MARYLAND DEPARTMENT OF TRANSPORTATION

State Highway Administration

MANAGEMENT PLAN
for
HISTORIC HIGHWAY BRIDGES

April 2012

Prepared By:
KCI Technologies, Inc. &
TranSystems

Management Plan for Historic Highway Bridges

SHA Contract No. BCS 2010-02B

Project No. SP312C44

Prepared For:

Maryland State Highway Administration (SHA)
707 North Calvert Street
Baltimore, MD 21202

Prepared By:

KCI Technologies, Inc.
5001 Louise Drive, Suite 201
Mechanicsburg, PA 17055

TranSystems
One Oxford Valley, Suite 818
Langhorne, PA 19047

April 2012

TABLE OF CONTENTS

List of Tables

Appendices

Introduction

Introduction

The Management Plan for Historic Highway Bridges is a manual the Maryland State Highway Administration (SHA) will use to manage its historic highway bridges. Input by both bridge engineers and architectural historians was incorporated into the publication to guide preservation and maintenance of SHA's eligible bridges. In 1995, SHA began the National Register of Historic Places (NRHP) eligibility evaluations for over 1000 bridges on Maryland's state and county highways. In 2001, SHA determined 168 of their bridges were eligible for the NRHP. In order to determine the best candidates for long-term preservation, SHA reevaluated its bridges based on 21st century historic preservation standards.

As a result of the reevaluation, SHA selected 17 bridges to be managed as Preservation Priority Eligible Bridges, 91 bridges as Eligible and 60 bridges as Non-priority Eligible bridges. These bridges were selected because of their historic importance found in their designs and materials - stone, concrete and metal arches; through and pony metal trusses; bascule and swing movables; and the state's only aluminum girder bridge. The structures also represent Maryland's history of bridge building on nineteenth and twentieth century highways such as the National Road and US 13 Business. In addition to historic significance, we considered practical and safety data such as the bridge's condition and accident history. The 17 Preservation Priority Bridges represent the best of SHA's bridge building efforts from across the state and *SHA's Management Plan for Historic Highway Bridges* contains written guidance for these bridges.

SHA will maintain the Preservation Priority Bridges in good condition while retaining the original fabric whenever possible. SHA's Management Plan contains individual plans for each of the Preservation Priority Bridges as well as Best Practice Treatments to guide the maintenance and repair of Eligible and when appropriate, Non-priority Eligible bridges. This guidance should be used by SHA's Office of Structures' Engineering and Inspection and Remedial Engineering Divisions, Inspectors, Maintenance crews, and Cultural Resources staff. Following the guidelines contained herein will help SHA reduce the number of adverse effects to historic bridges.

All of the Preservation Priority, Eligible, and Non-Priority Eligible Bridges are listed at the end of the Introduction.

While SHA is committed to indefinitely preserving these 17 bridges, the remaining 91 Eligible bridges will be evaluated on a case-by-case basis when project undertakings are proposed by SHA or when unanticipated maintenance is warranted for a bridge due to safety concerns.[1] The 60 Non-priority Eligible bridges will be subject to the requirements of the Programmatic Agreement (PA) for SHA's Historic Highway Bridges in Maryland. This policy will provide SHA the flexibility to preserve its historic resources, to identify bridges for preservation, and to maintain safety.

---

[1] The list may be updated from time to time as warranted by identification of new bridges or the selection of a bridge or small structure for preservation in place.

During bridge maintenance, SHA will incorporate methods that may involve repair, strengthening or replacement of bridge components in an attempt to indefinitely preserve the priority bridges. All repair, strengthening or replacement of bridge components will follow the requirements of the *Secretary of Interior's Standards for Rehabilitation* (36 CFR Part 67), as well as the guidance contained in the individual bridge management plans or best practice treatments. The bridge's maintenance treatment could potentially last up to 20 years. When rehabilitation of an historic bridge or small structure is planned, the Office of Structures is encouraged to consider applying for Transportation Enhancement Program (TEP) funds and the Cultural Resources Section will work with the Office of Structures to ensure that the work is completed in accordance with the Management Plan and follows the Secretary of Interior's guidance.

