushes (non-metallic)

PART 3---EXECUTION

3.01 PREPARATION

- A. Protection:
 - 1. Protect persons, motor vehicles, surrounding surfaces of building whose masonry surfaces are being restored, building site, and surrounding buildings from injury resulting from masonry restoration work.
 - 2. Erect temporary protection covers over pedestrian walkways and at points of entrance and exit for persons and vehicles which must remain in operation during course of masonry restoration work.
 - 3. Contractor shall test those areaway drains, window well drains, etc., which will be used to assure that drains are functioning properly prior to performing masonry restoration operations in those areas. The Contractor shall report immediately to the Construction Engineer the location of drains which are found to be stopped up or blocked.
 - 4. Prevent grout or mortar used in repointing and repair work from staining face of surrounding masonry and other surfaces. Remove immediately grout and mortar in contact with exposed masonry and other surfaces.
 - 5. Protect sills, ledges, windows, and projections from patching material droppings.

3.02 ERECTION, INSTALLATION, APPLICATION

- A. Remove deteriorated concrete at spalls to sound material. Grind, chisel or saw cut 1" deep undercut around perimeter of patch. Clean with compressed air. Thoroughly remove any concrete showing traces of oils or grease.
- B. Thoroughly wet patched area prior to casting concrete patching material. If cement patching material manufacturer recommends a different procedure, such procedure is to be followed and executed in accordance with published instructions and in accordance with approved test patch.
- C. Install cement patching material in strict accordance with manufacturer's published instructions.
- D. Finish surface to match surface being patched, by grinding, troweling, sacking, or brushing.

3.03 ADJUSTING/CLEANING

- A. After mortar has fully hardened, thoroughly clean exposed masonry surfaces of excess mortar and foreign matter using stiff nylon or bristle brushes and clean water, spray applied at low pressure.
- B. Use of metal scrapers or brushes will not be permitted.
- C. Use of acid or alkali cleaning agents will not be permitted.

1.1.2.8 Patching scaling (GSA 2017c)

Patching Scaling Concrete Masonry

Procedure code:

373202S

Source:

Hspg Prepared For Nps - Sero

Division:

Concrete

Section:

Concrete Repair

Last Modified:

02/21/2017

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on patching scaling concrete with a mortar patch.
- B. Scaling of concrete masonry is the local flaking or peeling away of the near surface portion of concrete or mortar. It is often caused by:
 - 1. Overtroweling: Weakens the bond of the surface concrete to the concrete below by bringing an excess of fines to the surface.
 - 2. Insufficient concrete strength: Often a result of cool temperatures that do not allow the concrete to cure properly and gain sufficient strength to withstand freeze/thaw cycles and the application of de-icing chemicals.
 - 3. The use of concrete with low air contents in areas exposed to severe winter weather.
 - 4. Heavy application of salts and/or de-icing chemicals.
 - 5. The use of high slump concrete.
 - 6. Improper curing methods or lack of curing.
 - 7. Insufficient protection of fresh concrete during cold temperatures.
- C. See "General Project Guidelines" 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. Scaling: The local flaking or peeling away of the near surface portion of concrete or mortar.
- B. Peeling: Thin flakes of mortar are broken away from the concrete surface.
- C. Light scaling: Loss of surface mortar without exposure of coarse aggregate.
- D. Medium scaling: Loss of surface mortar without exposure of coarse aggregate.
- E. Severe scaling: Loss of surface mortar 5 to 10 mm in depth with some loss of mortar surrounding aggregate particles 10 to 20 mm in depth so that aggregate is clearly exposed and stands out from the concrete.
- F. Very severe scaling: Loss of coarse aggregate particles as well as surface mortar surrounding aggregate, generally greater than 20 mm in depth.
- G. Spalling: a more extreme form of scaling.

1.03 MAINTENANCE

- A. Check to see that all gutters, downspouts and other water run-off systems are in good repair and clear of debris.
- B. Correct conditions of "rising damp", splash-back, and foundation wetness.
- C. Remove water-entrapping vegetation from on or near the concrete walls.
- D. Do not use salt to melt snow anywhere near concrete walls.

PART 2---PRODUCTS

2.01 MANUFACTURERS

- A. Thoro System Products
Miami, FL

2.02 MATERIALS

- A. Mortar Patching Material: Composition to be determined by Regional Historical Preservation Officer (RHPO)
- B. Bonding Agent or Cement paste such as "Acryl" (Thoro System Products), or as specified by RHPO
- C. Rebars and/or stainless steel pins as required
- D. Epoxy as required
- E. Clean, potable water

2.03 EQUIPMENT

- A. Hammer and chisel
- B. Trowel

- C. Mortar board
- D. Masonry drill

PART 3---EXECUTION

3.01 ERECTION,INSTALLATION, APPLICATION

- A. Cut back damaged area to stable material. Roughen the surface with a hammer and chisel.
CAUTION: AVOID GRINDING THE MATERIAL IN THIS PROCESS, BECAUSE IT LEAVES THE SURFACE TOO SMOOTH TO ACHIEVE A PROPER BOND.
 - B. Remove all rust from any exposed rebar.
 - C. Cut out any rebar which is severely corroded and splice Paint freshly cleaned rebar with an epoxy coating to prevent further rusting.
 - D. If the patch is unusually large, drill holes into soundsubstrate and insert stainless steel pins anchored with epoxy.
 - E. Remove all dust and debris by water blasting, air blasting, or with a broom or vacuum.
 - F. Square off the perimeter of the area to be patched sothat a feathered edge will not be required.
 - G. About 1 hour before making repair, moisten surface of area to be patched.
 - H. To insure a good bond between patch and substrate, brush substrate surface with either a cement wash or a bonding agent such as Acryl.
 - I. Apply patching material, with a trowel, in 3/4" layers, compacting thoroughly after each layer.
 - J. Work the finished surface carefully making sure to match texture and appearance of surrounding surfaces.
- NOTE: PATCHING MIX SHOULD MATCH AS CLOSELY AS POSSIBLE, THE TEXTURE AND COLOR OF THE ORIGINAL.

1.1.2.9 Guidelines for cutting and patching (GSA 2016d)

General Guidelines for Cutting and Patching

Procedure code:

104501S

Source:

Federal Building and USPO, Spokane, WA - GSA/PBS

Division:

Masonry

Section:

Cutting and Patching

Last Modified:

08/17/2016

PART 1-- GENERAL

1.01 SUMMARY

This specification provide general guidelines to follow when performing cutting and patching in original work.

1.02 DEFINITIONS

- A. "Cutting and patching" refers to cutting into existing construction to provide for the installation or performance of other work, and the subsequent fitting and patching required to restore surfaces to their original condition.
1. Cutting and patching is performed for coordination of the work, to uncover work for access or inspection, to obtain samples for testing, to permit alterations to be performed, or for other similar purposes.
 2. Cutting and patching performed during the manufacture of products, or during the initial fabrication, erection or installation processes is not considered to be "cutting and patching" under this definition.
 3. Drilling of holes to install fasteners and similar operations are also not considered to be "cutting and patching".
- B. "Selective Demolition" is recognized as related but separate category of work, which may or may not include cutting and patching as defined in this specification.

1.03 SUBMITTALS

Where prior approval of cutting and patching is required, submit proposed procedures for this work well in advance of the time work will be performed, and request approval to proceed. Include the following information, as applicable, in the submittal.

- A. Describe nature of the work and how it is to be performed, indicating why cutting and patching cannot be avoided.

- B. Describe anticipated results of the work in terms of changes to the existing site conditions, including structural, operational and visual changes, as well as how historic materials or other significant elements may be affected by the proposed cutting and patching.
- C. List products to be used, and firms (including their qualifications), that will perform the work.
- D. Give dates when the work is expected to be performed.
- E. List utilities that will be disturbed or otherwise be affected by work, including those that will be relocated and those that will be temporarily out of service.
- F. If utility service will be disrupted, an estimated time that it will be out of operation must be included in the proposal.
- G. When cutting and patching of structural work involves the substitution, movement, removal or addition of structural elements or reinforcement of any kind, submit engineering details and calculations that have been signed and stamped by a suitably experienced and licensed professional to show how the new work is integrated with the original structure to satisfy the requirements of the undertaking.
- H. Indicate changes to designated landmark areas or highly rated HBPP zones.
- I. All welding and hot work require formal, written notification to the Building Manager no later than the first thing in the morning of each day such work is to be done. No welding or hot work is permitted without such prior notification.

1.04 QUALITY ASSURANCE

- A. The General Contractor shall do all cutting and patching of wall and ceiling surfaces for the removal, relocation or installation of new piping, conduit, electrical boxes, asbestos abatement, PCB removal.
- B. Cutting which will disturb the asbestos material shall be done under the direction of the Asbestos Abatement Subcontractor and be properly documented in writing.
- C. Cutting and patching of all nonstructural concrete floors for mechanical and electrical work shall be done by the respective subcontractors in accordance with the provisions of this section, under the supervision of the General Contractor.
- D. Cutting and patching of all walls for ducts shall be done by the Mechanical Subcontractor in accordance with the provisions of this section, under the supervision of the General Contractor.
- E. Requirements for Structural Work:
 - 1. As in 1.03.F above, when cutting and patching of structural work involves the substitution, movement, removal or addition of structural elements or reinforcement of any kind, submit engineering details and calculations that have been signed and stamped by a suitably experienced and licensed professional to show how the new work is integrated with the original structure to satisfy the requirements of the undertaking.
 - 2. Cutting and patching structural work in a manner that would result in a reduction of load-carrying capacity or of load-deflection ratio is not acceptable. All work must have the written approval of project's Structural Engineer in advance.
 - 3. Before cutting and patching the following categories of work, obtain approval to proceed from both the GSA Contracting Officer and the GSA Regional Historic Preservation Officer:

- a. Structural steel
- b. Miscellaneous structural metals, including lintels, equipment supports, stair systems and similar categories of work
- c. Structural concrete
- d. Foundation construction
- e. Timber and primary wood framing
- f. Structural decking
- g. Bearing and retaining walls
- h. Piping, ductwork, vessels and equipment
- i. Shoring, bracing, and sheeting
- j. Primary operational systems and equipment
- k. Water/moisture/vapor/air/smoke barriers, membranes and flashings
- l. Noise and vibration control elements and systems
- m. Control, communication, conveying, and electrical wiring systems, including fire and life safety systems

F. Visual Requirements:

- 1. Do not cut and patch work exposed on the building's exterior or in its occupied spaces in a manner that would, in the Contracting Officer's opinion, result in lessening the building's aesthetic qualities.
- 2. Do not cut and patch in a manner that would result in substantial visual evidence of cut and patch work. Any work judged by the Contracting Officer to be done in a visually unsatisfactory manner must be removed and replaced.

G. Retain a recognized, experienced, and specialized firm to cut and patch the following categories of exposed work.

- 1. Processed concrete finishes
- 2. Stonework and stone masonry
- 3. Ornamental metal
- 4. Matched-veneer woodwork
- 5. Roofing
- 6. Stucco and ornamental plaster
- 7. Terrazzo
- 8. Finished wood flooring
- 9. Carpeting
- 10. Wall covering

11. HVAC enclosures, cabinets or covers

PART 2--PRODUCTS

2.01 MATERIALS

- A. Except as otherwise indicated, or as directed by the Contracting Officer, materials for cutting and patching must be identical to existing materials.
- B. If identical materials are not available or cannot be used, use pre-approved materials that match existing adjacent surfaces to the fullest extent possible with regard to visual effect.
- C. Use materials for cutting and patching that will result in equal-or-better performance characteristics in comparison to the original.

PART 3--EXECUTION

3.01 EXAMINATION

- A. Before cutting, examine the surfaces to be cut and patched and the conditions under which the work is to be performed.
- B. If unsafe or otherwise unsatisfactory conditions are encountered, take corrective action before proceeding with the work.
- C. Before the start of cutting work, meet at the worksite with all parties involved in cutting and patching, including mechanical and electrical trades.
 - 1. Review areas of potential interference and conflict between the various trades.
 - 2. Coordinate layout of the work and resolve potential conflicts before proceeding.

3.02 PREPARATION

- A. Temporary Support: Provide adequate temporary support during cutting and patching so as to prevent damage work to be retained or adjoining work.
- B. Protection:
 - 1. Protect adjoining surfaces during cutting and patching to prevent damage.
 - 2. Provide protection from cold and moisture as directed by the patching product manufacturer.
 - 3. Avoid interference with the use of adjoining areas or interruption of free passage to adjoining areas to the extent possible given the scope of work.
 - 4. Utilize safe workplace practices.

3.03 ERECTION, INSTALLATION, APPLICATION

- A. General:
 - 1. Employ workers skilled in cutting and patching to do said work.
 - 2. Except as otherwise indicated or as approved by the Contracting Officer, proceed with cutting and patching at the earliest feasible time (given proper notice) and complete work without delay.
- B. Cutting:

1. Cut the work using methods that are least likely to damage work to be retained or adjoining work.
2. In general, use hand tools or small power tools designed for sawing or grinding, not hammering and chopping.
3. Cut through concrete and masonry using a cutting machine such as a Carborundum saw or core drill to ensure a neat hole.
4. Cut holes and slots neatly to required size, with minimum disturbance of adjacent work.
5. To avoid marring existing finished surfaces, cut or drill from the exposed or finished side into concealed surfaces.
6. Temporarily cover openings when not in use, taking into consideration life safety and fire regulations for occupied spaces.
7. Comply with other applicable requirements where cutting and patching requires excavating and backfilling.
8. If the area includes utility services enclosed in pipe or conduit that are scheduled to be removed as part of the undertaking, these should be disconnected and removed before cutting and patching as their later disturbance could damage the new patch.
 - a. Be on the alert for undocumented and unprotected cabling for alarms, computer networks, and security systems that often follow the same path as conduit and piping. These are frequently found passing through enclosed spaces.
 - b. Any cut-off conduit or pipe in walls or partitions is to be removed when possible.
 - c. Any remaining openings need to be sealed to meet fire and building codes, and shall prevent the entrance of moisture or other foreign matter into the space.

C. Patching:

1. Patch with durable seams that are as inconspicuous as possible and that comply with specified tolerances for the work.
2. Where feasible, inspect and test patched areas to demonstrate integrity of work.
3. Restore exposed finishes of patched areas.
 - a. Where necessary, extend finish restoration into retained adjoining work in a manner which will eliminate evidence of patching and refinishing.
 - b. Where a patch occurs in a smooth painted surface, paint patched area with proper primer and base coat, and then extend the final paint coat over the entire unbroken surface which now contains the new patch.
4. Where removal of walls or partitions has newly extended one finished area into another, floor and wall surfaces in the new space shall be patched and repaired to provide an even surface of uniform color and appearance. If necessary, remove the existing floor and wall coverings and replace with new materials to achieve uniform color and appearance.
5. Patch, repair or re-hang existing ceilings as necessary to provide a surface with an even plane of uniform appearance.

3.04 ADJUSTING/CLEANING

Clean adjoining surfaces that become soiled due to the cutting and patching work.

1.1.2.10 Patching chips and cracks (GSA 2017d)

Patching Chips And Cracks In Ornamental Concrete Block

Procedure code:

422003S

Source:

Developed For Hspg (Nps - Sero)

Division:

Masonry

Section:

Concrete Unit Masonry

Last Modified:

04/17/2017

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on repairing chips, cracks or holes in ornamental concrete block. Small areas may be patched using a mortar mixture; larger areas may require pins and mortar for additional reinforcement.
- 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).

1.02 REFERENCES

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

1.03 PROJECT/SITE CONDITIONS

A. Environmental Requirements:

1. Check manufacturer's literature for precautions and effects of products and procedures on adjacent building materials, components, and especially vegetation; Take appropriate protective measures as necessary.
2. Wet Weather: Do not apply or mix mortar on outside surfaces with standing water or outside during rain.
3. Do not proceed with patching under adverse weather conditions, or when temperatures are below or above manufacturer's recommended limitations for installation; Proceed with the work only when forecasted weather conditions are favorable for proper cure.
4. Cold Weather, winter construction is not allowed without consent of Regional Architect; Winter construction is defined as any time when surface temperature of masonry is below 50 degrees F. or air temperature is predicted to be below 40 degrees F. within 48 hours; Heat mortar materials to above 50 degrees F. if necessary.
5. Work must not be done at temperatures above 80 degrees F. unless shading and water-misted burlap over new work is provided. Mortar mixing should be done only in the shade; cover mortar in hot weather to reduce evaporation. Pointing work should be done in the shade. Work around the building during the day so that the fresh work will be shielded from direct sunlight to reduce evaporation rate.

PART 2---PRODUCTS

2.01 MATERIALS

- A. Clean, potable water
- B. Portland cement
- C. Hydrated lime
- D. Sand
- E. Epoxy cement
- F. Teflon or nylon pins with scored and threaded surface. (Stainless steel or bronze may be used if teflon or nylon are unavailable).

2.02 EQUIPMENT

- A. Stiff bristle brushes or vacuum
- B. Trowels
- C. Hawks
- D. Carbon-tipped masonry bit

PART 3---EXECUTION

3.01 ERECTION, INSTALLATION, APPLICATION

- A. Patching small cracks and holes with grout (a wetter version of mortar mix):
1. Cut out the deteriorated area to a sound surface. Under-cut the edge where possible to create a "key".
 2. Brush or vacuum out all dirt or debris.
 3. Flush the area with clean, clear water. Be sure no standing water remains.
 4. Mix 1 part Portland cement, ASTM C150, Type I, part hydrated lime, and 2 to 3 parts sand
-OR-
1 part Portland cement Type P (lime pre-mixed), and 2 to 3 parts sand
NOTE: ADJUST MIX TO MATCH COLOR, TEXTURE AND PHYSICAL PROPERTIES OF THE ORIGINAL MORTAR.
 5. Thin mortar to a slushy batter consistency.
 6. Trowel apply mortar to damaged area in layers no more than 1 inch thick. Several layers may be required. DO NOT APPLY PATCHES OVER JOINTS.
- B. Patching large chips, holes or broken corners using pins and mortar:
1. Using a stiff bristle brush, clean surfaces to be joined or patched.
 2. Using a carbon-tipped masonry bit, drill staggered rows of holes approximately 2 inches deep (no more than 4 times the pin diameter), 1-1/2 inch apart and 1/8 inch wider than the pin diameter.
 3. Again, brush debris from the surface.
 4. Fill the holes with mortar mix or epoxy cement.
 5. Set the pins in the holes.
 6. Trowel apply mortar to damaged area in layers no more than 1 inch thick. Several layers may be required. DO NOT APPLY PATCHES OVER JOINTS.
 7. To patch a chipped corner, fill the cavity with the concrete mix or bonding material, forcing it in and around the exposed pins, which will act to support and reinforce the patch.
- C. To rejoin two broken parts (such as a concrete baluster), coat both broken surfaces with epoxy adhesive and gently tap the parts together.

1.1.2.11 Removing bronze and copper stains (GSA 2016e)

Poulticing Bronze and Copper Stains from Concrete

Procedure code:

371044S

Source:

Hstrc Concrete: Investigation & Rpr/Pre-Conf Training - 1989

Division:

Concrete

Section:

Concrete Cleaning

Last Modified:

08/17/2016

PREFACE: The cleaning or removal of stains from concrete may involve the use of liquids, detergents or solvents which may run off on adjacent material, discolor the concrete or drive the stains deeper into porous concrete. Use the products and techniques described here only for the combinations of dirt/stain and concrete specified.