Melinda B. Peters, Administrator

3/19/12

Date

Table 1. Preservation Priority Historic Bridges

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Date	Preservation Level
MD 144E (Nat'l Pike) over Town Crk	0103500	AL-II-A-149	MD 144E (Nat'l Pike) over Town Crk	Flintstone	Allegany	1925	Priority
MD 51 over C & O Canal	0104800	AL-I-C-075	MD 51 over C & O Canal	Keifars	Allegany	1932	Priority
Blue Bridge (MD 942 over N. Br. Potomac R)	0106600	AL IV-A-153	MD 942 over North Branch	Cumberland	Allegany	1955	Priority
MD 214 over the Patuxent R	0205400	AA-761	MD 214 over the Patuxent R	Davidsonville	Anne Arundel	1935	Priority
Parkton Stone Arch Bridge (MD 463 over Little Gunpowder	0310500	BA-593	MD 463 over Little Gunpowder Falls	Parkton	Baltimore	1809	Priority
Patapsco R Bridge (US 40, Edmondson Ave Extended)	0310900	BA-2557	US 40 (Nat'l Pike, Edmondson Ave Extended) over Patapsco R	Catonsville	Baltimore	1936	Priority
US 40 (National Pike) over Middle Crk	1003100	F-4-116	US 40 (National Pike) over Middle Crk	Myersville	Frederick	1936	Priority
US 40 Alternate over Casselman R	1100700	G-II-C-101	US 40 Alt over Casselman R	Grantsville	Garrett	1932	Priority
MD 32 over River Rd, Patapsco R and B&O RR	1304600	HO-673	MD 32 over River Rd, Patapsco R and B&O RR	Sykesville	Howard	1963	Priority
Dover Bridge (MD 331 over Choptank R)	2002300	T-487	MD 331over Choptank R	Tanyard	Talbot	1933	Priority
Little Antietam Crk Bridge (MD 845A)	2100400	WA-II-1125	MD 845 A (Main St) over Little Antietam Crk	Keedysville	Washington	1927	Priority
US 40 over Licking Crk	2101000	WA-V-416	US 40 over Licking Crk	Big Pool	Washington	1938	Priority
US 40 (Nat’l Pike) over Conococheague Crk	2101200	WA-V-211	US 40 (Nat’l Pike) over Conococheague Crk	Wilson	Washington	1936	Priority
Booth's Mill Bridge (Delemere Bridge)	2103800	WA-II-0009	MD 68 over Antietam Crk	Boonsboro	Washington	1833	Priority
Wicomico R Bridge (MD 991 over Wicomico R)	2200900	WI-117	MD 991 over Wicomico R	Salisbury	Wicomico	1928	Priority
Snow Hill Bridge (MD 12 over Pocomoke R)	2300200	WO-178	MD 12 over Pocomoke R	Snow Hill	Worcester	1932	Priority
Pocomoke City Bridge (US 13 Bus over Pocomoke R	2300400	WO-177	MD 675 across the Pocomoke R	Pocomoke City	Worcester	1920	Priority