PART 1---GENERAL**1.01 SUMMARY**

- A. This procedure includes guidance on removing bronze and copper stains from concrete by poulticing with a mixture of aluminum chloride or ammonium chloride, ammoniumhydroxide and water.
- B. Green stains on concrete, and sometimes brown stains, are common where water has flowed over copper or bronze.
- C. Safety Precautions:
 - 1. DO NOT save unused portions of stain-removal materials.
 - 2. DO NOT store any chemicals in unmarked containers.
 - 3. EXCELLENT VENTILATION MUST BE PROVIDED WHEREVER ANY SOLVENT IS USED. USE RESPIRATORS WITH SOLVENT FILTERS.
 - 4. No use of organic solvents indoors should be allowed without substantial air movement. Use only spark-proof fans near operations involving flammable liquids.
 - 5. Provide adequate clothing and protective gear where the chemicals are indicated to be dangerous.
 - 6. Have available antidote and accident treatment chemicals where noted.
- D. See "General Project Guidelines" 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. Aluminum Chloride: Available from chemical supply house, drugstore or pharmaceutical supply distributor.
-OR-
- B. Ammonium Chloride - salt-like substance (NH₄Cl):
 1. A white crystalline volatile salt that is used in dry cells and as an expectorant.
 2. Other chemical or common names include Ammonium hydrochloride; Chloride of Ammonia*; Hydrochloride of Ammonia*; Muriate of Ammonia*; Sal Ammoniac*.
 3. Potential hazards: TOXIC; CAUSTIC TO FLESH; CORROSIVE TO CONCRETE, STEEL, WOOD OR GLASS.
 4. Available from chemical supply house, dry cleaning supply distributor, drugstore or pharmaceutical supply distributor, or hardware store.
- C. Ammonium Hydroxide:
 1. Other chemical or common names include Ammonia water*; Aqua ammonia*; Household ammonia*.
 2. Potential hazards: TOXIC; MAY IRRITATE THE EYES.
 3. Available from chemical supply house, grocery store or pharmaceutical supply distributor, or hardware store.
- D. Filler material such as diatomaceous earth or talc
- E. Mineral water
- F. Plastic sheeting
- G. Clean dry towels for blotting the area after treatment
- H. Masking tape
- I. Scouring Powder
- J. Clean, potable water
- K. Accessible source of water, soap and towels for washing and rinsing in case of emergencies associated with the use of chemicals

2.02 EQUIPMENT

- A. Glass or ceramic container for mixing the solution
- B. Wooden utensil for stirring the ingredients
- C. Wood or plastic spatula
- D. Stiff bristle brush (non-metallic)

PART 3---EXECUTION

3.01 PREPARATION

A. Protection:

1. Provide adequate wash solutions (i.e. water, soap and towels) before starting the job.
2. Whenever acid is used, the surface should be thoroughly rinsed with water as soon as its action has been adequate. Otherwise it will continue etching the concrete even though the stain is gone.

3.02 ERECTION, INSTALLATION, APPLICATION

NOTE: DO NOT TRY MORE THAN ONE TREATMENT ON A GIVEN AREA UNLESS THE CHEMICALS USED FROM PRIOR TREATMENT HAVE BEEN WASHED AWAY.

- A. Dry mix by weight 1 part ammonium chloride or aluminum chloride with 4 parts fine-powdered inert material such as diatomaceous earth or talc.
- B. Combine the dry mix with (1 part concentrated ammonium hydroxide diluted with 2 to 9 parts of water) to form a smooth paste. If the concentrated solution is not available, use household ammonia without diluting.
- C. Thoroughly wet the concrete surface to be treated with clean, clear water.
- D. Apply the mixture to the stained area using a wood or plastic spatula (approximately 1/8 to 1/4 inch thick) and allow to dry. Be sure to spread the poultice well beyond the stained area. The liquid portion of the paste will migrate into the concrete where it will dissolve some of the staining material. Then the liquid will gradually move back beyond the concrete surface and into the poultice, where it will evaporate, leaving the dissolved staining material in the poultice.
- E. When the poultice has dried, brush or scrape it off with a wooden scraper.
- F. Using a stiff bristle brush, scrub the surface with scouring powder and clean water to remove any residual staining.
- G. Thoroughly rinse the area with clean, clear water and allow to dry.
- H. Repeat the process as necessary to sufficiently remove the stain.

1.1.2.12 Removing surface dirt (GSA 2016f)

Removing Surface Dirt From Concrete

Procedure code:

371015S

Source:

Hstrc Concrete: Investigation & Rpr/Pre-Conf Training - 1989

Division:

Concrete

Section:

Concrete Cleaning

Last Modified:

08/02/2016

PREFACE: The cleaning or removal of stains from concrete may involve the use of liquids, detergents or solvents which may run off on\ adjacent material, discolor the concrete or drive the stains deeper into porous concrete. Use the products and techniques described here only for the combinations of dirt/stain and concrete specified.

PART 1---GENERAL**1.01 SUMMARY**

- A. This procedure includes guidance on removing dirt from concrete using a detergent, chemical solvent or steam.
- B. Dirt encompasses deposits of almost any material in a location where it's not wanted, but it usually includes fine, dark-colored solid particles, often surrounded by some kind of oily film. It is particularly troublesome on architectural and decorative concrete, including exposed aggregate surfaces.
- C. Safety Precautions:
 - 1. DO NOT save unused portions of stain-removal materials.
 - 2. DO NOT store any chemicals in unmarked containers.
 - 3. EXCELLENT VENTILATION MUST BE PROVIDED WHEREVER ANY SOLVENT IS USED. USE RESPIRATORS WITH SOLVENT FILTERS.
 - 4. Whenever acid is used, the surface should be thoroughly rinsed with water as soon as its action has been adequate. Otherwise it will continue etching the concrete even though the stain is gone.
 - 5. Provide adequate clothing and protective gear where the chemicals are indicated to be dangerous.
 - 6. Have available antidote and accident treatment chemicals where noted.
- D. See "General Project Guidelines" 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. Hydrochloric Acid:

1. A strong corrosive irritating acid.
2. Other chemical or common names include Chlorhydric acid; Hydrogen chloride; Muriatic acid*; Marine acid*; Spirit of salt*; Spirit of sea salt*.
3. Available from chemical supply house, drugstore, hardware store.

B. Detergent:

1. CAUTION: SOME DETERGENTS CONTAIN AMMONIA AND MAY REACT VIGOROUSLY WITH HYDROCHLORIC ACID.

C. Clean, potable water

D. Clean white cloths or towels

2.02 EQUIPMENT

A. Steam cleaning equipment

B. Stiff bristle brushes (non-metallic)

PART 3---EXECUTION

3.01 PREPARATION

A. Protection:

1. Provide adequate wash solutions (i.e. water, soap and towels) before starting the job.
2. Whenever acid is used, the surface should be thoroughly rinsed with water as soon as its action has been adequate. Otherwise it will continue etching the concrete even though the stain is gone.

3.02 ERECTION, INSTALLATION, APPLICATION

NOTE: DO NOT TRY MORE THAN ONE TREATMENT ON A GIVEN AREA UNLESS THE CHEMICALS USED FROM PRIOR TREATMENT HAVE BEEN WASHED AWAY.

- A. Brush affected area with water and strong detergent.
- B. Rinse the area thoroughly with clean, clear water and blot the surface dry with clean towels.
- C. Repeat the treatment as necessary until the desired level of cleanliness is achieved.
- OR-
- D. Mix 1 part hydrochloric acid in 19 parts water.
- E. Scrub the concrete surface with this solution. NOTE: THIS IS A STRONG METHOD AND MAY ROUGHEN THE CONCRETE.
- F. Rinse the area thoroughly with clean, clear water, blot the surface dry with clean towels.

- G. Repeat the treatment as necessary until the desired level of cleanliness is achieved.
- OR-
- H. Steam cleaning is generally effective and may be used in combination with proprietary materials, such as detergents for dirt removal.
- I. If there is oil present in the dirt, follow the procedure described for removing lubricating oil, see 03710-31-R "Poulticing Lubricating and Petroleum Oil Stains From Concrete".

1.1.2.13 Removing mildew stains (GSA 2017e)

Removing Mildew Stains From Concrete

Procedure code:

371028S

Source:

Hstrc Concrete: Investigation & Rpr/Pre-Conf Training - 1989

Division:

Concrete

Section:

Concrete Cleaning

Last Modified:

02/21/2017

PART 1---GENERAL

PREFACE: The cleaning or removal of stains from concrete may involve the use of liquids, detergents or solvents which may run off on adjacent material, discolor the concrete or drive the stains deeper into porous concrete. Use the products and techniques described here only for the combinations of dirt/stain and concrete specified.

1.01 SUMMARY

- A. This procedure includes guidance on removing mildew stains from concrete using chemical solvents.
- B. Safety Precautions:
 - 1. DO NOT save unused portions of stain-removal materials.
 - 2. DO NOT store any chemicals in unmarked containers.
 - 3. EXCELLENT VENTILATION MUST BE PROVIDED WHEREVER ANY SOLVENT IS USED. USE RESPIRATORS WITH SOLVENT FILTERS.
 - 4. No use of organic solvents indoors should be allowed without substantial air movement. Use only spark-proof fans near operations involving flammable liquids.
 - 5. Provide adequate clothing and protective gear where the chemicals are indicated to be dangerous.
 - 6. Have available antidote and accident treatment chemicals where noted.

C. See "General Project Guidelines" 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. Sodium Hypochlorite (NaOCl):

1. An unstable salt produced usually in aqueous solution and used as a bleaching and disinfecting agent.
2. Other chemical or common names include Bleaching solution*; Household bleach*; Laundry bleach*; Solution of chlorinated soda*.
3. Potential Hazards: CAUSTIC TO FLESH; DO NOT MIX WITH AMMONIA AS CHLORINE GAS WILL BE CREATED; FLAMMABLE IN CONTACT WITH DRY ORGANIC MATERIAL.
4. Available from chemical supply house, grocery store or supermarket, hardware store or janitorial supply distributor.

B. Sodium Orthophosphate:

1. Other chemical or common names include Tribasic sodium phosphate; Trisodium orthophosphate; Trisodium phosphate; TSP*; Phosphate of soda*.
2. Potential Hazards: CORROSIVE TO FLESH.
3. Available from chemical supply distributor, supermarket, grocery, or hardware store.

C. Laundry detergent

D. Clean, potable water

E. Accessible source of water, soap and towels for washing and rinsing in case of emergencies associated with the use of chemicals

2.02 EQUIPMENT

A. Stiff bristle brushes (non-metallic)

PART 3---EXECUTION

3.01 PREPARATION

A. Protection:

1. Provide adequate wash solutions (i.e. water, soap and towels) before starting the job.
2. Whenever acid is used, the surface should be thoroughly rinsed with water as soon as its action has been adequate. Otherwise it will continue etching the concrete even though the stain is gone.

3.02 ERECTION, INSTALLATION, APPLICATION

NOTE: DO NOT TRY MORE THAN ONE TREATMENT ON A GIVEN AREA UNLESS THE CHEMICALS USED FROM PRIOR TREATMENT HAVE BEEN WASHED AWAY.

- A. Mix together 1 ounce by weight of powdered laundry detergent, 1 ounce by weight of sodium orthophosphate, 1 quart of commercial sodium hypochlorite solution (which contains about 5% sodium hypochlorite) and 3 quarts of water.
- B. Brush apply the solution to the stained area, and allow to sit for a few days.
- C. Thoroughly rinse the surface with clean, clear water while scrubbing with a stiff bristle brush.
- D. CAUTION: SODIUM HYPOCHLORITE SOLUTION BLEACHES COLOR CLOTHING AND MAY CORRODE METALS.

1.1.2.14 Removing moss stains (GSA 2016g)

Removing Moss Stains From Concrete

Procedure code:

371029S

Source:

Hstrc Concrete: Investigation & Rpr/Pre-Conf Training - 1989

Division:

Concrete

Section:

Concrete Cleaning

Last Modified:

08/17/2016

PREFACE: The cleaning or removal of stains from concrete may involve the use of liquids, detergents or solvents which may run off on adjacent material, discolor the concrete or drive the stains deeper into porous concrete. Use the products and techniques described here only for the combinations of dirt/stain and concrete specified.

PART 1---GENERAL**1.01 SUMMARY**

- A. This procedure includes guidance on removing moss stains from concrete using chemical solvents.
- B. Safety Precautions:
 - 1. DO NOT save unused portions of stain-removal materials.
 - 2. DO NOT store any chemicals in unmarked containers.
 - 3. EXCELLENT VENTILATION MUST BE PROVIDED WHEREVER ANY SOLVENT IS USED. USE RESPIRATORS WITH SOLVENT FILTERS.
 - 4. No use of organic solvents indoors should be allowed without substantial air movement. Use only spark-proof fans near operations involving flammable liquids.
 - 5. Provide adequate clothing and protective gear where the chemicals are indicated to be dangerous.
 - 6. Have available antidote and accident treatment chemicals where noted.
- C. See "General Project Guidelines" 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. Chemicals for Cleaning and Removing Concrete Stains

1. Ammonium Sulfamate:

CAUTION: THE USE OF AMMONIUM SULFAMATE MAY BE DEPENDENT UPON REGIONAL, STATE OR LOCAL RESTRICTIONS. ENVIRONMENTAL CONDITIONS AND APPROPRIATENESS SHOULD BE REVIEWED. IRRITATION FROM CONTACT OR INHALATION.

- a. Past use was a base for weed killers; Not now readily available; Substitute any brand weed killer solution.
 - b. Available from chemical supply house, construction specialties distributor, garden and lawn supply center.
- OR-

2. Copper Nitrate:

- a. Other chemical or common names include Cupric Nitrate. DO NOT USE THE COPPER NITRATE KNOWN AS CUPROUS NITRATE.
 - b. Potential Hazards: TOXIC AND FLAMMABLE (WHEN IN
 - c. CONTACT WITH ORGANIC SOLVENTS).
 - d. Available from chemical supply house, drugstore or pharmaceutical supply distributor, garden and lawn supply center, or hardware store.
- OR-

3. Copper Sulfate (CuSO₄H₂O):

- a. A sulfate of copper especially the normal sulfate that is white in the anhydrous form but blue in the crystalline hydrous form and that is often used as an algicide and fungicide.
 - b. Other chemical or common names include Cupric Sulfate; Blue stone*; Blue vitriol*; Roman vitriol*.
 - c. Potential Hazards: TOXIC BY INGESTION AND CONTACT.
 - d. Available from chemical supply house, drugstore or pharmaceutical supply distributor, garden and lawn supply center, hardware store, swimming pool supply distributor, or water and sanitation supply distributor.
- OR-

4. Formaldehyde (CH₂O):

- a. A colorless pungent irritating gas used chiefly as a disinfectant and preservative and in synthesizing other compounds and resins.
- b. Other chemical or common names include Formic aldehyde; Methanal; Methyl aldehyde; Oxomethane; Oxymethylene; Formalin*.
- c. Potential Hazards: TOXIC BY INHALATION OR CONTACT, CARCINOGEN, AND FLAMMABLE.

- d. Available from chemical supply house, dairy supply distributor, drugstore or pharmaceutical supply distributor, photographic supply distributor (not camera shop), or printer's supply distributor.

-OR-

5. Sodium Hypochlorite (NaOCl):

- a. An unstable salt produced usually in aqueous solution and used as a bleaching and disinfecting agent.
- b. Other chemical or common names include Bleaching solution*; Household bleach*; Laundry bleach*; Solution of chlorinated soda*.
- c. Potential Hazards: TOXIC BY INHALATION AND CONTACT, DO NOT MIX WITH AMMONIA AS CHLORINE GAS IS CREATED; FLAMMABLE IN CONTACT WITH DRY ORGANIC MATERIAL.
- d. Available from chemical supply house, grocery store or supermarket, hardware store or janitorial supply distributor.

B. Chemicals for Sealing Concrete:

1. Magnesium Fluosilicate:

- a. Other chemical or common names include Magnesium silicofluoride.
 - b. Potential Hazards: TOXIC.
 - c. Available from construction specialties distributor (often sold under manufacturer's brand name; the chemical name may appear on the label).
- OR-
- d. Paints containing cuprous oxide or mercurous oxide.

2.02 EQUIPMENT

A. Stiff bristle brush (non-metallic)

PART 3---EXECUTION

3.01 PREPARATION

A. Protection:

- 1. Provide adequate wash solutions (i.e. water, soap and towels) before starting the job.
- 2. Whenever acid is used, the surface should be thoroughly rinsed with water as soon as its action has been adequate. Otherwise it will continue etching the concrete even though the stain is gone.

3.02 ERECTION, INSTALLATION, APPLICATION

NOTE: DO NOT TRY MORE THAN ONE TREATMENT ON A GIVEN AREA UNLESS THE CHEMICALS USED FROM PRIOR TREATMENT HAVE BEEN WASHED AWAY.

A. To remove moss and related staining:

- 1. Use ammonium sulfamate and follow manufacturer's instructions for removing moss.
- OR-
- 2. Mix one of the following:
 - a. Sodium Hypochlorite (laundry bleach, which contains about 5% sodium hypochlorite, is adequate).
 - b. Formaldehyde (1 part formalin [37% formaldehyde solution] in 49 parts water).
 - c. Copper Nitrate (4 to 7 ounces by weight in 1 gallon of water).
 - d. Copper Sulfate (4 to 7 ounces by weight in 1 gallon of water).
 - e. Saturate the moss with the chemical using a stiff bristle brush.

3. Allow to sit in place about 7 days. Reapply solution if it rains during the first 24 hours after application.
 4. Brush off the dead vegetable growth. The treatment should keep the concrete free of new growth for some time.
- B. To seal the concrete (sealing the concrete may make it easier to clean in the future and, at the same time, provide some fungicidal action against moss growth):
1. Apply a solution of 7 ounces by weight of magnesium fluosilicate in 1 gallon of water.
 2. Paints containing cuprous oxide or mercurous oxide (BOTH OF WHICH ARE TOXIC TO HUMANS) may also be applied to inhibit future growth.

1.1.2.15 Using substitute exterior materials (Park 1988 – Preservation Brief #16)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 16 Substitute Materials

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PRESERVATION BRIEFS

16

The Use of Substitute Materials on Historic Building Exteriors

Sharon C. Park, AIA

[Introduction](#)

[Historical Use of Substitute Materials](#)

[When to Consider Using Substitute Materials](#)

[Cautions and Concerns](#)

[Choosing an Appropriate Substitute Material](#)

[Pros and Cons of Various Substitute Materials](#)

[Summary and References](#)

[Reading List](#)

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Cast aluminum used as a replacement for cast iron. Photo: NPS files.

The Secretary of the Interior's Standards for Rehabilitation require that "deteriorated architectural features be repaired rather than replaced, wherever possible. In the event that replacement is necessary, the new material should match the material being replaced in composition, design, color, texture, and other visual properties." Substitute materials should be used only on a limited basis and only when they will match the appearance and general properties of the historic material and will not damage the historic resource.

Introduction

When deteriorated, damaged, or lost features of a historic building need repair or replacement, it is almost always best to use historic materials. In limited circumstances substitute materials that imitate historic materials may be used if the appearance and properties of the historic materials can be matched closely and no damage to the remaining historic fabric will result.

Great care must be taken if substitute materials are used on the exteriors of historic buildings. Ultraviolet light, moisture penetration behind joints, and stresses caused by changing temperatures can greatly impair the performance of substitute materials over time. Only after consideration of all options, in consultation with qualified professionals, experienced fabricators and contractors, and development of carefully written specifications should this work be undertaken.

The practice of using substitute materials in architecture is not new, yet it continues to pose practical problems and to raise philosophical questions. On the practical level the inappropriate choice or improper installation of substitute materials can cause a radical change in a building's appearance and can cause extensive physical damage over time. On the more philosophical level,

In the reconstruction of the clock tower at Independence Hall, the substitute materials used were cast stone and wood with fiberglass and polyester bronze ornamentation. Photo: NPS files.

the wholesale use of substitute materials can raise questions concerning the integrity of historic buildings largely comprised of new materials. In both cases the integrity of the historic resource can be destroyed.

Some preservationists advocate that substitute materials should be avoided in all but the most limited cases. The fact is, however, that substitute materials are being used more frequently than ever in preservation projects, and in many cases with positive results. They can be cost-effective, can permit the accurate visual duplication of historic materials, and last a reasonable time. Growing evidence indicates that with proper planning, careful specifications and supervision, substitute materials can be used successfully in the process of restoring the visual appearance of historic resources.

This Brief provides general guidance on the use of substitute materials on the exteriors of historic buildings. While substitute materials are frequently used on interiors, these applications are not subject to weathering and moisture penetration, and will not be discussed in this Brief. Given the general nature of this publication, specifications for substitute materials are not provided. The guidance provided should not be used in place of consultations with qualified professionals. This Brief includes a discussion of when to use substitute materials, cautions regarding their expected performance, and descriptions of several substitute materials, their advantages and disadvantages. This review of materials is by no means comprehensive, and attitudes and findings

will change as technology develops.

Historical Use of Substitute Materials

The tradition of using cheaper and more common materials in imitation of more expensive and less available materials is a long one. George Washington, for example, used wood painted with sand-impregnated paint at Mount Vernon to imitate cut ashlar stone. This technique along with scoring stucco into block patterns was fairly common in colonial America to imitate stone.

Molded or cast masonry substitutes, such as dry-tamp cast stone and poured concrete, became popular in place of quarried stone during the 19th century. These masonry units were fabricated locally, avoiding expensive quarrying and shipping costs, and were versatile in representing either ornately carved blocks, plain wall stones or rough cut textured surfaces. The end result depended on the type of patterned or textured mold used and was particularly popular in conjunction with mail order houses. Later, panels of cementitious permastone or formstone and less expensive asphalt and sheet metal panels were used to imitate brick or stone.

Metal (cast, stamped, or brake-formed) was used for storefronts, canopies, railings, and other features, such as galvanized metal cornices substituting for wood or stone, stamped metal panels for Spanish clay roofing tiles, and cast-iron column capitals and even entire building fronts in imitation of building stone.

Terra-cotta, a molded fired clay product, was itself a substitute material and was very popular in the late 19th and early 20th centuries. It simulated the appearance of intricately carved stonework, which was expensive and time-consuming to produce. Terra cotta could be glazed to imitate a variety of natural stones, from brownstones to limestones, or could be colored for a polychrome effect.

Nineteenth century technology made a variety of materials readily available that not only were able to imitate more expensive materials but were also cheaper to fabricate and easier to use. Throughout the century, imitative materials continued to evolve. For example, ornamental window hoods were originally made of wood or carved stone. In an effort to find a cheaper substitute for carved stone and to speed fabrication time, cast stone, an early form of concrete, or cast-iron hoods often replaced stone. Toward the end of the century, even less expensive sheet metal hoods, imitating stone, also came into widespread use. All of these materials, stone, cast stone, cast iron, and various pressed metals were in production at the same time and were selected on the basis of the availability of materials and local craftsmanship, as well as durability and cost. The criteria for selection today are not much different.

Many of the materials used historically to imitate other materials are still available. These are often referred to as the traditional materials: wood, cast stone, concrete, terra cotta and cast metals. In the last few decades, however, and partly as a result of the historic preservation movement, new families of synthetic materials, such as fiberglass, acrylic polymers,

Substitute materials need to be located with care to avoid damage. The fiberglass column base has chipped, whereas the historic cast iron would have remained sound. Photo: NPS files.

and epoxy resins, have been developed and are being used as substitute materials in construction. In some respects these newer products (often referred to as high tech materials) show great promise; in others, they are less satisfactory, since they are often difficult to integrate physically with the porous historic materials and may be too new to have established solid performance records.

When to Consider Using Substitute Materials in Preservation Projects

Because the overzealous use of substitute materials can greatly impair the historic character of a historic structure, all preservation options should be explored thoroughly before substitute materials are used. It is important to remember that the purpose of repairing damaged features and of replacing lost and irreparably damaged ones is both to match visually what was there and to cause no further deterioration. For these reasons it is not appropriate to cover up historic materials with synthetic materials that will alter the appearance, proportions and details of a historic building and that will conceal future deterioration.

Some materials have been used successfully for the repair of damaged features such as epoxies for wood infilling, cementitious patching for sandstone repairs, or plastic stone for masonry repairs. Repairs are preferable to replacement whether or not the repairs are in kind or with a synthetic substitute material.

In general, four circumstances warrant the consideration of substitute materials:

1. the unavailability of historic materials;
2. the unavailability of skilled craftsmen;
3. inherent flaws in the original materials; and
4. code-required changes (which in many cases can be extremely destructive of historic resources).

The core of a deteriorated wood outrigger was first drilled out. Photos (left and right): Courtesy, Harrison Goodall.

An inert material was injected into the hollow outrigger, permitting the outer wood to be retained and preserved.

Cost may or may not be a determining factor in considering the use of substitute materials. Depending on the area of the country, the amount of material needed, and the projected life of less durable substitute materials, it may be cheaper in the long run to use the original material, even though it may be harder to find.

Due to many early failures of substitute materials, some preservationist are looking abroad to find materials (especially stone) that match the historic materials in an effort to restore historic buildings accurately and to avoid many of the uncertainties that come with the use of substitute materials.

1. The unavailability of the historic material.

The most common reason for considering substitute materials is the difficulty in finding a good match for the historic material (particularly a problem for masonry materials where the color and texture are derived from the material itself). This may be due to the actual unavailability of the material or to protracted delivery dates. For example, the local quarry that supplied the sandstone for a building may no longer be in operation. All efforts should be made to locate another quarry that could supply a satisfactory match. If this approach fails, substitute materials such as dry-tamp cast stone or textured precast concrete may be a suitable substitute if care is taken to ensure that the detail, color and texture of the original stone are matched. In some cases, it may be possible to use a sand-impregnated paint on wood as a replacement section, achieved using readily available traditional materials, conventional tools and work skills. Simple solutions should not be overlooked.

2. The unavailability of historic craft techniques and lack of skilled artisans.

These two reasons complicate any preservation or rehabilitation project. This is particularly true for intricate ornamental work, such as carved wood, carved stone, wrought iron, cast iron, or molded terra cotta. However, a number of stone and wood cutters now employ sophisticated carving machines, some even computerized. It is also possible to cast substitute replacement pieces using aluminum, cast stone, fiberglass, polymer concretes, glass fiber reinforced concretes and terra cotta. Mold making and casting takes skill and craftsmen who can undertake this work are available. Efforts should always be made, prior to replacement, to seek out artisans who might be able to repair ornamental elements and thereby save the historic features in place.

3. Poor original building materials.

Some historic building materials were of inherently poor quality or their modern counterparts are inferior. In addition, some materials were naturally incompatible with other materials on the building, causing staining or galvanic corrosion. Examples of poor quality materials were the very soft sandstones which eroded quickly. An example of poor quality modern replacement material is the tin coated steel roofing which is much less durable than the historic tin or terne iron which is no longer available. In some cases, more durable natural stones or precast concrete might be available as substitutes for the soft stones and modern terne-coated stainless steel or lead-coated copper might produce a more durable yet visually compatible replacement roofing.

4. Code-related changes.

Sometimes referred to as life and safety codes, building codes often require changes to historic buildings. Many cities in earthquake zones, for example, have laws requiring that overhanging masonry parapets and cornices, or freestanding urns or finials be securely re-anchored to new structural frames or be removed completely. In some cases, it may be acceptable to replace these heavy historic elements with light replicas. In other cases, the extent of historic fabric removed may be so great as to diminish the integrity of the resource. This could affect the significance of the structure and jeopardize National Register status. In addition, removal of repairable historic materials could result in loss of Federal tax credits for rehabilitation. Department of the Interior regulations make clear that the Secretary of the Interior's Standards for Rehabilitation take precedence over other regulations and codes in determining whether a project is consistent with the historic character of the building undergoing rehabilitation.

Two secondary reasons for considering the use of substitute materials are their lighter weight and for some materials, a reduced need of maintenance. These reasons can become important if there is a need to keep dead loads to a minimum or if the feature being replaced is relatively inaccessible for routine maintenance.

Cast aluminum has been used as a replacement material for cast iron. Photo: NPS files.

Cautions and Concerns

In dealing with exterior features and materials, it must be remembered that moisture penetration, ultraviolet degradation, and differing thermal expansion and contraction rates of dissimilar materials make any repair or replacement problematic. To ensure that a repair or replacement will perform well over time, it is critical to understand fully the properties of both the original and the substitute materials, to install replacement materials correctly, to assess their impact on adjacent historic materials, and to have reasonable expectations of future performance.

Many high tech materials are too new to have been tested thoroughly. The differences in vapor permeability between some synthetic materials and the historic materials have in some cases caused unexpected further deterioration. It is therefore difficult to recommend substitute materials if the historic materials are still available. As previously mentioned, consideration should always be given first to using traditional materials and methods of repair or replacement before accepting unproven techniques, materials or applications.

Substitute materials must meet three basic criteria before being considered: they must be compatible with the historic materials in appearance; their physical properties must be similar to those of the historic materials, or be installed in a manner that tolerates differences; and they must meet certain basic performance expectations over an extended period of time.

Matching the Appearance of the Historic Materials

In order to provide an appearance that is compatible with the historic material, the new material should match the details and craftsmanship of the original as well as the color, surface texture, surface reflectivity and finish of the original material. The closer an element is to the viewer, the more closely the material and craftsmanship must match the original.

Matching the color and surface texture of the historic material with a substitute material is normally difficult. To enhance the chances of a good match, it is advisable to clean a portion of the building where new materials are to be used. If pigments are to be added to the substitute material, a specialist should determine the formulation of the mix, the natural aggregates and the types of pigments to be used. As all exposed material is subject to ultraviolet degradation, if possible, samples of the new materials made during the early planning phases should be tested or allowed to weather over several seasons to test for color stability.

A waterproof coating is an inappropriate substitute material to apply to adobe as it seals in moisture and may result in spalling. Photo: NPS files.

Fabricators should supply a sufficient number of samples to permit onsite comparison of color, texture, detailing, and other critical qualities. In situations where there are subtle variations in color and texture within the original materials, the substitute materials should be similarly varied so that they are not conspicuous by their uniformity.

Substitute materials, notably the masonry ones, may be more water-absorbent than the historic material. If this is visually distracting, it may be appropriate to apply a protective vapor-permeable coating on the substitute material. However, these clear coatings tend to alter the reflectivity of the material, must be reapplied periodically, and may trap salts and moisture, which can in turn produce spalling. For these reasons, they are not recommended for use on historic materials.

Matching the Physical Properties

While substitute materials can closely match the appearance of historic ones, their physical properties may differ greatly. The chemical composition of the material (i.e., presence of acids, alkalines, salts, or metals) should be evaluated to ensure that the replacement materials will be compatible with the historic resource. Special care must therefore be taken to integrate and to anchor the new materials properly. The thermal expansion and contraction coefficients of each adjacent material must be within tolerable limits. The function of joints must be understood and detailed either to eliminate moisture penetration or to allow vapor permeability. Materials that will cause galvanic corrosion or other chemical reactions must be isolated from one another.

To ensure proper attachment, surface preparation is critical. Deteriorated underlying material must be cleaned out. Noncorrosive anchoring devices or fasteners that are designed to carry the new material and to withstand wind, snow and other destructive elements should be used. Properly chosen fasteners allow attached materials to expand and contract at their own rates. Caulking, flexible sealants or expansion joints between the historic material and the substitute material can absorb slight differences of movement. Since physical failures often result from poor anchorage or improper installation techniques, a structural engineer should be a member of any team undertaking major repairs.

Some of the new high tech materials such as epoxies and polymers are much stronger than historic materials and generally impermeable to moisture. These differences can cause serious problems unless the new materials are modified to match the expansion and contraction properties of adjacent historic materials more closely, or unless the new materials are isolated from the historic ones altogether. When stronger or vapor impermeable new materials are used alongside historic ones, stresses from trapped moisture or differing expansion and contraction rates generally hasten deterioration of the weaker historic material. For this reason, a conservative approach to repair or replacement is recommended, one that uses more pliant materials rather than high-strength ones. Since it is almost impossible for substitute materials to match the properties of historic materials perfectly, the new system incorporating new and historic materials should be designed so that if material failures occur, they occur within the new material rather than the historic material.

Performance Expectations

While a substitute material may appear to be acceptable at the time of installation, both its appearance and its performance may deteriorate rapidly. Some materials are so new that industry standards are not available, thus making it difficult to specify quality control in fabrication, or to predict maintenance requirements and long term performance. Where possible, projects involving substitute materials in similar circumstances should be examined. Material specifications outlining stability of color and texture; compressive or tensile strengths if appropriate; the acceptable range of thermal coefficients, and the durability of coatings and finishes should be included in the contract documents. Without these written documents, the owner may be left with little recourse if failure occurs.

The historic cornice was successfully replaced with a fiberglass cornice. Photo: NPS files.

The tight controls necessary to ensure long-term performance extend beyond having written performance standards and selecting materials that have a successful track record. It is important to select qualified fabricators and installers who know what they are doing and who can follow up if repairs are necessary. Installers and contractors unfamiliar with specific substitute materials and how they function in your local environmental conditions should be avoided.

The surfaces of substitute materials may need special care once installed. For example, chemical residues or mold release agents should be removed completely prior to installation, since they attract pollutants and cause the replacement materials to appear dirtier than the adjacent historic materials. Furthermore, substitute materials may require more frequent cleaning, special cleaning products and

protection from impact by hanging window-cleaning scaffolding. Finally, it is critical that the substitute materials be identified as part of the historical record of the building so that proper care and maintenance of all the building materials continue to ensure the life of the historic resource.

Choosing an Appropriate Substitute Material

Once all reasonable options for repair or replacement in kind have been exhausted, the choice among a wide variety of substitute materials currently on the market must be made. The charts at the end of this Brief describe a number of such materials, many of them in the family of modified concretes which are gaining greater use. The charts do not include wood, stamped metal, mineral fiber cement shingles and some other traditional imitative materials, since their properties and performance are better known. Nor do the charts include vinyls or molded urethanes which are sometimes used as cosmetic claddings or as substitutes for wooden millwork. Because millwork is still readily available, it should be replaced in kind.

The charts describe the properties and uses of several materials finding greater use in historic preservation projects, and outline advantages and disadvantages of each. It should not be read as an endorsement of any of these materials, but serves as a reminder that numerous materials must be studied carefully before selecting the appropriate treatment. Included are three predominantly masonry materials (cast stone, precast concrete, and glass fiber reinforced concrete); two predominantly resinous materials (epoxy and glass fiber reinforced polymers also known as fiberglass), and cast aluminum which has been used as a substitute for various metals and woods.

Pros and Cons of Various Substitute Materials

Cast Aluminum

Material: Cast aluminum is a molten aluminum alloy cast in permanent (metal) molds or onetime sand molds which must be adjusted for shrinkage during the curing process. Color is from paint applied to primed aluminum or from a factory finished coating. Small sections can be bolted together to achieve intricate or sculptural details. Unit castings are also available for items such as column plinth blocks.

Application: Cast aluminum can be a substitute for cast iron or other decorative elements. This would include grillwork, roof crestings, cornices, ornamental spandrels, storefront elements, columns, capitals, and column bases and plinth blocks. If not self-supporting, elements are generally screwed or bolted to a structural frame. As a result of galvanic corrosion problems with dissimilar metals, joint details are very important.

Advantages:

- light weight (1/2 of castiron)
- corrosion-resistant, noncombustible
- intricate castings possible
- easily assembled, good delivery time
- can be prepared for a variety of colors
- long life, durable, less brittle than cast iron

Disadvantages:

- lower structural strength than castiron
- difficult to prevent galvanic corrosion with other metals
- greater expansion and contraction than castiron; requires
- gaskets or caulked joints
- difficult to keep paint on aluminum

Checklist:

- Can existing be repaired or replaced in kind?
- How is cast aluminum to be with other metals attached?
- Have full-size details been developed for each piece to be cast?
- How are expansion joints detailed?
- Will there be a galvanic corrosion problem?
- have factory finishes been protected during installation?
- Are fabricators/installers experienced?

Cast Stone (dry tamped)

Material: Cast stone is an almost-dry cement, lime and aggregate mixture which is dry-tamped into a mold to produce a dense stone-like unit. Confusion arises in the building industry as many refer to high quality precast concrete as cast stone. In fact, while it is a form of precast concrete, the drytamp fabrication method produces an outer surface resembling a stone surface. The inner core can be either drytamped or poured full of concrete. Reinforcing bars and anchorage devices can be installed during fabrication.

Application: Cast stone is often the most visually similar material as a replacement for unveined deteriorated stone, such as brownstone or sandstone, or terra cotta in imitation of stone. It is used both for surface wall stones and for ornamental features such as window and door surrounds, voussoirs, brackets and hoods. Rubberlike molds can be taken of good stones on site or made up at the factory from shop drawings.

Advantages:

- replicates stone texture with good molds (which can come from extant stone) and fabrication
- expansion/contraction similar to stone
- minimal shrinkage of material
- anchors and reinforcing bars can be built in
- material is fire-rated
- range of color available
- vapor permeable

Disadvantages:

- heavy units may require additional anchorage
- color can fade in sunlight
- may be more absorbent than natural stone
- replacement stones are obvious if too few models and molds are made

Checklist:

- Are the original or similar materials available?
- How are units to be installed and anchored?
- Have performance standards been developed to ensure color stability?
- Have large samples been delivered to site for color, finish and absorption testing?
- Has mortar been matched to adjacent historic mortar to achieve a good color/tooling match?
- Are fabricators/installers experienced?

Glass Fiber Reinforced Concretes (GFRC)

Material: Glass fiber reinforced concretes are lightweight concrete compounds modified with additives and reinforced with glass fibers. They are generally fabricated as thin shelled panels and applied to a separate structural frame or anchorage system. The GFRC is most commonly sprayed into forms although it can be poured. The glass must be alkaline resistant to avoid deteriorating effects caused by the cement mix. The color is derived from the natural aggregates and if necessary a small percentage of added pigments.

Application: Glass fiber reinforced concretes are used in place of features originally made of stone, terra cotta, metal or wood, such as cornices, projecting window and door trims, brackets, finials, or wall murals. As a molded product it can be produced in long sections of repetitive designs or as sculptural elements. Because of its low shrinkage, it can be produced from molds taken directly from the building. It is installed with a separate noncorrosive anchorage system. As a predominantly cementitious material, it is vapor permeable.

Advantages:

- lightweight, easily installed
- good molding ability, crisp detail possible
- weather resistant
- can be left uncoated or else painted
- little shrinkage during fabrication
- molds made directly from historic features

- cements generally breathable
- material is fire-rated

Disadvantages:

- non-loadbearing use only
- generally requires separate anchorage system
- large panels must be reinforced
- color additives may fade with sunlight
- joints must be properly detailed
- may have different absorption rate than adjacent historic material

Checklist:

- Are the original materials and craftsmanship still available?
- Have samples been inspected on the site to ensure detail/texture match?
- Has anchorage system been properly designed?
- Have performance standards been developed?
- Are fabricators/installers experienced?

Precast Concrete

Material: Precast concrete is a wet mix of cement and aggregate poured into molds to create masonry units. Molds can be made from existing good surfaces on the building. Color is generally integral to the mix as a natural coloration of the sand or aggregate, or as a small percentage of pigment. To avoid unsightly air bubbles that result from the natural curing process, great care must be taken in the initial and longterm vibration of the mix. Because of its weight it is generally used to reproduce individual units of masonry and not thin shell panels.

Application: Precast concrete is generally used in place of masonry materials such as stone or terra cotta. It is used both for flat wall surfaces and for textured or ornamental elements. This includes wall stones, window and door surrounds, stair treads, paving pieces, parapets, urns, balusters and other decorative elements. It differs from cast stone in that the surface is more dependent on the textured mold than the hand tamping method of fabrication.

Advantages:

- easily fabricated, takes shape well
- rubber molds can be made from building stones
- minimal shrinkage of material
- can be load bearing or anchorage can be cast in
- expansion/contraction similar to stone
- material is fire-rated
- range of color and aggregate available
- vapor permeable

Disadvantages:

- may be more moisture absorbent than stone although coatings may be applied
- color fades in sunlight
- small air bubbles may disfigure units
- replacement stones are conspicuous if too few models and molds are made

Checklist:

- Is the historic material still available?
- What are the structural/anchorage requirements?
- Have samples been matched for color/texture/absorption? Have shop drawings been made for each shape?
- Are there performance standards?
- Has mortar been matched to adjacent historic mortar to achieve good color/tooling match?

- Are fabricators/installers experienced?

Fiber Reinforced Polymers (FRP, Fiberglass)

Material: Fiberglass is the most well known of the FRP products generally produced as a thin rigid laminate shell formed by pouring a polyester or epoxy resin gelcoat into a mold. When tack-free, layers of chopped glass or glass fabric are added along with additional resins. Reinforcing rods and struts can be added if necessary; the gel coat can be pigmented or painted.

Application: Fiberglass, a non load-bearing material attached to a separate structural frame, is frequently used as a replacement where a lightweight element is needed or an inaccessible location makes frequent maintenance of historic materials difficult. Its good molding ability and versatility to represent stone, wood, metal and terra cotta make it an alternative to ornate or carved building elements such as column capitals, bases, spandrel panels, beltcourses, balustrades, window hoods or parapets. Its ability to reproduce bright colors is a great advantage.

Advantages:

- lightweight, long spans available with a separate structural frame
- high ratio of strength to weight
- good molding ability
- integral color with exposed high quality pigmented gel-coat or takes paint well
- easily installed, can be cut, patched, sanded
- non-corrosive, rot-resistant

Disadvantages:

- requires separate anchorage system
- combustible (fire retardants can be added); fragile to impact.
- high coefficient of expansion and contraction requires frequently placed expansion joints
- ultraviolet sensitive unless surface is coated or pigments are in gelcoat
- vapor impermeability may require ventilation detail

Checklist:

- Can original materials be saved/used?
- Have expansion joints been designed to avoid unsightly appearance?
- Are there standards for color stability/durability?
- Have shop drawings been made for each piece?
- Have samples been matched for color and texture?
- Are fabricators/installers experienced?
- Do codes restrict use of FRP?

Epoxies (Epoxy Concretes, Polymer Concretes)

Material: Epoxy is a resinous two-part thermosetting material used as a consolidant, an adhesive, a patching compound, and as a molding resin. It can repair damaged material or recreate lost features. The resins which are poured into molds are usually mixed with fillers such as sand, or glass spheres, to lighten the mix and modify their expansion/contraction properties. When mixed with aggregates, such as sand or stone chips, they are often called epoxy concrete or polymer concrete, which is a misnomer as there are no cementitious materials contained within the mix. Epoxies are vapor impermeable, which makes detailing of the new elements extremely important so as to avoid trapping moisture behind the replacement material. It can be used with wood, stone, terra cotta, and various metals.