Table 2. Eligible Historic Bridges

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
MD 36 over Jennings Run	0100800	AL-V-A-314	MD 36 over Jennings Run	Mount Savage	Allegany	State	1929	Eligible
US 40 Alt (Nat'l Pike) over Wills Crk	0102800	AL-V-B-316	US 40 Alt (Nat'l Pike) over Wills Crk	Cumberland	Allegany	State	1932	Eligible
MD 144 (Nat'l Pike) over Flintstone Crk	0103300	AL-II-A-043	MD 144 (Nat'l Pike) over Flintstone Crk	Flintstone	Allegany	State	(c)1900/ 1925	Eligible
MD 51 over Town Crk	0104700	AL-II-B-130	MD 51 (Old Town Rd) over Town Crk	Town Creek	Allegany	State	1932	Eligible
US 40 Scenic over Sideling Hill Crk	0106400	AL-I-B-084	US 40 Scenic (McFarland Rd.) over Sideling Hill Crk	Bellegrove	Allegany	State	1925	Eligible
Stony Crk Bridge (MD 173 over Stony Crk)	0204500	AA-2196	MD 173 (Ft. Smallwood Rd) over Stony Crk	Riviera Beach/Orchard Beach	Anne Arundel	State	1947	Eligible
Annapolis Eastport Bridge (MD 181 over Spa Crk)	0205300	AA-2195	MD 181(Compromise St.) over Spa Crk	Annapolis	Anne Arundel	State	1946	Eligible
MD 174 over AMTRAK	0207500	AA-2125	MD 174 over AMTRAK	Severn	Anne Arundel	State	1931	Eligible
US 1 Alt. NB, AMTRAK, and Herberts Run	0301100	BA-2782	Alt. US 1 (Washington Blvd)	Halethorpe	Baltimore	State	1936	Eligible
Little Gunpowder Bridge (MD 7 over Little Gunpowder)	0301200	BA-2857	MD 7 (Philadelphia Rd) over Little Gunpowder Falls	Bradshaw	Baltimore	State	1927	Eligible
MD 45 (York Rd) over Western Run	0304200	BA-2858	MD 45 (York Rd) over Western Run	Hunt Valley	Baltimore	State	1917	Eligible
MD 45 (York Rd) over Little Gunpowder Falls	0304700	BA-2859	MD 45 (York Rd) over Little Gunpowder Falls	Parkton	Baltimore	State	1930	Eligible
Gunpowder Falls Bridge (MD 45 over Gunpowder Fall)	0304800	BA-2860	MD 45 (York Rd) over Gunpowder Falls	Hereford	Baltimore	State	1924	Eligible
Old Court Rd Bridge (MD 125 over Brice Run)	0306600	BA-2861	MD 125 (Old Court Rd)over Brice Run	Randallstown	Baltimore	State	1930	Eligible
Gwynns Falls Bridge (MD 126 over Gwynns Falls)	0306700	BA-2862	MD 126 (Gwynn Oak Ave) over Gwynns Falls	Woodlawn	Baltimore	State	1903/1930	Eligible
MD 128 over Piney Run	0306800	BA-2723	MD 128 over Piney Run	Dover	Baltimore	State	1945	Eligible
Glyndon Bridge (MD 128 over WMRR)	0307100	BA-2070	Glyndon Bridge (MD 128 over WMRR)	Glyndon	Baltimore	State	1947	Eligible
MD 140 over North Branch	0308300	BA-2185	MD 140 over North Branch of	Reisterstown/Fi	Baltimore	State	1946	Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
of Patapsco R (Liberty Reservoir)			Patapsco R	nksburg				
MD 147 (Harford Rd) over Little Gunpowder Falls	0309000	BA-2865	MD 147 (Harford Rd) over Little Gunpowder Falls	Reckford	Baltimore	State	1928	Eligible
MD 147 (Harford Rd) over Haystack Branch	0309100	BA-2866	MD 147 (Harford Rd) over Haystack Branch	Mt. Vista	Baltimore	State	1915	Eligible
MD 147 (Harford Rd) over Long Green Crk	0309300	BA-2867	MD 147 (Harford Rd) over Long Green Crk	Mt. Vista	Baltimore	State	1915	Eligible
MD 151 over Patapsco & Back R, RR and MD 151B	0309900	BA-2714	MD 151 over Patapsco & Back R, RR and MD 151B	Sparrows Point	Baltimore	State	1954	Eligible
Rolling Rd over CSX RR near MD 166	0310100	BA-2722	Rolling Rd over CSX RR near MD 166	Arbutus	Baltimore	State	1931	Eligible
Patuxent R. Bridge (Benedict Bridge) (MD 231 over Patuxent R)	0400800	CT-1214	MD 231 over Patuxent R	Bowens/Benedict	Calvert/ Charles	State	1950-1951	Eligible
MD 261 over Fishing Crk	0401100	CT-1187	MD 261	Chesapeake Beach	Calvert	State	1940	Eligible
Sandy Island Bridge (MD 287 over Choptank R)	0500200	CAR-257	MD 287 (Sandtown Rd) over Choptank R	Goldsboro	Caroline	State	1919	Eligible
MD 304 (Ruthsburg Rd) over Long Marsh Ditch	0501800	CAR-303	MD 304 (Ruthsburg Rd) over Long Marsh Ditch	Bridgetown	Caroline	State	(c) 1920	Eligible
Forge Branch Bridge	0501900	CAR-304	MD 480 (Ridgely Rd) over Forge Branch	Greensboro	Caroline	State	1932	Eligible
MD 315 (E. Central Ave) over Marshyhope Crk	0503000	CAR-305	MD 315 (E. Central Ave) over Marshyhope Crk	Federalsburg	Caroline	State	1910/1936	Eligible
MD 86 over Branch of Gunpowder Falls	0601800	CARR-1469	MD 86 over Branch of Gunpowder Falls	Lineboro	Carroll	State	1929	Eligible
MD 97 over Big Pipe Crk	0603100	CARR-1462	MD 97 over Big Pipe Crk	Union Mills	Carroll	State	1934	Eligible
MD 32 over Liberty Reservoir	0604900	CARR-1673	MD 32 over Liberty Reservoir	Finksburg	Carroll	State	1952	Eligible
US 1 over Octoraro Crk	0700300	CE-1480	US 1 over Octoraro Crk	Richardsmere	Cecil	State	1934	Eligible
Northeast Crk Bridge (MD 7C over Northeast Crk.	0700900	CE-1495	MD 7 (Old Philadelphia Rd) over Northeast Crk	Northeast	Cecil	State	1922	Eligible
US 40 (Pulaski Hwy) over Principio Crk	0701400	CE-1496	US 40 (Pulaski Hwy) over Principio Crk	Perryville	Cecil	State	1941	Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
US 222 over Octoraro Crk	0702600	CE-1482	US 222	Kilby Corner	Cecil	State	(c) 1877/ 1930	Eligible
MD 6 (Port Tobacco Rd) over Wards Run	0801300	CH-495	MD 6 (Port Tobacco Rd) over Wards Run	Welcome	Charles	State	1929	Eligible
Brookview Bridge (MD 14 over Marshyhope Crk)	0900100	D-584	MD 14 over Marshyhope Crk	Brookview	Dorchester	State	1931	Eligible
Cambridge Bridge (MD 795 over Cambridge Crk)	0900800	D-707	MD 795 over Cambridge Crk	Cambridge	Dorchester	State	1938	Eligible
US 15B (Catoctin Mountain Hwy) over Flat Run	1000100	F-6-117	US 15B (Catoctin Mountain Hwy) over Flat Run	Emmitsburg	Frederick	State	1927	Eligible
Toms Crk Bridge (US 15B over Toms Crk)	1000200	F-6-118	US 15B (Seton Ave South) over Toms Crk	Emmitsburg	Frederick	State	1923	Eligible
US 15 over B&O RR and Potomac R	1001700	F-2-34	US 15 over B&O RR and Potomac R	Point of Rocks	Frederick	State	1939	Eligible
Green Bridge (MD 17 over Catoctin Crk)	1001800	F-2-37	MD 17 over Catoctin Crk	Middletown	Frederick	State	1934	Eligible
MD 28 over Monocacy R	1002900	F-1-132	MD 28 over Monocacy R	Dickerson	Frederick	State	1931	Eligible
US 40 (Nat’l Pike) over Catoctin Crk	1003000	F-4-115	US 40 (Nat’l Pike) over Catoctin Crk	Myersville	Frederick	State	1936	Eligible
US 40 over Little Catoctin Crk	1003200	F-4-117	US 40 (Nat’l Pike) over Little Catoctin Crk	Myersville	Frederick	State	1936	Eligible
MD 144FA over the Monocacy R	1003803	F-3-205	MD 144FA over the Monocacy R	Frederick	Frederick	State	1955	Eligible
MD 144FA over the Monocacy R	1003804	F-3-251	MD 144FA over the Monocacy R	Frederick	Frederick	State	1942	Eligible
Catoctin Crk Bridge, US 40 Alt over Catoctin Crk	1004000	F-4-26	US 40 Alt (Old Nat'l Pike) over Catoctin Crk	Middletown	Frederick	State	1923	Eligible
MD 77 over Monocacy R	1005500	F-6-23	MD 77 over Monocacy R	Rocky Ridge	Frederick	State	1932	Eligible
MD 180 (Jefferson Pike) over Catoctin Crk	1008200	F-2-95	MD 180 (Jefferson Pike) over Catoctin Crk	Petersville	Frederick	State	1928	Eligible
MD 355 over Monocacy R	1008500	F-7-117	MD 355 (Urbana Pk) over Monocacy R	Frederick	Frederick	State	1930	Eligible
Old US 40 over Little Savage R	1100800	G-I-B-034	Old US 40 over Little Savage R (off of US 40 Alt)	Finzel	Garrett	State	1840	Eligible
MD 42 (Friendsville Hoyes Rd) over Buffalo Run	1101000	G-II-A-374	MD 42 (Friendsville Hoyes Rd) over Buffalo Run	Friendsville	Garrett	State	1930	Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