Application: Epoxy is one of the most versatile of the new materials. It can be used to bind together broken fragments of terra cotta; to build up or infill missing sections of ornamental metal; or to cast missing elements of wooden ornaments. Small cast elements can be attached to existing materials or entire new features can be cast. The resins are poured into molds and due to the rapid setting of the material and the need to avoid cracking, the molded units are generally small or hollow inside. Multiple molds can be combined for larger elements. With special rods, the epoxies can be structurally reinforced. Examples of epoxy replacement pieces include: finials, sculptural details, small column capitals, and medallions.

Advantages:

- can be used for repair/replacement
- lightweight, easily installed
- good casting ability; molds can be taken from building material can be sanded and carved.
- color and ultraviolet screening can be added; takes paint well
- durable, rot and fungus resistant

Disadvantages:

- materials are flammable and generate heat as they cure and may be toxic when burned
- toxic materials require special protection for operator and adequate ventilation while curing
- material may be subject to ultraviolet deterioration unless coated or filters added rigidity of material
- often must be modified with fillers to match expansion coefficients
- vapor impermeable

Checklist:

- Are historic materials available for molds, or for splicing-in as a repair option?
- Has the epoxy resin been formulated within the expansion/contraction coefficients of adjacent materials?
- Have samples been matched for color/finish?
- Are fabricators/installers experienced?
- Is there a sound substrate of material to avoid deterioration behind new material?
- Are there performance standards?

Summary and References

Substitute materials—those products used to imitate historic materials—should be used only after all other options for repair and replacement in kind have been ruled out. Because there are so many unknowns regarding the longterm performance of substitute materials, their use should not be considered without a thorough investigation into the proposed materials, the fabricator, the installer, the availability of specifications, and the use of that material in a similar situation in a similar environment.

Substitute materials are normally used when the historic materials or craftsmanship are no longer available, if the original materials are of a poor quality or are causing damage to adjacent materials, or if there are specific code requirements that preclude the use of historic materials. Use of these materials should be limited, since replacement of historic materials on a large scale may jeopardize the integrity of a historic resource. Every means of repairing deteriorating historic materials or replacing them with identical materials should be examined before turning to substitute materials.

The importance of matching the appearance and physical properties of historic materials and, thus, of finding a successful longterm solution cannot be overstated. The successful solutions illustrated in this Brief were from historic preservation projects involving professional teams of architects, engineers, fabricators, and other specialists. Cost was not necessarily a factor, and all agreed that whenever possible, the historic materials should be used. When substitute materials were selected, the solutions were often expensive and were reached only after careful consideration of all options, and with the assistance of expert professionals.

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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.

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1.2 Precast concrete / cast stone

A precast concrete/cast stone building unit is cast with a type of concrete mixture that employs molded shapes, decorative aggregates, and masonry pigments to simulate natural stone. The basic mixture includes water, sand, coarse aggregate, and cementing agents. Natural cements, Portland cements, oxychloride cements, and sodium silicate-based cements are used as binding agents.

Precast concrete/cast stone architectural elements such as window sills, window surrounds, door surrounds, cornices, and some exterior walls are used on the buildings of the USMMA.

1.2.1 Immediate concerns for precast concrete / cast stone

Precast concrete/cast stone is typically used in the form of a veneer, a block, or as an ornament. It is installed like natural stone—laid in place with mortar or fastened with metal anchors. Major signs of deterioration include the following: facing delamination, aggregate/alkali reaction, freeze-thaw reaction, erosion, cracking, and spalling. The following are examples of deterioration, with references to photos of structures showing the indicated problems. Of course, it is possible for a structure to exhibit more than one type of deterioration.

- Incorrect mortar or epoxy fill has been used for inappropriate repairs (Figure 33).
- Epoxy injection should be used for dormant cracks (i.e., cracks that remain unchanged). Dormant cracks generally pose little danger. However, if left unrepaired, they will provide channels for moisture penetration (Figure 34).
- Precast concrete/cast stone panels are cracked or broken, with missing materials leaving holes (Figure 35).
- Cracks should be examined by a structural engineer (see Figure 35)
- Flaking or spalling of the outer layer of precast concrete/cast stone panels is becoming visible (see Figure 35).
- Walls show efflorescence, a white powdery substance leaching onto the precast concrete/cast stone pieces (Figure 36–Figure 38).

- Surface dirt needs to be removed from precast concrete/cast stone elements following guidelines (see Figure 38–Figure 40).
- Staining from metal needs to be cleaned according to guidelines to prevent further damage to precast concrete/cast stone material (see Figure 41).
- Copper staining from lettering needs to be cleaned according to guidelines to prevent further damage to precast concrete elements (see Figure 42).
- Vegetation growth needs to be removed from cracks and surfaces of the precast concrete/cast stone elements (see Figure 43).

Figure 33. Inappropriate treatment on expansion joint leading to staining below on the library (ERDC-CERL, 2015).

Figure 34. Incorrect mortar or epoxy fill has been used for repairs (ERDC-CERL, 2015).

Figure 35. Cracks and flaking are apparent on the precast concrete/cast stone elements. Major cracks should be examined by a structural engineer (ERDC-CERL, 2015).

Figure 36. Walls show the presence of an inappropriate sealer that has stained and colored the precast concrete/cast stone panels; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).

Figure 37. Other walls also show the presence of an inappropriate sealer that has stained and colored the precast concrete/cast stone; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).

Figure 38. Precast/cast stone panel walls show the presence of surface dirt and efflorescence; the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2015).

Figure 39. Surface dirt should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 40. Surface dirt on precast concrete / cast stone architectural features should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 41. Surface dirt and staining from metal handrail should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 42. Staining should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 43. Damaged mortar should be replaced with material compatible with the original material, and all natural growth should be removed (ERDC-CERL, 2015).

1.2.2 Guidelines, briefs, bulletins, and sources for precast concrete / cast stone

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 precast concrete / cast stone (see subsections 1.2.2.1 and 1.2.2.2).

1.2.2.1 Cast stone characteristics, uses, and problems (GSA 2016h)

Cast Stone: Characteristics, Uses And Problems

Procedure code:

472001G

Source:

20Th Century Building Materials (Ed. Tom Jester, Nps)

Division:

Masonry

Section:

Cast Stone

Last Modified:

08/02/2016

This standard includes general information on the characteristics and common uses of cast stone and identifies typical problems associated with this material along with common causes of its deterioration.

Introduction

Characteristics of Cast Stone:

- Made from Portland cement, sand, crushed stone, fine and coarse aggregates and water in varying proportions and formulas.
- Manufactured in custom molds - either by dry-tamping or wet casting.
- Dry-tamping is cast in two layers - an inner core and a facing; due to cost, only the facing material usually contains the coloring aggregates and pigments; numerous casts from the same mold can be made in the same day.
- Wet-casting is one integral mix containing enough water for it to flow easily into the mold; this method produces a cast with integral coloring; typically only one piece can be cast in a mold in one day due to the high water content.
- Typical aggregates used included granites, marbles and blast- furnace slag.
- Can be manufactured in just about any shape or size.
- The strongest cast stone consisted of varying sizes of aggregates; this allowed large and small pieces to fit closely together, while cement filled in the voids.
- Historically, paint was often applied to the surface for the purposes of waterproofing.
- The aggregate primarily determines the cast stone color.
- Veining was created by placing dye-soaked strings or thin strips of wood into the mold and then removing them before casting; the dye could then soak into the concrete mixture; veining could also be achieved by applying color or dye to the surface using a fine brush
- Typical finishes include
 - Surfaced cast stone,
 - Cut cast stone, and

- Plain cast stone.
- Surfaced cast stone includes hand-rubbed, brushed and acid-washed finishes.
- Cut cast stone includes machine-rubbed, planar-rubbed, bush-hammered and machine- and hand-tooled finishes.

References: Cast Stone Institute (CSI), American Society for Testing and Materials, www.astm.org, see ASTM C1364, Standard Specifications for Architectural Cast Stone; for general information see: Wikipedia, "Cast Stone".

Typical Uses

Typical historical and current uses for cast stone include:

- Commonly used in the late 19th and early 20th centuries.
- Used in the form of a veneer, a block or as ornament.
- Used to simulate evenly veined and colored stones.
- Used to simulate natural stone by the late 1920s.
- Commonly used in the construction of houses, banks, churches, schools, libraries, and commercial buildings.
- Used for specific features such as window sill, steps, beltcourses, chimney caps, spandrel panels, sculpture and other ornament.
- Cast stone is installed like natural stone, laid in place with mortar, or fastened with metal anchors.
- Due to the high cost of manufacturing cast stone compared with lighter weight precast concrete, cast stone companies were almost non-existent by the early 1950s; many were absorbed into existing precast companies.
- The compressive strength of new cast stone is 6,500 pounds per square inch with an absorption rate not more than 6 percent; in the late 1920s, the standard compressive strength of cast stone was 5,000 pounds per square inch with an allowable absorption rate of 7 percent.

Natural or Inherent Problems:

- Facing Delamination: Common with dry-tamp cast stone; can result from flaws in manufacturing, or from differences in water absorption ratios combined with freeze/thaw cycles.
- Carbonation: Loss of alkalinity.
- Aggregate/Alkali Reaction.
- Freeze/Thaw: May result in surface scaling.
- Erosion: Visible as weathering of the aggregate and cement binder; surfaces look sandy, rough, with exposed aggregate and pockmarks; horizontal surfaces are especially vulnerable.
- Some types of cast stone (those containing calcareous sediments such as limestone) are sensitive to acidic environments.
- Cracking and Spalling: Typically caused by corrosion of metal reinforcement materials; visible as rust stains.

Vandalism or Human-Induced Problems:

- Cracking: Hairline cracks common especially with dry-tamp cast stone; a problem often caused by volume differences between the facing and backup material, or improper proportioning of the facing mix; visible by fine hairline cracks.
- When aggregates of uniform size are used, the cast stone tends to be more porous and less durable.

1.2.2.2 Maintenance, repair, and replacement of historic cast stone (Pieper 2001 – Preservation Brief #42)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 42 Cast Stone

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

42

The Maintenance, Repair and Replacement of Historic Cast Stone

Richard Pieper

[An Imitative Building Material with Many Names](#)

[History of Use and Manufacture](#)

[Mechanisms and Modes of Deterioration](#)

[Maintenance of Cast Stone Installations](#)

[Methods of Repair](#)

[Replacement of Historic Cast Stone Installations](#)

[Appropriateness of GFRC as a Replacement Material](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)

Detail of sculptural cast stone ornament on the Level Club, New York City (1926). Photo: Richard Pieper.

An Imitative Building Material with Many Names

The practice of using cheaper and more common materials on building exteriors in imitation of more expensive natural materials is by no means a new one. In the eighteenth century, sand impregnated paint was applied to wood to look like quarried stone. Stucco scored to simulate stone ashlar could fool the eye as well. In the 19th century, cast iron was also often detailed to appear like stone. Another such imitative building material was "cast stone" or, more precisely, precast concrete building units.

Cast stone was just one name given to various concrete mixtures that employed molded shapes, decorative aggregates, and masonry pigments to simulate natural stone. The basic mixtures included water, sand, coarse aggregate, and cementing agents. Natural cements, portland cements, oxychloride cements, and sodium silicate based cements were all used as binding agents. The differences in the resulting products reflected the different stone aggregates, binding agents, methods of manufacture and curing, and systems of surface finishing that were used to produce them. Versatile in representing both intricately carved ornament and plain blocks of wall ashlar, cast stone could be tooled with a variety of finishes.

During a century and a half of use in the United States, cast stone has been given various names. While the term "artificial stone" was commonly used in the 19th century, "concrete stone," "cast stone," and "cut cast stone" replaced it in the early 20th century. In addition, Coignet Stone, Frear Stone, and Ransome Stone were all names of proprietary systems for pre-cast concrete building units, which experienced periods of popularity in different areas of

The prominent Delaware and Hudson Building, Albany, New York, (1916) made extensive use of cast stone as trim combined with a random ashlar facing of natural granite. Photo: Richard Pieper.

the United States in the 19th century. These systems may be contrasted with "Artistic Concrete," decorative molded concrete construction, both precast and cast-in-place, which made little effort to simulate natural stone.

Having gained popularity in the United States in the 1860s, cast stone had become widely accepted as an economical substitute for natural stone by the early

decades of the 20th century. Now, it is considered an important historic material in its own right with unique deterioration problems that require traditional, as well as innovative solutions. This Preservation Brief discusses in detail the maintenance and repair of historic cast stone-precast concrete building units that simulate natural stone. It also covers the conditions that warrant replacement of historic cast stone with appropriate contemporary concrete products and provides guidance on their replication. Many of the issues and techniques discussed here are relevant to the repair and replacement of other precast concrete products, as well.

History of Use and Manufacture

Early Patented Systems

While some use of cast stone may be dated to the Middle Ages, more recent efforts to replicate stone with cementitious materials began in England and France at the end of the 18th century. Coade Stone, one of the best known of the early English manufactures, was used for architectural ornament and trim, and saw limited use for interior decoration in the United States as early as 1800. Significant advances in the artificial stone industry in the United States were tied to the production of natural cement or hydraulic lime, which began about 1820.

A large number of patented American, English, and French systems were marketed immediately after the Civil War. One of the earliest American patents for cast stone was awarded to George A. Frear of Chicago in 1868. Frear Stone was a mixture of natural cement and sand, to which a solution of shellac was added to provide initial curing strength. Frear's system was widely licensed around the country, and the resultant variation in materials and manufacturing methods apparently resulted in some significant failures.

Another product which utilized natural cement as its cementing agent was Beton Coignet (literally, "Coignet concrete," also known as "Coignet Stone"). Francois Coignet was a pioneer of concrete construction in France. He received United States patents in 1869 and 1870 for his system of pre-cast concrete construction, which consisted of portland cement, hydraulic lime, and sand. In the United States the formula was modified to a mix of sand with Rosendale Cement (a high quality natural cement manufactured in Rosendale, Ulster County, New York). In 1870 Coignet's U.S. patent rights were sold to an American, John C. Goodrich, Jr., who formed the New York and Long Island Coignet Stone Company. This company fabricated the cast stone for one of the earliest extant cast stone structures in the United States, the Cleft Ridge Span in Prospect Park, Brooklyn, New York.

Some proprietary systems substituted other cements for the portland cement or hydraulic lime. The British patent process of Frederick Ransome utilized a mixture of sand and sodium silicate, combined with calcium chloride, to form blocks of calcium silicate. The sodium chloride by-product was intended to be removed with water washes during the curing process. The Sorel cement process, developed in 1853 and later applied to the manufacture of grindstones, tiles, and cast stone for buildings, combined zinc oxide with zinc chloride, or magnesium oxide and magnesium chloride, to form a hydrated oxychloride cement mixture that bound together sand or crushed stone. The Union Stone Company in Boston manufactured cast stone using the Sorel process. Ultimately, however, alternate cementing systems were abandoned in favor of portland cement, which proved to be more dependable and less expensive.

Late 19th and 20th Century Development

The use of cast stone grew rapidly with the extraordinary development of the portland cement and concrete industries at the end of the 19th century. In the early decades of the 20th century, cast stone became widely accepted as an economical substitute for natural stone. It was sometimes used as the only exterior facing material for a building, but was more often used as trim on a rock-faced natural stone or brick wall.

In most early 20th century installations, cast stone was used for exterior window and door surrounds or lintels, copings, parapets and balustrades, banding courses, cornices and friezes,

Sculptural ornament was frequently produced in cast stone. Repetitive detail, such as these banding course panels on the Level Club in New York City (1926), were produced much more economically than they could be in natural stone. Photo: Richard Pieper.

Constructed in 1868 of Beton Coignet, the Cleft Ridge Span in New York City's Prospect Park is one of the earliest extant cast stone structures in the United States. Photo: Richard Pieper.

Cast stone was commonly used for molded trim in conjunction with brick or natural stone. This brick building in Rochester, New York, uses cast stone for the entry surround, and natural stone for unornamented window sills, thresholds, and water table units. Photo: Richard Pieper.

and sculptural ornament. On occasion, decorative interiors were also finished with cast stone, although elaborate interior cornices and ornaments were more frequently fabricated of plaster.

Manufacture

Manufacturers of cast stone used graded mixes of crushed marble, limestone, granite, and smelting slag to produce a variety of stone effects. A light cement matrix with an aggregate of crushed marble could replicate limestone, while a mix of marble and small amounts of smelting slag would give the effect of white granite. Some manufacturers added masonry pigments and varied colors on the faces of the stone to give a somewhat stylized effect of variegated sandstone. Each manufacturer prepared a variety of stock mixes as well. Not surprisingly, aggregates varied in different localities. In New York State, for example, crushed Gouverneur and Tuckahoe marbles were popular facing aggregates; in other areas crushed feldspar or granite and even silica sand were commonly used.

The two basic cast stone production systems were "dry tamp" and "wet cast." The **dry tamp** process employed a stiff, low slump concrete mix that was pressed and compacted into the molds. The decorative aggregate mix was frequently distributed only on the exterior facing of the cast units (typically 3/4" to 1 1/2" thick,) while the cores of the units were common

concrete. Because of the stiff mix, dry tamp units required a relatively short period of time in the molds, which could then be used several times a day. After removal from the molds, the dry tamp units were often cured in steam rooms to assure proper hydration of the cement. The **wet cast** process, on the other hand, used a much more plastic concrete mix that could be poured and vibrated into the molds. This system used significantly more water in the mix, assuring proper hydration of the cement mix without elaborate curing, but requiring that the units be left in the molds for at least a day. Because of this method of fabrication, wet cast products necessarily distributed their decorative aggregate mix through the entire unit, rather than simply an outer facing.

Concrete was cast in molds of wood, plaster, sand and, early in the 20th century, even hide glue or gelatin, depending upon the production method, the intricacy of the piece to be cast, and the number of units to be manufactured. Metal molds were sometimes used for stock ornamental items, less frequently for custom architectural work. When the units were adequately hard, finish surfaces were worked to expose the decorative stone aggregate. When removed from the mold, wet cast units exhibit a surface film of cement paste, which must be removed to expose the aggregate. Partially cured units could be sprayed with water, rubbed with natural bristle brushes, etched with acid, or sandblasted to remove the cement layer. The surface of dry tamp products required less finishing.

High quality cast stone was frequently "cut" or tooled with pneumatic chisels and hammers similar to those used to cut natural stone. In some cases, rows of small masonry blades were used to create shallow parallel grooves similar to lineal chisel marks. The results were often strikingly similar in appearance to natural stone. Machine and hand tooling was expensive, however, and simple molded cut cast stone was sometimes only slightly less costly than similar work in limestone. Significant savings could be achieved over the cost of natural stone when repetitive units of ornate carved trim were required.

For this column, the appearance of a "pink granite" was simulated by using a pinkish matrix with white and black aggregate. Erosion of a tinted matrix results in a significant lightening of the cast stone surface. Photo: Richard Pieper.

Finally, cast stone is sometimes today used to replace natural stone when the original historic stone is no longer available, or the greater strength of reinforced concrete is desired. Reinforced cast stone columns, for instance, are frequently used to replace natural stone columns in seismic retrofits of historic structures. Fine-grained stones, such as sandstones, may be very successfully replicated with cast stone. Coarse-grained granites and marbles with pronounced patterns or banding are, for obvious reasons, not so successfully matched with cast stone. The replacement of natural stone with cast stone requires careful attention to selection of fine aggregates and the pigmentation of the cementing matrix. Coarse aggregate, which is generally used in cast stone to control shrinkage and assure adequate compressive strength, can present an aesthetic problem if it is visible at the surface of cast stone elements which simulate sandstone. Careful control of aggregate sizes in the mix formulation can reduce this problem.

Historically, a point finish was put on with a single pointed chisel. Photo: From Onondaga Litholite Company Catalog. Courtesy, Collection of Michael F. Lynch.

Mechanisms and Modes of Deterioration

The best historic cast stone can rival natural stone in longevity. Many quality cast stone installations from the first decades of the twentieth century are still in excellent condition, and require little repair. Like any other building material, however, cast stone is subject to deterioration, which may occur in several ways:

- Separation of the facing and core layers
- Deterioration of the aggregate
- Deterioration or erosion of the cementing matrix
- Deterioration of the iron or steel reinforcement
- Deterioration of cramps and anchors used in its installation.

Separation of the Facing and Core Layers

Separation of the facing and core layers of dry tamp units is not uncommon, and often reflects fabrication defects such as poor compaction, lengthy fabrication time, or improper curing. Where separation of facing and core layers is suspected, cast stone units may be "sounded" to establish the extent of delamination.

Deterioration of the Aggregate

Cast stone failure caused by deterioration of the aggregate is uncommon. Granites, marbles, and silica sand are generally durable, although limestone and marble aggregate are subject to the same dissolution problems that affect quarried units of these stones. In rare instances, a reaction between the alkalis in the cement matrix and the stone aggregate may also cause deterioration.

Deterioration or Erosion of the Cementing Matrix

Scaling of cast stone units signals problems with the cementing mix and method of manufacture. Serious deterioration of cast stone, such as this, warrants replacement. Photos: Richard Pieper.

While it is relatively uncommon in twentieth century cast stone, serious deterioration of the cementing matrix can cause extensive damage to cast stone units. A properly prepared cementing mix will be durable in most exterior applications, and any flaking of exterior surfaces signals problems in the cementing mix and in the method of manufacture. The use of poor quality or improperly stored cement, impure water, or set accelerators can cause cement problems to occur years after a structure is completed. Improper mixing and compaction can also result in a porous concrete that is susceptible to frost damage and scaling. Severe cement matrix problems may be impossible to repair properly and often necessitate replacement of the deteriorating cast stone units.

More common and less serious than flaking or scaling caused by deterioration of the cementing matrix is the erosion of the surface of the matrix. This usually occurs on surfaces of projecting features exposed to water runoff, such as sills, water tables, and window hoods. In these areas, the matrix may erode, leaving small grains of aggregate projecting from the surface. The resultant rough surface is not at all the intended original appearance. In some historic cast stone installations, the thin layer of cement and fine sand at the surface of the cast stone units was not originally tooled from the molded surface, but was finished with patterns of masonry pigments in a stylized imitation of highly figured sandstones or limestones. Erosion of the pigmented surface layer on this type of cast stone results in an even more dramatic change in appearance.

Deterioration of the Iron or Steel Reinforcement

During their original manufacture, unusually long and thin cast stone units, such as window sills or balustrade railings, and units requiring structural capacity, such as lintels, were generally reinforced with mild steel reinforcing bars. Large pieces sometimes had cable loops or hooks cast into them to facilitate handling and attachment. On occasion, this reinforcement and wire may be too close (less than 2") to the surface of the piece and rusting will cause spalling of the surface. This frequently happens to sills, copings, and water tables where repeated heavy wetting leads to loss of alkalinity in the concrete, allowing the reinforcement to rust. If damage from the deteriorating reinforcement is extensive, as for instance, the splitting of a baluster from the rusting of a central reinforcing rod, the cast stone unit may require replacement.

Deterioration of Cramps and Anchors

Even when reinforcement has not been added to individual cast stone units, mild steel cramps may have been used to anchor a cast stone veneer to backup masonry. Where spalls have occurred primarily at the tops of ashlar or frieze units, this is generally the cause.

Rusting of reinforcement near the surface of the stone may result in spalling. Sections of reinforcement, such as this, may be cut out and the spall repaired with a matching composite mortar. Photo: Richard Pieper.

Maintenance of Cast Stone Installations

Cleaning

Cast stone installations with marble or limestone aggregates may sometimes be cleaned with the same alkaline pre-wash/acid afterwash chemical cleaning systems used to clean limestone and other calcareous natural stones. If no marble or limestone aggregates are present, acidic cleaners, such as those used for natural granites and sandstones, may be used.

Sandblasting and wet grit blasting can seriously erode the surface and should not be used to clean cast stone surfaces. Photo: Richard Pieper.

In either case, dark particulate staining in protected areas may be persistent, however, and require experimentation with other cleaning methods. Some micro-abrasive cleaning techniques used under very controlled circumstances by skilled cleaning personnel can be appropriate for removing tenacious soiling. Ordinary sand blasting or wet grit blasting can seriously damage the surface of the cast stone and should not be used.

Repointing

Early cast stone installations may have been constructed with natural cement mortars, but in late nineteenth century and twentieth century installations, cast stone units were generally bedded and pointed with mortars composed of portland cement, lime, and sand. When repointing or replacement of the historic mortar is required, a Type N mortar (about one part cement, and one part lime to six parts of sand) is generally appropriate. When repointing any historic masonry, it is important to match both the character and color of the sand and color of the cement matrix in the historic mortar. Cement matrix color can often be adjusted by using combinations of white, "light," and gray portland cement in the mortar.

Joints in historic cast stone installations can be quite thin and the dense mortar thus difficult to remove. Unnecessary repointing can cause significant damage to historic cast stone. Cracked and open joints will most often be found on exposed features such as balustrades and copings and, of course, require repointing. When a hard and tenacious mortar was used in the original installation or a later repointing, the removal of the mortar can easily chip the edges of the cast stone units.

While the careless use of "grinders" to remove mortar has damaged countless historic masonry buildings, a skilled mason may sometimes use a hand held grinder fitted with a thin diamond blade to score the center of a joint, and then remove the rest of the mortar with a hand chisel. If this method is not done carefully, however, wandering of the blade can widen or alter joints and cause significant damage to the cast stone. Care must be taken to prevent damage from over cutting of vertical joints by stopping blades well short of adjacent units. The use of small pneumatic chisels, such as those used to tool stone, can also work well for mortar removal, but even this method can cause chipping to the edges of cast stone units if it is not done carefully.

Methods of Repair

Much historic cast stone is unnecessarily replaced when it could easily be repaired in situ, or left untreated. This is especially true of areas that exhibit isolated spalls from rusting reinforcement bars or anchorage, or installations where erosion of the matrix has left a rough surface of exposed aggregate.

The weathering of cast stone, while different from that of natural stone, produces a patina of age, and does not warrant large-scale replacement, unless severe cement matrix problems or rusting reinforcement bars have caused extensive scaling or spalling. Severe rusting of reinforcement bars on small decorative features, such as balusters, may signal carbonation (loss of alkalinity) of the matrix. Where carbonation of the matrix has occurred, untreated reinforcement will continue to rust. Replacement may be an acceptable approach for exposed and severely deteriorated features, such as hand railings, roof balustrades, or wall copings, where disassembly is unlikely to damage adjacent construction. Conversely, small areas of damage should generally be repaired with mortar "composites," or left alone.

Re-securing Separated Surface Facing

A delaminated layer of ornamental cast stone on the Orpheum Theater, San Francisco.

Where the decorative facing of dry tamped cast stone has separated from core layers, injected grouts may be used to re-secure the facing. Re-attachment of a separated facing layer may be time consuming, and should be undertaken by a conservator, rather than a mason. This technique may be the best, most economical, approach for repair of figurative sculpture or unique elements that are not repeated elsewhere on a building. Theoretically, cementitious grouts are most appropriate for re-attaching separated facings, but hairline fissures may require the use of resin adhesives. Low-viscosity epoxies have been used for this purpose, and may be applied through small injection ports. Cracks that would allow adhesive to leak must

California (1925), was successfully re-attached using epoxy. The multiple delivery ports for the epoxy are removed after treatment and the holes patched. Photo: David P. Wessell.

be repaired prior to injection, of course. Holes made for adhesive injection will require patching after re-attachment is complete.

Repairing Reinforcement Spalls and Mechanical Damage

Drilled holes, mechanically damaged corners, and occasional spalls from rusting reinforcement bars and anchorage are repairable conditions that do not warrant the replacement of cast stone. Small "composite" repairs to damaged masonry units can be made with mortar formulated to visually match the original material, and may be successfully undertaken by a competent and sensitive mason. If deterioration appears widespread, however, or if large surface areas are spalling or cracking and replacement appears necessary, the owner may wish to consult a preservation architect or consultant to determine the cause of deterioration and to specify necessary repairs or replacement, as appropriate.

The methods of composite repair used for stone masonry are also generally applicable for the repair of historic cast stone. For repairs to damaged cast stone to be successful, however, both the cement matrix color and the aggregate size and coloration must match that of the historic unit. Crushed stone and slag (such as "Black Beauty" abrasive grit), which are similar to many common traditional aggregates, are widely available, although some additional crushing and/or sieving may be necessary to obtain aggregate of an appropriate size. Remember that half or more of a weathered surface is exposed aggregate, so careful aggregate selection and size grading is extremely important for patching. Even differences in aggregate angularity (rounded pebbles vs. crushed stone) will be noticeable in the final repair. If more than one aggregate was used in the cast stone, the ratio of the selected aggregates in the mix is, of course, equally important. Variation in coloring of the cement matrix may be achieved through the use of either white, "light," or gray portland cement. If additional tinting is required, only inorganic alkali-resistant masonry pigments should be used. Because most historic cast stone was manufactured primarily from portland cement and aggregate (with a less than 15% lime/cement ratio), it is not necessary to add large amounts of hydrated lime to cast stone composite repair mixtures. Small amounts of lime may be added for plasticity of the working mix.

To repair a spall caused by deterioration of a ferrous reinforcement bar or anchorage, it is necessary to remove all cracked concrete adjacent to the spall; grind and brush the reinforcement to remove all rust and scale; and paint the metal with a rust-inhibiting primer prior to applying the cast stone composite. If the reinforcement bar is much too close to the surface of the stone, it may be advisable to cut out the deteriorating section of reinforcement after consultation with a structural engineer. If deteriorating cramps are removed, it may be necessary to install new stainless steel anchorage.

Where spalls have a feather edge, it will be necessary to cut back the repair area to a uniform depth (1/2" or more). As with natural stone composite repairs, a bonding agent may assist adhesion of the repair material to the original concrete. For unusually large or deep patches, mechanical anchoring of the repair with small nylon or stainless steel rods may be required. If the adjacent cast stone is tooled or weathered, it will be necessary to scribe or brush the repaired area to give it a matching surface texture. Adding enough coarse aggregate to match adjacent original material will sometimes interfere with adhesion of the composite, and it may be necessary to press additional aggregate into the applied patch prior to finishing. If this is not skillfully done, however, the surface of the patch may take on a mosaic appearance. For this reason, it is advisable to undertake test composite repairs in an unobtrusive location first.

Surface Refinishing

While re-tooling of deteriorated natural stone may sometimes be appropriate, restoring the original appearance of cast stone where surface erosion has occurred is difficult or impossible.

Tooling or grinding of the surface of the cast stone may expose coarse aggregate beneath the surface and will not, in any case, restore original patterned pigmentation that has weathered away. Silicate paints or masonry stains may be applied in patterns to replicate the original appearance, but may not be durable or completely successful aesthetically. Where matrix has eroded, it is advisable to accept the weathered

This completed composite repair could have been improved by brushing to remove the matrix residue at the edges of the repair before the surface cured. Photo: Richard Pieper.

The composite mortar is applied to the void with a small spatula or trowel. Photo: Richard Pieper.

The damaged area is cut out to create a shallow void of even depth, half inch or more. Photo: Richard Pieper.

Unlike natural stone, cast stone generally may not be tooled in place to reduce lippage of uneven surfaces at joints. Tooling often exposes coarse aggregate from below the surface. Photo: Richard Pieper.

appearance of the cast stone, unless extensive replacement is mandated by other factors.

Because cast stone depends on exposed aggregate to achieve its aesthetic effect, the use of an applied cementitious surface coating dramatically alters the visual effect of the material and is inappropriate as a cast stone repair technique. A cementitious surface coating can also trap moisture in the cast units and cause surface spalling.

Replacement of Historic Cast Stone Installations

Individual cast stone units, which are subject to repeated wetting (such as copings, railings and balusters) and exhibit severe failure due to spalling or reinforcement deterioration, may require replacement with new cast stone and can replicate

deteriorated units in existing buildings.

After removal from the mold, the new cast stone units are scrubbed to remove surface paste and expose underlying aggregate. End cast pieces, such as this sculpture, may have numerous air bubbles at the surface. Photo: Richard Pieper.

Fortunately, a number of companies custom manufacture precast concrete units. The variables involved in manufacture are considerable, and it is wise to use a firm with experience in ornamental and custom work rather than a precast concrete firm which manufactures stock structural items, concrete pipe, or the like. Several trade organizations, including the Cast Stone Institute, the National Precast Concrete Association, and the Architectural Precast Association, have developed recommendations and/or guide specifications for the manufacture of cast stone and precast concrete. These specifications set standards for characteristics such as compressive strength and water absorptivity, and discuss additives such as air entraining agents and water reducing agents, which influence the longevity of new cast stone. Trade references and guide specifications should be consulted before contracting for replacement of historic cast stone.

Fabrication defects in new cast stone. While the cement matrix coloration and aggregate considerations previously mentioned require the most careful attention, project staff should also look for defects which are common to cast stone fabrication:

Air bubbles. Small pits on the surface of the stone may form if the unit is not given adequate vibration to release trapped air during pouring. Bubbles can also be a problem when end casting long items such as columns or railings, where it is difficult to vibrate bubbles away from the finish surface of the unit.

The holes on the surface of the casting (see above, left) are being filled with a mortar similar to the concrete mix used to cast the element. Photo: Richard Pieper.

Surface cracking or checking. Overly wet mixes and insufficient moisture during curing can result in surface cracking of large castings, such as columns. Such cracking dramatically reduces the durability of new cast stone. Small reinforced elements, such as balusters, also frequently crack at thin "necks" in the castings.

Aggregate segregation. Cast stone formulations generally include a range of coarse aggregates (crushed stone) and fine aggregates (sand). When units are vibrated to assure compaction of the mix and liberate trapped air bubbles, coarse aggregates may begin to settle and separate from the paste of cement and sand. Aggregate segregation results in a visible concentration of coarse aggregate at one end of the casting. Segregation is more problematic when end casting long pieces such as columns.

Surface cracking may reduce the durability of cast stone units. Cracking is often problematic on reinforced elements with thin "necks," such as balusters, unless curing is carefully controlled. Photo: Richard Pieper.

Surface rippling or irregularity. Production molds for fabrication are often made of rubber mold facings encased in larger "mother molds" of plaster and wood. Vibration can loosen the rubber facing from the outer mold and result in rippling or irregularities on the surface of the finished casting. Even when rippling is not noticeable, irregularity caused by mold movement can make it difficult to line up surfaces of adjacent units when assembling cast stone installations.

Mold lines. Freestanding elements, such as columns, must be cast in two-part molds, which are separated to release the completed cast piece. If the mold parts do not join tightly, some leakage of cement paste will occur at the mold joint, resulting in a projecting line on the surface of the casting. This is generally tooled off before the casting completely cures. A mold line will be visible on the completed piece if the projecting material is not completely removed, or if the tooling at the mold line does

not match the adjacent surface of the casting. Tooling at mold lines may also expose contrasting coarse aggregate beneath the surface of the casting.

Other Considerations for Replacement of Cast Stone

Several other considerations are worth noting when it is necessary to replace historic cast stone elements with matching new cast stone.

Reinforcement. The alkalinity of new concrete generally provides adequate protection to steel reinforcement. In exposed areas where deterioration due to rusting of reinforcement has previously been a problem, however, the use of stainless steel reinforcement is recommended.

Surface finishing. Post-fabrication surface tooling of new cast stone is not currently common. Sandblasting is typically used to remove the surface film of cement and expose the aggregate. For replacement units replicating historic cast stone pieces in highly visible locations, it is sometimes possible to make a mold of a sound or repaired existing piece to incorporate the original tooling in the casting process. If the historic unit is too deteriorated to use as a pattern, a plaster model may be made to replicate the damaged piece. This is tooled to replicate the desired surface treatment or appearance, and a production mold is then made from the plaster model.

Production molds made of durable rubbers backed with wood and plaster supports are used to fabricate new cast stone. Photo: Richard Pieper.

Moist curing. Surface crystallization of soluble salts (efflorescence) during curing may lighten the surface of some precast units, especially those simulating darker stone. Some manufacturers use a series of wet/dry curing cycles or washing with acetic acid to remove soluble salts that might otherwise discolor finished surfaces. For most wet cast products, simple moist curing under a plastic cover is sufficient.

Appropriateness of Glass Fiber Reinforced Concrete as a Replacement Material

Light-Weight Alternative

Glass fiber reinforced concrete (GFRC) is more and more frequently encountered in building restoration and is used to replicate deteriorated stone and cast stone, and even architectural terra cotta. This is a relatively new material that uses short chopped strands of glass fiber to reinforce a matrix of sand and cement. GFRC has become a popular low cost alternative to traditional precast concrete or stone masonry for some applications. Fabricators use a spray gun to spray the mortar-like mix into a mold of the shape desired. The resulting concrete unit, typically only ¾" thick, is quite rigid, but requires a metal frame or armature to secure it to the building substrate. The metal frame is joined to the GFRC unit with small "bonding pads" of GFRC.

GFRC has a dramatic advantage over traditional precast concrete where the weight of the installation is a concern, such as with cornices or window hoods. Many cast stone mixes can successfully be replicated with GFRC. Where it is used to simulate natural stone, GFRC, like cast stone, is most appropriate for simulation of fine-grained sandstones or limestones.

The attachment hardware inside this GFRC cartouche (left) will not be visible when the unit is installed (armature visible at right). Photos: Towne House Restorations, Inc.

GFRC is sometimes used to replicate deteriorated elements of cast or fine grained natural stone. Because the GFRC element is a rigid, but relatively thin shell, it must be supported and attached with an interior framework of steel.

Not for Use in Load Bearing Applications

Because the GFRC system is in effect a "skin," GFRC cannot be used for load bearing applications without provision of additional support. This makes it unsuitable for some tasks such as replacement of individual ashlar units. It is also not appropriate for small freestanding elements such as balusters, or for most columns, unless they are engaged to surrounding masonry or can be vertically seamed, which may significantly alter the historic appearance. GFRC units must also allow for expansion and contraction, and are generally separated by sealant joints, not by mortar. A sealant joint may be unacceptable for some historic applications; however, substitution of GFRC for cast stone may be appropriate when an entire assembly, such as a cornice, roof dormer, or window hood, requires replacement. Great care must be taken when detailing a GFRC replacement for existing cast stone.

Deterioration of GFRC

Because it is a relatively new material, the long term durability of GFRC is still untested. When GFRC was first introduced, some installations experienced deterioration caused by alkaline sensitivity of the glass fiber reinforcement. Alkali resistant

glass is now used for GFRG manufacture. Even when the GFRG skin is well manufactured, however, the steel armature and bonding pad system used to mount the material is vulnerable to damage from leakage at sealant joints or small cracks in wash surfaces. The use of galvanized or stainless steel armatures, and stainless steel fasteners and bonding pad anchors is advisable.

Summary and References

Cast stone—a mixture of water, sand, coarse aggregate, and cementing agents—has proven over time to be an attractive and durable building material, when properly manufactured. It gained popularity in the 1860s and, by the early decades of the 20th century, became widely accepted as an economical substitute for natural stone. Unfortunately, much historic cast stone is unnecessarily replaced when it could easily be repaired and preserved in situ, or left untreated. Appropriate repair of damaged units can extend the life of any cast stone installation. Because of the necessity of matching both matrix color and aggregate size and ratio, conservation projects which involve repair or replication of cast stone should allow adequate lead time for the assembly of materials and the preparation of test samples. Understanding which conditions require repair, which warrant replacement, and which should be accepted as normal weathering is key to selecting the most appropriate approach to the protection and care of historic cast stone.

Helpful Organizations

Cast Stone Institute

10 West Kimball Street
Winder, GA 30680-2535

National Precast Concrete Association

10333 North Meridian Street, Suite 272
Indianapolis, IN 46290

Architectural Precast Association

P.O. Box 08669
Fort Myers, FL 33908-0669

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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.

Photographs included in this publication may not be used to illustrate other publications without permission of the owners.

September 2001

Reading List

Childe, H.L. *Manufacture and Uses of Concrete Products and Cast Stone*, London: Concrete Publications Limited, 1930.

Jester, Thomas C., ed., *Twentieth Century Building Materials*, New York, NY: McGraw-Hill, 1995.

Precast/Prestressed Concrete Institute, *Architectural Precast Concrete*, 2nd ed., Chicago, Illinois: Precast/Prestressed Concrete Institute, 1989.

Whipple, Harvey, *Concrete Stone Manufacture*, Detroit: Concrete-Cement Age Publishing Company, 1918.

1.3 Concrete – cast stone posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins

In most early 20th century installations, cast stone was used for exterior window and door surrounds or for lintels, copings, parapets and balustrades, banding courses, cornices and friezes, and sculptural ornaments.

Several of the USMMAHD contributing buildings have cast stone architectural elements that are placed at the lintel and sill levels on windows, and cast stone is also utilized for entrance door surrounds, belt courses, quoins, and cornices.

1.3.1 Immediate concerns for concrete posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins

Major signs of cast stone deterioration include separation of the facing and core layers, deterioration of the aggregate, deterioration or erosion of the cementing matrix, deterioration of the iron or steel reinforcement, and deterioration of cramps and anchors used in installation. Whatever the causes of deterioration, careful analysis (supplemented by testing) is vital to the success of any historic cast stone element repair project. Repair of historic cast stone may consist of either patching the historic material or filling in with new material worked to match the historic material. If replacement is necessary, duplication of historic materials and detailing should be exact as possible to assure a repair that is functionally and aesthetically acceptable.

The following are examples of deterioration and actions to be taken, with references to photos of USMMAHD structures that show the indicated problems. It is, of course, possible for a structure to exhibit more than one type of deterioration.

- Cutting damaged cast stone elements back to remove the source of deterioration (often corrosion on metal reinforcement bars) and the new patch must be applied carefully so that the patch will bond and match the historic cast stone element (Figure 44 and Figure 48).

- Severely damaged cast stone elements should be replaced by using materials compatible with the original in material, design, scale, color, and finish (Figure 44).
- Damaged or missing pieces of cast stone should be repaired using in-kind materials (Figure 45 and Figure 46).
- Cast stone elements are showing signs of flaking or spalling on the outer layer of the material (Figure 47–Figure 50).
- Formerly repaired areas of spalling on the cast stone elements do not meet the standards and should be repaired in accordance with the Standards (see Figure 48).
- Incorrect mortar or epoxy fill has been used for inappropriate repairs (Figure 51).
- Improper patching material used to repair cracks on cast stone element (Figure 52).
- Inappropriate sealant should be removed and replaced with appropriate epoxy resin (Figure 53).
- Cast stone elements (unpainted and painted) need to be cleaned according to the guidelines (Figure 44 and Figure 54).
- Damaged or deteriorated paint should be removed only to the next sound layer by using the gentlest method possible.
- Cast stone elements should be repainted with colors that match the original (Figure 44, Figure 54, and Figure 55).
- Epoxy injection should be used for dormant cracks (i.e., cracks that remain unchanged). Dormant cracks generally pose little danger. However, if left unrepaired, they will provide channels for moisture penetration (Figure 54 and Figure 55).
- Stucco failure over cast stone posts should be repaired by removing the damaged material and patching with new stucco that duplicates the old in strength, composition, color, and texture (Figure 56).
- Cast stone elements such as posts, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, quoins, and capitals show efflorescence (a white powdery substance) leaching onto the cast stone elements (Figure 57–Figure 62).

- Concrete block walls and precast concrete/cast stone elements such as beltcourse and cornice show the presence of an inappropriate sealer that has stained and discolored the concrete elements; the gentlest cleaning methods should be performed on these surfaces following the guidelines (Figure 63 and Figure 64).
- Precast concrete/cast stone elements should be cleaned only when necessary to halt deterioration or remove heavy soiling.
- Surface dirt needs to be removed from precast concrete/cast stone elements following guidelines (Figure 65 and Figure 66).
- Cast stone elements appear wet, indicating a moisture problem within the wall and material (Figure 67).
- All gutters, downspouts, and other water run-off systems must be checked to see they are in good repair and clear of debris.
- Biological growth needs to be removed from the surface of the precast concrete/cast stone elements (Figure 68).
- Vegetation such as trees and shrubbery should be kept trimmed so that it is not touching precast concrete/cast stone elements.
- Any maintenance of precast concrete/cast stone is to be executed by a qualified professional.

Figure 44. Damaged precast concrete/cast stone elements should be replaced using materials compatible with original materials (ERDC-CERL, 2015).

Figure 45. Damaged concrete should be patched with in-kind material and finished to match existing material (ERDC-CERL, 2015).

Figure 46. Damaged concrete should be patched with in-kind material finished to match the existing (ERDC-CERL, 2015).

Figure 47. Spalling in precast concrete/cast stone should be repaired in accordance with the standards (ERDC-CERL, 2015).

Figure 48. Formerly repaired spalls that do not meet the standards should be repaired in accordance with the standards (ERDC-CERL, 2015).

Figure 49. Spalling in precast concrete/cast stone should be repaired in accordance with the standards (ERDC-CERL, 2015).

Figure 50. Spalling concrete should be repaired in accordance with the standards (ERDC-CERL, 2015).

Figure 51. Inappropriate epoxy and mortar has been used to fill joints of precast concrete/cast stone elements (ERDC-CERL, 2015).

Figure 52. Improper patching material was used (ERDC-CERL, 2015).

Figure 53. Visible sealant should be removed and replaced with appropriate epoxy resin (ERDC-CERL, 2015).

Figure 54. Cracks in cast concrete should be repaired (ERDC-CERL, 2015).

Figure 55. Cracks should be patched by injecting epoxy resin according to the standards and guidelines (ERDC-CERL, 2015).

Figure 56. Missing stucco from precast concrete/cast stone should be repaired; however, the cause for it failing should be investigated since it might be a failure in the concrete system (ERDC-CERL, 2015).

Figure 57. Efflorescence and surface dirt should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 58. Efflorescence and surface dirt should be removed with the gentlest cleaning method per guidelines. [Note that the efflorescence on O'Hara is due to water pooling on the roof behind the parapet] (ERDC-CERL, 2015).

Figure 59. Efflorescence and surface dirt should be removed with the gentlest cleaning method per guidelines. [Note that the efflorescence on O'Hara is due to water pooling on the roof behind the parapet.] (ERDC-CERL, 2015).

Figure 60. Efflorescence and surface dirt on cornice and beltcourse should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 61. Efflorescence on cornice should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 62. Efflorescence on precast concrete/cast stone columns and capitals should be removed with the gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 63. Precast concrete/cast stone quoins show the presence of an inappropriate sealer that has stained and colored the concrete elements; the gentlest cleaning method per guidelines should be performed on these surfaces (ERDC-CERL, 2015).

Figure 64. Concrete block walls and precast concrete/cast stone beltcourse and cornice show the presence of an inappropriate sealer that has stained and colored the concrete elements, the gentlest cleaning method should be performed on these surfaces (ERDC-CERL, 2013).

Figure 65. Surface dirt on precast concrete/cast stone elements such as the cornice should be removed with gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 66. Surface dirt on precast concrete/cast stone elements like the door pediments should be removed with gentlest cleaning method per guidelines (ERDC-CERL, 2015).

Figure 67. Moisture present on material (ERDC-CERL, 2015).

Figure 68. Biological growth should be removed from the stairs by using the gentlest cleaning method (ERDC-CERL, 2015).

1.3.2 Guidelines, briefs, bulletins, and sources for cast posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins

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 cast stone posts, columns, balustrades, window lintels and sills, door surrounds, steps, beltcourses, cornices, and quoins (see subsections 1.3.2.1 and 1.3.2.2).

1.3.2.1 Maintenance, repair, and replacement of historic cast stone (Pieper 2001 – Preservation Brief #42)

Technical Preservation Services

National Park Service
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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

42

The Maintenance, Repair and Replacement of Historic Cast Stone

Richard Pieper

[An Imitative Building Material with Many Names](#)

[History of Use and Manufacture](#)

[Mechanisms and Modes of Deterioration](#)

[Maintenance of Cast Stone Installations](#)

[Methods of Repair](#)

[Replacement of Historic Cast Stone Installations](#)

[Appropriateness of GFRC as a Replacement Material](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)

Detail of sculptural cast stone ornament on the Level Club, New York City (1926). Photo: Richard Pieper.

An Imitative Building Material with Many Names

The practice of using cheaper and more common materials on building exteriors in imitation of more expensive natural materials is by no means a new one. In the eighteenth century, sand impregnated paint was applied to wood to look like quarried stone. Stucco scored to simulate stone ashlar could fool the eye as well. In the 19th century, cast iron was also often detailed to appear like stone. Another such imitative building material was "cast stone" or, more precisely, precast concrete building units.

Cast stone was just one name given to various concrete mixtures that employed molded shapes, decorative aggregates, and masonry pigments to simulate natural stone. The basic mixtures included water, sand, coarse aggregate, and cementing agents. Natural cements, portland cements, oxychloride cements, and sodium silicate based cements were all used as binding agents. The differences in the resulting products reflected the different stone aggregates, binding agents, methods of manufacture and curing, and systems of surface finishing that were used to produce them. Versatile in representing both intricately carved ornament and plain blocks of wall ashlar, cast stone could be tooled with a variety of finishes.

During a century and a half of use in the United States, cast stone has been given various names. While the term "artificial stone" was commonly used in the 19th century, "concrete stone," "cast stone," and "cut cast stone" replaced it in the early 20th century. In addition, Coignet Stone, Frear Stone, and Ransome Stone were all names of proprietary systems for pre-cast concrete building units, which experienced periods of popularity in different areas of

The prominent Delaw and Hudson Building, Albany, New York, (1916) made extensive use of cast stone as trim combined with a random ashlar facing of natural granite. Photo: Richard Pieper.

the United States in the 19th century. These systems may be contrasted with "Artistic Concrete," decorative molded concrete construction, both precast and cast-in-place, which made little effort to simulate natural stone.

Having gained popularity in the United States in the 1860s, cast stone had become widely accepted as an economical substitute for natural stone by the early

decades of the 20th century. Now, it is considered an important historic material in its own right with unique deterioration problems that require traditional, as well as innovative solutions. This Preservation Brief discusses in detail the maintenance and repair of historic cast stone-precast concrete building units that simulate natural stone. It also covers the conditions that warrant replacement of historic cast stone with appropriate contemporary concrete products and provides guidance on their replication. Many of the issues and techniques discussed here are relevant to the repair and replacement of other precast concrete products, as well.

History of Use and Manufacture

Early Patented Systems

While some use of cast stone may be dated to the Middle Ages, more recent efforts to replicate stone with cementitious materials began in England and France at the end of the 18th century. Coade Stone, one of the best known of the early English manufactures, was used for architectural ornament and trim, and saw limited use for interior decoration in the United States as early as 1800. Significant advances in the artificial stone industry in the United States were tied to the production of natural cement or hydraulic lime, which began about 1820.

A large number of patented American, English, and French systems were marketed immediately after the Civil War. One of the earliest American patents for cast stone was awarded to George A. Frear of Chicago in 1868. Frear Stone was a mixture of natural cement and sand, to which a solution of shellac was added to provide initial curing strength. Frear's system was widely licensed around the country, and the resultant variation in materials and manufacturing methods apparently resulted in some significant failures.

Another product which utilized natural cement as its cementing agent was Beton Coignet (literally, "Coignet concrete," also known as "Coignet Stone"). Francois Coignet was a pioneer of concrete construction in France. He received United States patents in 1869 and 1870 for his system of pre-cast concrete construction, which consisted of portland cement, hydraulic lime, and sand. In the United States the formula was modified to a mix of sand with Rosendale Cement (a high quality natural cement manufactured in Rosendale, Ulster County, New York). In 1870 Coignet's U.S. patent rights were sold to an American, John C. Goodrich, Jr., who formed the New York and Long Island Coignet Stone Company. This company fabricated the cast stone for one of the earliest extant cast stone structures in the United States, the Cleft Ridge Span in Prospect Park, Brooklyn, New York.

Some proprietary systems substituted other cements for the portland cement or hydraulic lime. The British patent process of Frederick Ransome utilized a mixture of sand and sodium silicate, combined with calcium chloride, to form blocks of calcium silicate. The sodium chloride by-product was intended to be removed with water washes during the curing process. The Sorel cement process, developed in 1853 and later applied to the manufacture of grindstones, tiles, and cast stone for buildings, combined zinc oxide with zinc chloride, or magnesium oxide and magnesium chloride, to form a hydrated oxychloride cement mixture that bound together sand or crushed stone. The Union Stone Company in Boston manufactured cast stone using the Sorel process. Ultimately, however, alternate cementing systems were abandoned in favor of portland cement, which proved to be more dependable and less expensive.

Late 19th and 20th Century Development

The use of cast stone grew rapidly with the extraordinary development of the portland cement and concrete industries at the end of the 19th century. In the early decades of the 20th century, cast stone became widely accepted as an economical substitute for natural stone. It was sometimes used as the only exterior facing material for a building, but was more often used as trim on a rock-faced natural stone or brick wall.

In most early 20th century installations, cast stone was used for exterior window and door surrounds or lintels, copings, parapets and balustrades, banding courses, cornices and friezes,

Sculptural ornament was frequently produced in cast stone. Repetitive detail, such as these banding course panels on the Level Club in New York City (1926), were produced much more economically than they could be in natural stone. Photo: Richard Pieper.

Constructed in 1868 of Beton Coignet, the Cleft Ridge Span in New York City's Prospect Park is one of the earliest extant cast stone structures in the United States. Photo: Richard Pieper.

Cast stone was commonly used for molded trim in conjunction with brick or natural stone. This brick building in Rochester, New York, uses cast stone for the entry surround, and natural stone for unornamented window sills, thresholds, and water table units. Photo: Richard Pieper.

and sculptural ornament. On occasion, decorative interiors were also finished with cast stone, although elaborate interior cornices and ornaments were more frequently fabricated of plaster.

Manufacture

Manufacturers of cast stone used graded mixes of crushed marble, limestone, granite, and smelting slag to produce a variety of stone effects. A light cement matrix with an aggregate of crushed marble could replicate limestone, while a mix of marble and small amounts of smelting slag would give the effect of white granite. Some manufacturers added masonry pigments and varied colors on the faces of the stone to give a somewhat stylized effect of variegated sandstone. Each manufacturer prepared a variety of stock mixes as well. Not surprisingly, aggregates varied in different localities. In New York State, for example, crushed Gouverneur and Tuckahoe marbles were popular facing aggregates; in other areas crushed feldspar or granite and even silica sand were commonly used.

The two basic cast stone production systems were "dry tamp" and "wet cast." The **dry tamp** process employed a stiff, low slump concrete mix that was pressed and compacted into the molds. The decorative aggregate mix was frequently distributed only on the exterior facing of the cast units (typically 3/4" to 1" thick,) while the cores of the units were common

concrete. Because of the stiff mix, dry tamp units required a relatively short period of time in the molds, which could then be used several times a day. After removal from the molds, the dry tamp units were often cured in steam rooms to assure proper hydration of the cement. The **wet cast** process, on the other hand, used a much more plastic concrete mix that could be poured and vibrated into the molds. This system used significantly more water in the mix, assuring proper hydration of the cement mix without elaborate curing, but requiring that the units be left in the molds for at least a day. Because of this method of fabrication, wet cast products necessarily distributed their decorative aggregate mix through the entire unit, rather than simply an outer facing.

Concrete was cast in molds of wood, plaster, sand and, early in the 20th century, even hide glue or gelatin, depending upon the production method, the intricacy of the piece to be cast, and the number of units to be manufactured. Metal molds were sometimes used for stock ornamental items, less frequently for custom architectural work. When the units were adequately hard, finish surfaces were worked to expose the decorative stone aggregate. When removed from the mold, wet cast units exhibit a surface film of cement paste, which must be removed to expose the aggregate. Partially cured units could be sprayed with water, rubbed with natural bristle brushes, etched with acid, or sandblasted to remove the cement layer. The surface of dry tamp products required less finishing.

High quality cast stone was frequently "cut" or tooled with pneumatic chisels and hammers similar to those used to cut natural stone. In some cases, rows of small masonry blades were used to create shallow parallel grooves similar to lineal chisel marks. The results were often strikingly similar in appearance to natural stone. Machine and hand tooling was expensive, however, and simple molded cut cast stone was sometimes only slightly less costly than similar work in limestone. Significant savings could be achieved over the cost of natural stone when repetitive units of ornate carved trim were required.

For this column, the appearance of a "pink granite" was simulated by using a pinkish matrix with white and black aggregate. Erosion of a tinted matrix results in a significant lightening of the cast stone surface. Photo: Richard Pieper.

Finally, cast stone is sometimes today used to replace natural stone when the original historic stone is no longer available, or the greater strength of reinforced concrete is desired. Reinforced cast stone columns,

for instance, are frequently used to replace natural stone columns in seismic retrofits of historic structures. Fine-grained stones, such as sandstones, may be very successfully replicated with cast stone. Coarse-grained granites and marbles with pronounced patterns or banding are, for obvious reasons, not so successfully matched with cast stone. The replacement of natural stone with cast stone requires careful attention to selection of fine aggregates and the pigmentation of the cementing matrix. Coarse aggregate, which is generally used in cast stone to control shrinkage and assure adequate compressive strength, can present an aesthetic problem if it is visible at the surface of cast stone elements which simulate sandstone. Careful control of aggregate sizes in the mix formulation can reduce this problem.

Historically, a point finish was put on with a single pointed chisel. Photo: From Onondaga Litholite Company Catalog. Courtesy, Collection of Michael F. Lynch.

Mechanisms and Modes of Deterioration

The best historic cast stone can rival natural stone in longevity. Many quality cast stone installations from the first decades of the twentieth century are still in excellent condition, and require little repair. Like any other building material, however, cast stone is subject to deterioration, which may occur in several ways:

- Separation of the facing and core layers
- Deterioration of the aggregate
- Deterioration or erosion of the cementing matrix
- Deterioration of the iron or steel reinforcement
- Deterioration of cramps and anchors used in its installation.

Separation of the Facing and Core Layers

Separation of the facing and core layers of dry tamp units is not uncommon, and often reflects fabrication defects such as poor compaction, lengthy fabrication time, or improper curing. Where separation of facing and core layers is suspected, cast stone units may be "sounded" to establish the extent of delamination.

Deterioration of the Aggregate

Cast stone failure caused by deterioration of the aggregate is uncommon. Granites, marbles, and silica sand are generally durable, although limestone and marble aggregate are subject to the same dissolution problems that affect quarried units of these stones. In rare instances, a reaction between the alkalis in the cement matrix and the stone aggregate may also cause deterioration.

Deterioration or Erosion of the Cementing Matrix

Scaling of cast stone units signals problems with the cementing mix and method of manufacture. Serious deterioration of cast stone, such as this, warrants replacement. Photos: Richard Pieper.

While it is relatively uncommon in twentieth century cast stone, serious deterioration of the cementing matrix can cause extensive damage to cast stone units. A properly prepared cementing mix will be durable in most exterior applications, and any flaking of exterior surfaces signals problems in the cementing mix and in the method of manufacture. The use of poor quality or improperly stored cement, impure water, or set accelerators can cause cement problems to occur years after a structure is completed. Improper mixing and compaction can also result in a porous concrete that is susceptible to frost damage and scaling. Severe cement matrix problems may be impossible to repair properly and often necessitate replacement of the deteriorating cast stone units.

More common and less serious than flaking or scaling caused by deterioration of the cementing matrix is the erosion of the surface of the matrix. This usually occurs on surfaces of projecting features exposed to water runoff, such as sills, water tables, and window hoods. In these areas, the matrix may erode, leaving small grains of aggregate projecting from the surface. The resultant rough surface is not at all the intended original appearance. In some historic cast stone installations, the thin layer of cement and fine sand at the surface of the cast stone units was not originally tooled from the molded surface, but was finished with patterns of masonry pigments in a stylized imitation of highly figured sandstones or limestones. Erosion of the pigmented surface layer on this type of cast stone results in an even more dramatic change in appearance.

Deterioration of the Iron or Steel Reinforcement

During their original manufacture, unusually long and thin cast stone units, such as window sills or balustrade railings, and units requiring structural capacity, such as lintels, were generally reinforced with mild steel reinforcing bars. Large pieces sometimes had cable loops or hooks cast into them to facilitate handling and attachment. On occasion, this reinforcement and wire may be too close (less than 2") to the surface of the piece and rusting will cause spalling of the surface. This frequently happens to sills, copings, and water tables where repeated heavy wetting leads to loss of alkalinity in the concrete, allowing the reinforcement to rust. If damage from the deteriorating reinforcement is extensive, as for instance, the splitting of a baluster from the rusting of a central reinforcing rod, the cast stone unit may require replacement.

Deterioration of Cramps and Anchors

Even when reinforcement has not been added to individual cast stone units, mild steel cramps may have been used to anchor a cast stone veneer to backup masonry. Where spalls have occurred primarily at the tops of ashlar or frieze units, this is generally the cause.

Rusting of reinforcement near the surface of the stone may result in spalling. Sections of reinforcement, such as this, may be cut out and the spall repaired with a matching composite mortar. Photo: Richard Pieper.

Maintenance of Cast Stone Installations

Cleaning

Cast stone installations with marble or limestone aggregates may sometimes be cleaned with the same alkaline pre-wash/acid afterwash chemical cleaning systems used to clean limestone and other calcareous natural stones. If no marble or limestone aggregates are present, acidic cleaners, such as those used for natural granites and sandstones, may be used.

Sandblasting and wet grit blasting can seriously erode the surface and should not be used to clean cast stone surfaces. Photo: Richard Pieper.

In either case, dark particulate staining in protected areas may be persistent, however, and require experimentation with other cleaning methods. Some micro-abrasive cleaning techniques used under very controlled circumstances by skilled cleaning personnel can be appropriate for removing tenacious soiling. Ordinary sand blasting or wet grit blasting can seriously damage the surface of the cast stone and should not be used.

Repointing

Early cast stone installations may have been constructed with natural cement mortars, but in late nineteenth century and twentieth century installations, cast stone units were generally bedded and pointed with mortars composed of portland cement, lime, and sand. When repointing or replacement of the historic mortar is required, a Type N mortar (about one part cement, and one part lime to six parts of sand) is generally appropriate. When repointing any historic masonry, it is important to match both the character and color of the sand and color of the cement matrix in the historic mortar. Cement matrix color can often be adjusted by using combinations of white, "light," and gray portland cement in the mortar.

Joints in historic cast stone installations can be quite thin and the dense mortar thus difficult to remove. Unnecessary repointing can cause significant damage to historic cast stone. Cracked and open joints will most often be found on exposed features such as balustrades and copings and, of course, require repointing. When a hard and tenacious mortar was used in the original installation or a later repointing, the removal of the mortar can easily chip the edges of the cast stone units.

While the careless use of "grinders" to remove mortar has damaged countless historic masonry buildings, a skilled mason may sometimes use a hand held grinder fitted with a thin diamond blade to score the center of a joint, and then remove the rest of the mortar with a hand chisel. If this method is not done carefully, however, wandering of the blade can widen or alter joints and cause significant damage to the cast stone. Care must be taken to prevent damage from over cutting of vertical joints by stopping blades well short of adjacent units. The use of small pneumatic chisels, such as those used to tool stone, can also work well for mortar removal, but even this method can cause chipping to the edges of cast stone units if it is not done carefully.

Methods of Repair

Much historic cast stone is unnecessarily replaced when it could easily be repaired in situ, or left untreated. This is especially true of areas that exhibit isolated spalls from rusting reinforcement bars or anchorage, or installations where erosion of the matrix has left a rough surface of exposed aggregate.

The weathering of cast stone, while different from that of natural stone, produces a patina of age, and does not warrant large-scale replacement, unless severe cement matrix problems or rusting reinforcement bars have caused extensive scaling or spalling. Severe rusting of reinforcement bars on small decorative features, such as balusters, may signal carbonation (loss of alkalinity) of the matrix. Where carbonation of the matrix has occurred, untreated reinforcement will continue to rust. Replacement may be an acceptable approach for exposed and severely deteriorated features, such as hand railings, roof balustrades, or wall copings, where disassembly is unlikely to damage adjacent construction. Conversely, small areas of damage should generally be repaired with mortar "composites," or left alone.

Re-securing Separated Surface Facing

A delaminated layer of ornamental cast stone on the Orpheum Theater, San Francisco.

Where the decorative facing of dry tamped cast stone has separated from core layers, injected grouts may be used to re-secure the facing. Re-attachment of a separated facing layer may be time consuming, and should be undertaken by a conservator, rather than a mason. This technique may be the best, most economical, approach for repair of figurative sculpture or unique elements that are not repeated elsewhere on a building. Theoretically, cementitious grouts are most appropriate for re-attaching separated facings, but hairline fissures may require the use of resin adhesives. Low-viscosity epoxies have been used for this purpose, and may be applied through small injection ports. Cracks that would allow adhesive to leak must

California (1925), was successfully re-attached using epoxy. The multiple delivery ports for the epoxy are removed after treatment and the holes patched. Photo: David P. Wessell.

be repaired prior to injection, of course. Holes made for adhesive injection will require patching after re-attachment is complete.

Repairing Reinforcement Spalls and Mechanical Damage

Drilled holes, mechanically damaged corners, and occasional spalls from rusted reinforcement bars and anchorage are repairable conditions that do not warrant the replacement of cast stone. Small "composite" repairs to damaged masonry units can be made with mortar formulated to visually match the original material, and may be successfully undertaken by a competent and sensitive mason. If deterioration appears widespread, however, or if large surface areas are spalling or cracking and replacement appears necessary, the owner may wish to consult a preservation architect or consultant to determine the cause of deterioration and to specify necessary repairs or replacement, as appropriate.

The methods of composite repair used for stone masonry are also generally applicable for the repair of historic cast stone. For repairs to damaged cast stone to be successful, however, both the cement matrix color and the aggregate size and coloration must match that of the historic unit. Crushed stone and slag (such as "Black Beauty" abrasive grit), which are similar to many common traditional aggregates, are widely available, although some additional crushing and/or sieving may be necessary to obtain aggregate of an appropriate size. Remember that half or more of a weathered surface is exposed aggregate, so careful aggregate selection and size grading is extremely important for patching. Even differences in aggregate angularity (rounded pebbles vs. crushed stone) will be noticeable in the final repair. If more than one aggregate was used in the cast stone, the ratio of the selected aggregates in the mix is, of course, equally important. Variation in coloring of the cement matrix may be achieved through the use of either white, "light," or gray portland cement. If additional tinting is required, only inorganic alkali-resistant masonry pigments should be used. Because most historic cast stone was manufactured primarily from portland cement and aggregate (with a less than 15% lime/cement ratio), it is not necessary to add large amounts of hydrated lime to cast stone composite repair mixtures. Small amounts of lime may be added for plasticity of the working mix.

To repair a spall caused by deterioration of a ferrous reinforcement bar or anchorage, it is necessary to remove all cracked concrete adjacent to the spall; grind and brush the reinforcement to remove all rust and scale; and paint the metal with a rust-inhibiting primer prior to applying the cast stone composite. If the reinforcement bar is much too close to the surface of the stone, it may be advisable to cut out the deteriorating section of reinforcement after consultation with a structural engineer. If deteriorating cramps are removed, it may be necessary to install new stainless steel anchorage.

Where spalls have a feather edge, it will be necessary to cut back the repair area to a uniform depth (1/2" or more). As with natural stone composite repairs, a bonding agent may assist adhesion of the repair material to the original concrete. For unusually large or deep patches, mechanical anchoring of the repair with small nylon or stainless steel rods may be required. If the adjacent cast stone is tooled or weathered, it will be necessary to scribe or brush the repaired area to give it a matching surface texture. Adding enough coarse aggregate to match adjacent original material will sometimes interfere with adhesion of the composite, and it may be necessary to press additional aggregate into the applied patch prior to finishing. If this is not skillfully done, however, the surface of the patch may take on a mosaic appearance. For this reason, it is advisable to undertake test composite repairs in an unobtrusive location first.

Surface Refinishing

While re-tooling of deteriorated natural stone may sometimes be appropriate, restoring the original appearance of cast stone where surface erosion has occurred is difficult or impossible.

Tooling or grinding of the surface of the cast stone may expose coarse aggregate beneath the surface and will not, in any case, restore original patterned pigmentation that has weathered away. Silicate paints or masonry stains may be applied in patterns to replicate the original appearance, but may not be durable or completely successful aesthetically. Where matrix has eroded, it is advisable to accept the weathered

This completed composite repair could have been improved by brushing to remove the matrix residue at the edges of the repair before the surface cured. Photo: Richard Pieper.

The composite mortar is applied to the void with a small spatula or trowel. Photo: Richard Pieper.

The damaged area is cut out to create a shallow void of even depth, half inch or more. Photo: Richard Pieper.

Unlike natural stone, cast stone generally may not be tooled in place to reduce lippage of uneven surfaces at joints. Tooling often exposes coarse aggregate from below the surface. Photo: Richard Pieper.

appearance of the cast stone, unless extensive replacement is mandated by other factors.

Because cast stone depends on exposed aggregate to achieve its aesthetic effect, the use of an applied cementitious surface coating dramatically alters the visual effect of the material and is inappropriate as a cast stone repair technique. A cementitious surface coating can also trap moisture in the cast units and cause surface spalling.

Replacement of Historic Cast Stone Installations

Individual cast stone units, which are subject to repeated wetting (such as copings, railings and balusters) and exhibit severe failure due to spalling or reinforcement deterioration, may require replacement with new cast stone and can replicate

deteriorated units in existing buildings.

After removal from the mold, the new cast stone units are scrubbed to remove surface paste and expose underlying aggregate. End cast pieces, such as this sculpture, may have numerous air bubbles at the surface. Photo: Richard Pieper.

Fortunately, a number of companies custom manufacture precast concrete units. The variables involved in manufacture are considerable, and it is wise to use a firm with experience in ornamental and custom work rather than a precast concrete firm which manufactures stock structural items, concrete pipe, or the like. Several trade organizations, including the Cast Stone Institute, the National Precast Concrete Association, and the Architectural Precast Association, have developed recommendations and/or guide specifications for the manufacture of cast stone and precast concrete. These specifications set standards for characteristics such as compressive strength and water absorptivity, and discuss additives such as air entraining agents and water reducing agents, which influence the longevity of new cast stone. Trade references and guide specifications should be consulted before contracting for replacement of historic cast stone.

Fabrication defects in new cast stone. While the cement matrix coloration and aggregate considerations previously mentioned require the most careful attention, project staff should also look for defects which are common to cast stone fabrication:

Air bubbles. Small pits on the surface of the stone may form if the unit is not given adequate vibration to release trapped air during pouring. Bubbles can also be a problem when end casting long items such as columns or railings, where it is difficult to vibrate bubbles away from the finish surface of the unit.

The holes on the surface of the casting (see above, left) are being filled with a mortar similar to the concrete mix used to cast the element. Photo: Richard Pieper.

Surface cracking or checking. Overly wet mixes and insufficient moisture during curing can result in surface cracking of large castings, such as columns. Such cracking dramatically reduces the durability of new cast stone. Small reinforced elements, such as balusters, also frequently crack at thin "necks" in the castings.

Aggregate segregation. Cast stone formulations generally include a range of coarse aggregates (crushed stone) and fine aggregates (sand). When units are vibrated to assure compaction of the mix and liberate trapped air bubbles, coarse aggregates may begin to settle and separate from the paste of cement and sand. Aggregate segregation results in a visible concentration of coarse aggregate at one end of the casting. Segregation is more problematic when end casting long pieces such as columns.

Surface cracking may reduce the durability of cast stone units. Cracking is often problematic on reinforced elements with thin "necks," such as balusters, unless curing is carefully controlled. Photo: Richard Pieper.

Surface rippling or irregularity. Production molds for fabrication are often made of rubber mold facings encased in larger "mother molds" of plaster and wood. Vibration can loosen the rubber facing from the outer mold and result in rippling or irregularities on the surface of the finished casting. Even when rippling is not noticeable, irregularity caused by mold movement can make it difficult to line up surfaces of adjacent units when assembling cast stone installations.

Mold lines. Freestanding elements, such as columns, must be cast in two-part molds, which are separated to release the completed cast piece. If the mold parts do not join tightly, some leakage of cement paste will occur at the mold joint, resulting in a projecting line on the surface of the casting. This is generally tooled off before the casting completely cures. A mold line will be visible on the completed piece if the projecting material is not completely removed, or if the tooling at the mold line does

not match the adjacent surface of the casting. Tooling at mold lines may also expose contrasting coarse aggregate beneath the surface of the casting.

Other Considerations for Replacement of Cast Stone

Several other considerations are worth noting when it is necessary to replace historic cast stone elements with matching new cast stone.

Reinforcement. The alkalinity of new concrete generally provides adequate protection to steel reinforcement. In exposed areas where deterioration due to rusting of reinforcement has previously been a problem, however, the use of stainless steel reinforcement is recommended.

Surface finishing. Post-fabrication surface tooling of new cast stone is not currently common. Sandblasting is typically used to remove the surface film of cement and expose the aggregate. For replacement units replicating historic cast stone pieces in highly visible locations, it is sometimes possible to make a mold of a sound or repaired existing piece to incorporate the original tooling in the casting process. If the historic unit is too deteriorated to use as a pattern, a plaster model may be made to replicate the damaged piece. This is tooled to replicate the desired surface treatment or appearance, and a production mold is then made from the plaster model.

Moist curing. Surface crystallization of soluble salts (efflorescence) during curing may lighten the surface of some precast units, especially those simulating darker stone. Some manufacturers use a series of wet/dry curing cycles or washing with acetic acid to remove soluble salts that might otherwise discolor finished surfaces. For most wet cast products, simple moist curing under a plastic cover is sufficient.

Production molds made of durable rubbers backed with wood and plaster supports are used to fabricate new cast stone. Photo: Richard Pieper.

Appropriateness of Glass Fiber Reinforced Concrete as a Replacement Material

Light-Weight Alternative

Glass fiber reinforced concrete (GFRC) is more and more frequently encountered in building restoration and is used to replicate deteriorated stone and cast stone, and even architectural terra cotta. This is a relatively new material that uses short chopped strands of glass fiber to reinforce a matrix of sand and cement. GFRC has become a popular low cost alternative to traditional precast concrete or stone masonry for some applications. Fabricators use a spray gun to spray the mortar-like mix into a mold of the shape desired. The resulting concrete unit, typically only ¾" thick, is quite rigid, but requires a metal frame or armature to secure it to the building substrate. The metal frame is joined to the GFRC unit with small "bonding pads" of GFRC.

GFRC has a dramatic advantage over traditional precast concrete where the weight of the installation is a concern, such as with cornices or window hoods. Many cast stone mixes can successfully be replicated with GFRC. Where it is used to simulate natural stone, GFRC, like cast stone, is most appropriate for simulation of fine-grained sandstones or limestones.

Not for Use in Load Bearing Applications

Because the GFRC system is in effect a "skin," GFRC cannot be used for load bearing applications without provision of additional support. This makes it unsuitable for some tasks such as replacement of individual ashlar units. It is also not appropriate for small freestanding elements such as balusters, or for most columns, unless they are engaged to surrounding masonry or can be vertically seamed, which may significantly alter the historic appearance. GFRC units must also allow for expansion and contraction, and are generally separated by sealant joints, not by mortar. A sealant joint may be unacceptable for some historic applications; however, substitution of GFRC for cast stone may be appropriate when an entire assembly, such as a cornice, roof domer, or window hood, requires replacement. Great care must be taken when detailing a GFRC replacement for existing cast stone.

Deterioration of GFRC

Because it is a relatively new material, the long term durability of GFRC is still untested. When GFRC was first introduced, some installations experienced deterioration caused by alkaline sensitivity of the glass fiber reinforcement. Alkali resistant

The attachment hardware inside this GFRC cartouche (left) will not be visible when the unit is installed (armature visible at right). Photos: Towne House Restorations, Inc.

GFRC is sometimes used to replicate deteriorated elements of cast or fine grained natural stone. Because the GFRC element is a rigid, but relatively thin shell, it must be supported and attached with an interior framework of steel.

glass is now used for GFRG manufacture. Even when the GFRG skin is well manufactured, however, the steel armature and bonding pad system used to mount the material is vulnerable to damage from leakage at sealant joints or small cracks in wash surfaces. The use of galvanized or stainless steel armatures, and stainless steel fasteners and bonding pad anchors is advisable.

Summary and References

Cast stone—a mixture of water, sand, coarse aggregate, and cementing agents—has proven over time to be an attractive and durable building material, when properly manufactured. It gained popularity in the 1860s and, by the early decades of the 20th century, became widely accepted as an economical substitute for natural stone. Unfortunately, much historic cast stone is unnecessarily replaced when it could easily be repaired and preserved in situ, or left untreated. Appropriate repair of damaged units can extend the life of any cast stone installation. Because of the necessity of matching both matrix color and aggregate size and ratio, conservation projects which involve repair or replication of cast stone should allow adequate lead time for the assembly of materials and the preparation of test samples. Understanding which conditions require repair, which warrant replacement, and which should be accepted as normal weathering is key to selecting the most appropriate approach to the protection and care of historic cast stone.

Helpful Organizations

Cast Stone Institute

10 West Kimball Street
Winder, GA 30680-2535

National Precast Concrete Association

10333 North Meridian Street, Suite 272
Indianapolis, IN 46290

Architectural Precast Association

P.O. Box 08669
Fort Myers, FL 33908-0669

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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.

Photographs included in this publication may not be used to illustrate other publications without permission of the owners.

September 2001

Reading List

Childe, H.L. *Manufacture and Uses of Concrete Products and Cast Stone*, London: Concrete Publications Limited, 1930.

Jester, Thomas C., ed., *Twentieth Century Building Materials*, New York, NY: McGraw-Hill, 1995.

Precast/Prestressed Concrete Institute, *Architectural Precast Concrete*, 2nd ed., Chicago, Illinois: Precast/Prestressed Concrete Institute, 1989.

Whipple, Harvey, *Concrete Stone Manufacture*, Detroit: Concrete-Cement Age Publishing Company, 1918.

1.3.2.2 Removing and replacing deteriorated cast stone balusters (GSA 2014)

Removing And Replacing Deteriorated Cast Stone Balusters

Procedure code:

472001S

Source:

National Capitol Region Specifications

Division:

Masonry

Section:

Cast Stone

Last Modified:

12/23/2014

REMOVING AND REPLACING DETERIORATED CAST STONE BALUSTERS

PART 1---GENERAL

1.01 SUMMARY

A. This procedure includes guidance on the removal of deteriorating exterior cast stone (concrete) balusters and their replacement.

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).

1.02 REFERENCES

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

B. American Concrete Institute (ACI), www.concrete.org

C. Cast Stone Institute, www.caststone.org

D. Architectural Precast Association, www.archprecast.org

1.03 SUBMITTALS

A. Product Data: Submit specifications and other data for cast stone, including certification that it complies with specified requirements. Include instructions for handling, storage, installation and protection.

B. Shop Drawings: Submit drawings showing sizes, dimensions, sections and profiles of cast stone units, arrangement and provisions for jointing, anchoring and fastening, supports and other necessary details for lifting devices and reception of other work. Indicate location of each unit on setting drawings with number designation corresponding to number marked on each unit.

1.04 QUALITY ASSURANCE

A. Regulatory Requirements: Provide cast stone which complies with requirements of "Specifications for Cast Stone" (ACI 704-44) of the American Concrete Institute;

Or "Standard Specification for Architectural Cast Stone" (Section 04-72-00 (2011) of Cast Stone Institute;

Or "Architectural Cast Stone" (Section 04720),
Architectural Precast Association.

B. Mock-Ups:

1. Prior to installation of stonework, provide one sample railing with all balusters to indicate proposed range of color, texture and workmanship to be expected in completed work. Build mock-up at site as directed, using stone, anchors and jointing, as specified in accordance with final shop drawings.

2. Obtain Contracting Officer's acceptance of visual qualities of balusters before start of stonework. Replace unsatisfactory mock-up work as directed, until acceptable to Contracting Officer. Retain sample panels during construction as a standard for judging completed stonework. Do not alter, move or destroy mock-up until work is completed.

1.05 DELIVERY, STORAGE AND HANDLING

A. Packing and Shipping:

1. Finished cast stone shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

2. Protect cast stone during storage and construction against moisture, soiling, staining and physical damage.

3. Handle stone to prevent chipping, breakage, soiling or other damage. Do not use pinch or wrecking bars without protecting edges of stone with wood or other rigid materials. Lift with wide-belt type slings wherever possible. Do not use wire rope or ropes containing tar or other substances which might cause staining.

B. Storage and Protection: Store stone on wood skids or pallets, covered with non-staining, waterproof membrane. Place and stack skids and stones to distribute weight evenly and to prevent breakage or cracking of stones.

Protect stored stone from weather with waterproof, non-staining coverings or enclosures, but allow air to circulate around stones.

1.06 PROJECT/SITE CONDITIONS

A. Existing Conditions: Do not set cast stone in temperatures 40 F or below.

1.07 SEQUENCING AND SCHEDULING

A. Coordinating Work: Installer must review installation procedures and coordination with other work, with Contractor, and other contractors and subcontractors whose work will be affected by stonework.

PART 2---PRODUCTS

2.01 MANUFACTURERS

See "References, 1.02" and consult industry groups (1.02 - B, C, and D) for membership directories.

2.02 MATERIALS

A. Cast Stone:

1. Cast stone shall be a building stone manufactured from Portland cement concrete, precast, and of the same composition throughout the piece.
2. Cement and aggregates shall be carefully chosen to produce a cast stone equal in color and texture to the appearance of the existing stone. Match only cleaned samples of the existing stone.
3. All added colors shall be mineral oxide pigments guaranteed by the manufacturer to be sun-fast and lime-proof.
4. Finish shall duplicate in all respects the finish of specific example(s) of the existing cast stone as designated by the Contracting Officer.
5. Aggregates shall be of known durability and shall be proportioned to produce maximum density.

6. Before delivery, cast stone shall be properly cured and shall have a minimum compressive strength of 5,000 psi and a maximum average water absorption of 7.5 percent.

7. All cast stone shall be sound and perfect. Make all edges sharp and true. Provide continuous slots, bevels, reglets, rebates and other features, as required.

C. Mortar and Grout:

1. Portland cement: ASTM C150, except complying with the non-staining requirements of ASTM C91 for not more than 0.03% water soluble alkali.

2. Hydrated Lime: ASTM C207, Type S.

3. Sand: ASTM C144.

4. Water: Clean and potable.

D. Stonework Accessories:

1. Anchors: Clean existing base anchors set in stone.

2. Setting Buttons: Lead or plastic buttons of the thickness required for the joint size indicated, and of the size required to maintain uniform joint width.

2.03 MIXES

A. Mortar: Non-staining, cement/lime mortar, complying with ASTM C270, Proportion Specification. Mortar color should match adjacent historic mortar; match tooling and other details.

PART 3---EXECUTION

3.01 PREPARATION

A. Surface Preparation: Clean all adjoining stone surfaces before setting by thoroughly scrubbing with fiber brushes, followed by a thorough drenching with clear water. Use only mild cleaning compounds that contain no

caustic or harsh fillers or abrasives. If not thoroughly wet at time of setting, drench or sponge stone.

3.03 ERECTION, INSTALLATION, APPLICATION

A. Measure the existing conditions prior to fabrication of the cast stone. Match the existing placement and dimensions.

B. Execute stonework by skilled mechanics, and employ skilled stone fitters at the site to do necessary field cutting as stone is set.

C. Set stone in accordance with drawings and final shop drawings for stonework. Provide anchors, supports, fasteners and other attachments shown or necessary to secure stonework in place. Shim and adjust accessories for proper setting of stone. Completely fill holes, slots and other sinkages for anchors, dowels, fasteners and supports with mortar during setting of stones.

D. Joints: Set units in full bed of mortar, unless otherwise indicated.

1. Wet stone thoroughly before setting.

2. Set stone before initial set of cement bed occurs. Do not set stone on dry bed. Tamp and beat stone for a complete contact between stone and setting bed. Set and level each unit immediately. Set stone in pattern shown with uniform joints.

3. Grout joints as soon as possible after initial set of setting bed. Force grout into joints, and tool. Wet joint surfaces, if dry, prior to grouting.

4. Cure grout by maintaining in a moist condition for 7 days.

5. Remove grout spillage from face of stone as work progresses.

3.03 ADJUSTING/CLEANING

A. Clean stonework not less than six days after completion of work, using clean water and stiff-bristle brushes. Do not use wire brushes, acid-type cleaning agents or other

1.4 Preservation and rehabilitation guidelines for historic concrete

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 concrete 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 concrete (Grimmer 2017, 31–36).

Preservation Treatment for Concrete	
RECOMMENDED	NOT RECOMMENDED
Identifying, retaining, and preserving masonry features that are important in defining the overall historic character of the building (such as walls, brackets, railings, cornices, window and door surrounds, steps, and columns) and decorative ornament and other details, such as tooling and bonding patterns, coatings, and color.	Altering masonry features which are important in defining the overall historic character of the building so that, as a result, the character is diminished. Replacing historic masonry features instead of repairing or replacing only the deteriorated masonry. Applying paint or other coatings (such as stucco) to masonry that has been historically unpainted or uncoated. Removing paint from historically-painted masonry.
Stabilizing deteriorated or damaged masonry as a preliminary measure, when necessary, prior to undertaking preservation work.	Failing to stabilize deteriorated or damaged masonry until additional work is undertaken, thereby allowing further damage to occur to the historic building
Protecting and maintaining masonry by ensuring that historic drainage features and systems that divert rainwater from masonry surfaces (such as roof overhangs, gutters, and downspouts) are intact and functioning properly.	Failing to identify and treat the causes of masonry deterioration, such as leaking roofs and gutters or rising damp.
Cleaning masonry only when necessary to halt deterioration or remove heavy soiling.	Cleaning masonry surfaces when they are not heavily soiled to create a “like-new” appearance, thereby needlessly introducing chemicals or moisture into historic materials.
Carrying out masonry cleaning tests when it has been determined that cleaning is appropriate. Test areas should be examined to ensure that no damage has resulted and, ideally, monitored over a sufficient period of time to allow long-range effects to be predicted.	Cleaning masonry surfaces without testing or without sufficient time for the testing results to be evaluated.
Cleaning soiled masonry surfaces with the gentlest method possible, such as using low-pressure water and detergent and natural bristle or other soft-bristle brushes.	Cleaning or removing paint from masonry surfaces using most abrasive methods (including sandblasting, other media blasting, or high-pressure water) which can damage the surface of the masonry and mortar joints. Using a cleaning or paint-removal method that involves water or liquid chemical solutions when there is any possibility of freezing temperatures. Cleaning with chemical products that will damage some types of masonry (such as using acid on limestone or marble), or failing to neutralize or rinse off chemical cleaners from masonry surfaces.
Using biodegradable or environmentally-safe cleaning or paint-removal products.	
Using paint-removal methods that employ a poultice to which paint adheres, when possible, to neatly and safely remove old lead paint.	
Using coatings that encapsulate lead paint, when possible, where the paint is not required to be removed to meet environmental regulations.	
Allowing only trained conservators to use abrasive or laser-cleaning methods, when necessary, to clean hard-to-reach, highly-carved, or detailed decorative stone features.	
Removing damaged or deteriorated paint only to the next sound layer using the gentlest method possible (e.g., hand scraping) prior to repainting.	Removing paint that is firmly adhered to masonry surfaces.
Applying compatible paint coating systems to historically-painted masonry following proper surface preparation.	Failing to follow manufacturers’ product and application instructions when repainting masonry features.
Repainting historically-painted masonry features with colors that are appropriate to the building and district.	Using paint colors on historically-painted masonry features that are not appropriate to the building or district.

(Table continues on next page.)

RECOMMENDED	NOT RECOMMENDED
Protecting adjacent materials when working on masonry features.	Failing to protect adjacent materials when working on masonry features.
Evaluating the overall condition of the masonry to determine whether more than protection and maintenance, such as repairs to masonry features, will be necessary.	Failing to undertake adequate measures to ensure the protection of masonry features.
Repairing masonry by patching, splicing, consolidating, or otherwise reinforcing the masonry using recognized preservation methods.	Removing masonry that could be stabilized, repaired, and conserved, or using untested consolidants, improper repair techniques, or unskilled personnel, potentially causing further damage to historic materials.
Repairing masonry walls and other masonry features by repointing the mortar joints where there is evidence of deterioration, such as disintegrating mortar, cracks in mortar joints, loose bricks, or damaged plaster on the interior.	Removing non-deteriorated mortar from sound joints and then repointing the entire building to achieve a more uniform appearance.
Removing deteriorated lime mortar carefully by hand raking the joints to avoid damaging the masonry.	
Using power tools only on horizontal joints on brick masonry in conjunction with hand chiseling to remove hard mortar that is deteriorated or that is a non-historic material which is causing damage to the masonry units. Mechanical tools should be used only by skilled masons in limited circumstances and generally not on short, vertical joints in brick masonry.	Allowing unskilled workers to use masonry saws or mechanical tools to remove deteriorated mortar from joints prior to repointing.
Duplicating historic mortar joints in strength, composition, color, and texture when repointing is necessary. In some cases, a lime-based mortar may also be considered when repointing Portland cement mortar because it is more flexible.	Repointing masonry units with mortar of high Portland cement content (unless it is the content of the historic mortar).
Duplicating historic mortar joints in width and joint profile when repointing is necessary.	Using "surface grouting" or a "scrub" coating technique, such as a "sack rub" or "mortar washing," to repoint exterior masonry units instead of traditional repointing methods. Changing the width or joint profile when repointing.
Repairing stucco by removing the damaged material and patching with new stucco that duplicates the old in strength, composition, color, and texture.	Removing sound stucco or repairing with new stucco that is different in composition from the historic stucco. Patching stucco or concrete without removing the source of deterioration. Replacing deteriorated stucco with synthetic stucco, an exterior insulation and finish system (EIFS), or other non-traditional materials.
Using mud plaster or a compatible lime-plaster adobe render, when appropriate, to repair adobe.	Applying cement stucco, unless it already exists, to adobe.
Sealing joints in concrete with appropriate flexible sealants and backer rods, when necessary.	Repointing masonry units (other than concrete) with a synthetic caulking compound instead of mortar.
Cutting damaged concrete back to remove the source of deterioration, such as corrosion on metal reinforcement bars. The new patch must be applied carefully so that it will bond satisfactorily with, and match, the historic concrete.	Patching damaged concrete without first removing the source of deterioration.
Using a non-corrosive, stainless-steel anchoring system when replacing damaged stone, concrete, or terra-cotta units that have failed.	

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RECOMMENDED	NOT RECOMMENDED
Applying non-historic surface treatments, such as water-repellent coatings, to masonry only after repointing and only if masonry repairs have failed to arrest water penetration problems.	Applying waterproof, water-repellent, or non-original historical coatings (such as stucco) to masonry as a substitute for repointing and masonry repairs.
Applying permeable, anti-graffiti coatings to masonry when appropriate.	Applying water-repellent or anti-graffiti coatings that change the appearance of the masonry or that may trap moisture if the coating is not sufficiently permeable.
<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 masonry features when there are surviving prototypes, such as terra-cotta brackets or stone balusters, 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 masonry feature, such as a column or stairway, when limited replacement of deteriorated and missing components is appropriate. Using replacement material that does not match the historic masonry feature.

Table 2. Rehabilitation as a treatment for concrete (Grimmer 2017, 80–87).

Rehabilitation as a Treatment for Concrete	
RECOMMENDED	NOT RECOMMENDED
<i>Identifying, retaining and preserving</i> masonry features that are important in defining the overall historic character of the building (such as walls, brackets, railings, cornices, window and door surrounds, steps, and columns) and decorative ornament and other details, such as tooling and bonding patterns, coatings, and color.	<p>Removing or substantially changing masonry features which are important in defining the overall historic character of the building so that, as a result, the character is diminished.</p> <p>Replacing or rebuilding a major portion of exterior masonry walls that could be repaired, thereby destroying the historic integrity of the building.</p> <p>Applying paint or other coatings (such as stucco) to masonry that has been historically unpainted or uncoated to create a new appearance.</p> <p>Removing paint from historically-painted masonry.</p>
<i>Protecting and maintaining</i> masonry by ensuring that historic drainage features and systems that divert rainwater from masonry surfaces (such as roof overhangs, gutters, and downspouts) are intact and functioning properly.	Failing to identify and treat the causes of masonry deterioration, such as leaking roofs and gutters or rising damp.
Cleaning masonry only when necessary to halt deterioration or remove heavy soiling.	Cleaning masonry surfaces when they are not heavily soiled to create a “like-new” appearance, thereby needlessly introducing chemicals or moisture into historic materials.
Carrying out masonry cleaning tests when it has been determined that cleaning is appropriate. Test areas should be examined to ensure that no damage has resulted and, ideally, monitored over a sufficient period of time to allow long-range effects to be predicted.	Cleaning masonry surfaces without testing or without sufficient time for the testing results to be evaluated.
Cleaning soiled masonry surfaces with the gentlest method possible, such as using low-pressure water and detergent and natural bristle or other soft-bristle brushes.	<p>Cleaning or removing paint from masonry surfaces using most abrasive methods (including sandblasting, other media blasting, or high-pressure water) which can damage the surface of the masonry and mortar joints.</p> <p>Using a cleaning or paint-removal method that involves water or liquid chemical solutions when there is any possibility of freezing temperatures.</p> <p>Cleaning with chemical products that will damage some types of masonry (such as using acid on limestone or marble), or failing to neutralize or rinse off chemical cleaners from masonry surfaces.</p>
Using biodegradable or environmentally-safe cleaning or paint-removal products.	
Using paint-removal methods that employ a poultice to which paint adheres, when possible, to neatly and safely remove old lead paint.	
Using coatings that encapsulate lead paint, when possible, where the paint is not required to be removed to meet environmental regulations.	
Allowing only trained conservators to use abrasive or laser-cleaning methods, when necessary, to clean hard-to-reach, highly-carved, or detailed decorative stone features.	
Removing damaged or deteriorated paint only to the next sound layer using the gentlest method possible (e.g., hand scraping) prior to repainting.	Removing paint that is firmly adhered to masonry surfaces, unless the building was unpainted historically and the paint can be removed without damaging the surface.
Applying compatible paint coating systems to historically-painted masonry following proper surface preparation.	Failing to follow manufacturers’ product and application instructions when repainting masonry features.
Repainting historically-painted masonry features with colors that are appropriate to the historic character of the building and district.	Using paint colors on historically-painted masonry features that are not appropriate to the historic character of the building and district.
Protecting adjacent materials when cleaning or removing paint from masonry features.	Failing to protect adjacent materials when cleaning or removing paint from masonry features.

(Table continues on next page.)

RECOMMENDED	NOT RECOMMENDED
Evaluating the overall condition of the masonry to determine whether more than protection and maintenance, such as repairs to masonry features, will be necessary.	Failing to undertake adequate measures to ensure the protection of masonry features.
Repairing masonry by patching, splicing, consolidating, or otherwise reinforcing the masonry using recognized preservation methods. Repair may include the limited replacement in kind or with a compatible substitute material of those extensively deteriorated or missing parts of masonry features when there are surviving prototypes, such as terra-cotta brackets or stone balusters.	Removing masonry that could be stabilized, repaired, and conserved, or using untested consolidants and unskilled personnel, potentially causing further damage to historic materials. Replacing an entire masonry feature, such as a cornice or balustrade, when repair of the masonry and limited replacement of deteriorated or missing components are feasible.
Repairing masonry walls and other masonry features by repointing the mortar joints where there is evidence of deterioration, such as disintegrating mortar, cracks in mortar joints, loose bricks, or damaged plaster on the interior.	Removing non-deteriorated mortar from sound joints and then repointing the entire building to achieve a more uniform appearance.
Removing deteriorated lime mortar carefully by hand raking the joints to avoid damaging the masonry.	
Using power tools only on horizontal joints on brick masonry in conjunction with hand chiseling to remove hard mortar that is deteriorated or that is a non-historic material which is causing damage to the masonry units. Mechanical tools should be used only by skilled masons in limited circumstances and generally not on short, vertical joints in brick masonry.	Allowing unskilled workers to use masonry saws or mechanical tools to remove deteriorated mortar from joints prior to repointing.
Duplicating historic mortar joints in strength, composition, color, and texture when repointing is necessary. In some cases, a lime-based mortar may also be considered when repointing Portland cement mortar because it is more flexible.	Repointing masonry units with mortar of high Portland cement content (unless it is the content of the historic mortar). Using "surface grouting" or a "scrub" coating technique, such as a "sack rub" or "mortar washing," to repoint exterior masonry units instead of traditional repointing methods. Repointing masonry units (other than concrete) with a synthetic caulking compound instead of mortar.
Duplicating historic mortar joints in width and joint profile when repointing is necessary.	Changing the width or joint profile when repointing.
Repairing stucco by removing the damaged material and patching with new stucco that duplicates the old in strength, composition, color, and texture.	Removing sound stucco or repairing with new stucco that is different in composition from the historic stucco. Patching stucco or concrete without removing the source of deterioration. Replacing deteriorated stucco with synthetic stucco, an exterior finish and insulation system (EFIS), or other non-traditional materials.
Using mud plaster or a compatible lime-plaster adobe render, when appropriate, to repair adobe.	Applying cement stucco, unless it already exists, to adobe.
Sealing joints in concrete with appropriate flexible sealants and backer rods, when necessary.	
Cutting damaged concrete back to remove the source of deterioration, such as corrosion on metal reinforcement bars. The new patch must be applied carefully so that it will bond satisfactorily with and match the historic concrete.	Patching damaged concrete without removing the source of deterioration.

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RECOMMENDED	NOT RECOMMENDED
Using a non-corrosive, stainless-steel anchoring system when replacing damaged stone, concrete, or terra-cotta units that have failed.	
Applying non-historic surface treatments, such as water-repellent coatings, to masonry only after repointing and only if masonry repairs have failed to arrest water penetration problems.	Applying waterproof, water-repellent, or non-original historic coatings (such as stucco) to masonry as a substitute for repointing and masonry repairs.
Applying permeable, anti-graffiti coatings to masonry when appropriate.	Applying water-repellent or anti-graffiti coatings that change the historic appearance of the masonry or that may trap moisture if the coating is not sufficiently permeable.
Replacing in kind an entire masonry 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 can include large sections of a wall, a cornice, pier, or parapet. If using the same kind of material is not feasible, then a compatible substitute material may be considered.	Removing a masonry feature that is unrepairable and not replacing it, or replacing it with a new feature that does not match. Using substitute material for the replacement that does not convey the same appearance of the surviving components of the masonry feature.
<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 replacement masonry feature, such as a step or door pediment, 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 masonry 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 masonry feature that is incompatible in size, scale, material, or color.

1.5 Maintenance / management for historic concrete

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, such as historic concrete, to the USMMA historic district **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 Build-*

ings and Structures in the United States Merchant Marine Academy Historic District report (Smith, Enscoe, and Adams 2014) will help guide this process in coordination with the NY SHPO.

Operations and maintenance crews must understand that, with respect to concrete, there is no such thing as economical deferred maintenance. Failure to promptly provide the proper necessary maintenance will simply result in very expensive repairs or replacement of otherwise useful structures. It is important to understand the cause when developing a proper repair procedure so that the repair will result in extending the life of the structure or element.

An understanding of the original construction techniques (cement characteristics, mix design, original intent of assembly, type of placement, precast versus cast in place, etc.) and previous repair work performed on the concrete is important in determining causes of existing deterioration and the susceptibility of the structure to other potential types of deterioration. For example, concrete placed in short lifts (individual concrete placements) or constructed in precast segments will have numerous joints that can provide entry points for water infiltration. Inappropriate prior repairs, such as installation of patches using an incompatible material, can affect the future performance of the concrete. Such prior repairs may require corrective work (Gaudette and Slaton 2007).

- The maintenance of historic concrete involves the regular inspection of concrete to establish baseline conditions and identify needed repairs. Inspection tasks involve monitoring protection systems, including sealant joints, expansion joints, and protective coatings; reviewing existing conditions for development of distress such as cracking and delaminations; documenting conditions observed; and developing and implementing a cyclical repair program.
- The inspector should pay particular attention to loose mortar joints, cracks, stains, and wet spots on the wall.
- Cracks can be horizontal, vertical, diagonal, hairline, or major. Document the nature of the crack, explaining as best as possible the causes of the cracks. Note if cracks are running through just the mortar or also within individual concrete block units.

- Inspect mortar joints to determine if they are loose or missing and evaluate their condition as good, fair, or poor.
- Sealants are an important part of maintenance of historic concrete structures. Elastomeric sealants, which have replaced traditional oil-resin based caulks for many applications, are used to seal cracks and joints to keep out moisture and reduce air infiltration. Sealants are commonly used at windows and door perimeters, at interfaces between concrete and other materials, and at attachments to or through walls or roofs, such as with lamps, signs, or exterior plumbing fixtures.
- Where used for crack repairs on historic facades, the finished appearance of the sealant application must be considered, as it may be visually intrusive. In some cases, sand can be broadcast onto the surface of the sealant to help conceal the repair.
- Improper maintenance of historic buildings can cause long-term deterioration of concrete. Water is a principal source of damage to historic concrete (as to almost every other material) and prolonged exposure to it can cause serious problems. Unrepaired roof and plumbing leaks, leaks through exterior cladding, and unchecked absorption of water from damp earth are potential sources of building problems. Deferred repair of cracks that allows water penetration and freeze-thaw attacks can even cause a structure to collapse. In some cases, the application of waterproof surface coatings can aggravate moisture-related problems by trapping water vapor within the underlying material.
- Staining of the concrete surface can be related to soiling from atmospheric pollutants or other contaminants, dirt accumulation, and the presence of organic growth. However, stains can also indicate more serious underlying problems, such as corrosion of embedded reinforcing steel, improper previous surface treatments, alkali-aggregate reaction, or efflorescence (the deposition of soluble salts on the surface of the concrete resulting from water migration).
- Spalling (the loss of surface material) is often associated with freezing and thawing as well as cracking and delamination of the concrete cover over embedded reinforcing steel. Spalling occurs when reinforcing bars corrode and the corrosion by-products expand, creating high stresses on the adjacent concrete, which cracks and is displaced. Spalling can also occur when water absorbed by the concrete freezes and thaws. In

addition, surface spalling or scaling may result from the improper finishing, forming, or other surface phenomena when water-rich cement paste (laitance) rises to the surface. The resulting weak material is vulnerable to spalling of thin layers, or scaling. In some cases, spalling of the concrete can diminish the load-carrying capacity of the structure.

- Three primary methods are used for cleaning concrete: water methods, abrasive surface treatments, and chemical surface treatments. Low-pressure water (less than 200 psi) or steam cleaning can effectively remove surface soiling from sound concrete; however, care is required on fragile or deteriorated surfaces. In addition, water and steam methods are typically not effective in removing staining or severe soiling. Power washing with high-pressure water is sometimes used to clean or remove coatings from sound, high-strength concrete, but high-pressure water washing is generally damaging to and not appropriate for concrete on historic structures.

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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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