MD 135 over Savage R	1101800	G-I-E-199	MD 135 over Savage R	Bloomington	Garrett	State	1937	Eligible
US 1 over Susquehanna R/ Conowingo Dam	1200100	HA-1971	US 1 over Susquehanna R/ Conowingo Dam	Conowingo	Harford	State	1927	Eligible
Winters Run Bridge (US 1 Bel Air Rd)	1200400	HA-1984	US 1 Bus (Bel Air Rd) over Winters Run	Bel Air	Harford	State	1930	Eligible
MD 24 over Deer Crk	1201600	HA-1576	MD 24 over Deer Crk	Rocks	Harford	State	1934	Eligible
Priest Ford Rd Bridge	1203300	HA-1579	MD 136 over Deer Crk	Trappe	Harford	State	1931	Eligible
US 40 over Little Patuxent R	1303200	HO-649	US 40 over Little Patuxent R	Ellicott City	Howard	State	1939	Eligible
US 40 over Forest Rd Underpass	1303400	HO-656	US 40 over Forest Rd Underpass	Ellicott City	Howard	State	1936	Eligible
MD 299 over Herring Branch of Sassafras R	1401700	K-682	MD 299 (Sassafras Rd over Herring Branch of Sassafras R	Sassafras	Kent	State	1913	Eligible
MD 299 over Jacobs Crk	1401800	K-681	MD 299 (Massey Rd) over Jacobs Crk	Sassafras	Kent	State	1938	Eligible
Hopewell Bridge (MD 291 over Morgan Crk)	1402200	K-453	MD 291 over Morgan Crk	Hopewell	Kent	State	1934	Eligible
Snell Bridge (MD 108 over Patuxent R)	1500800	M: 15-95	MD 108 (Ashton Rd over Patuxent R)	Ashton	Montgomery	State	1928	Eligible
Sligo Crk Bridge (MD 195 over Sligo Crk)	1503300	M: 37-7	MD 195 (Carroll Ave) over Sligo Crk	Takoma Park	Montgomery	State	1932	Eligible
MD 212 over Indian Crk	1603800	PG: 61-27	MD 212 over Indian Crk	Greenbelt	Prince George’s	State	1937	Eligible
Northwest Branch Bridge (MD 212) over Northwest Bridge	1604200	PG:65-22	MD 212 (Riggs Rd) over Northwest Branch	Takoma Park	Prince George's	State	1932	Eligible
MD 412A (Riverdale Rd) over NE Branch of Anacostia	1606900	PG:68-84	MD 412A (Riverdale Rd) over NE Branch of Anacostia R	Riverdale	Prince George's	State	1931	Eligible
MD 201 (Edmonston Rd) over Beaverdam Crk	1611100	PG:67-6	MD 201 (Edmonston Rd) over Beaverdam Crk	Greenbelt	Prince George's	State	1940	Eligible
MD 18B over Kent Narrows	1700600	QA-542	MD 18B over Kent Narrows	Grasonville	Queen Anne’s	State	1951	Eligible
MD 238 (Maddox Rd) over Burroughs Run	1801800	SM-617	MD 238 (Maddox Rd) over Burroughs Run	Maddox	St. Mary's	State	1929	Eligible
US 40 over Branch of Antietam Crk	2101300	WA-I-730	US 40 over Branch of Antietam Crk	Hagerstown	Washington	State	1941	Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
US 40 WB (Nat'l Pike) over Antietam Crk	2101400	WA-I-842	US 40 WB (Nat'l Pike) over Antietam Crk	Hagerstown	Washington	State	1936	Eligible
US 40 over Landis Spring Branch	2101500	WA-II-1113	US 40 over Landis Spring Branch	Hagerstown	Washington	State	1936	Eligible
US 40 over Beaver Crk	2101600	WA-II-0476	US 40 over Beaver Crk	Wagners Crossroads	Washington	State	1936	Eligible
Funkstown Turnpike Bridge (First Funkstown Bridge)	2101800	WA-I-029	US 40 Alt over Antietam Crk	Funkstown	Washington	State	1823/1931	Eligible
Kline's Mill Bridge (Newcomer's Mill/ US40 Alt Bridge)	2102000	WA-II-042	US 40 Alt over Beaver Crk	Benevola	Washington	State	1840/1948	Eligible
MD 56 (Big Pool Rd) over Little Conococheague Crk	2102300	WA-V-063	MD 56 (Big Pool Rd) over Little Conococheague Crk	Clear Spring	Washington	State	1907	Eligible
Antietam Crk Bridge (MD 64)	2102800	WA-I-843	MD 64 (Jefferson Blvd) over Antietam Crk	Hagerstown	Washington	State	1934	Eligible
MD 68 over Conococheague Crk	2103600	WA-I-020	MD 68 over Conococheague Crk	Williamsport	Washington	State	1829/1984	Eligible
Devil's Backbone Bridge	2103900	WA-II-0017	MD 68 over Beaver Crk	Boonsboro	Washington	State	1824/1979	Eligible
Sandy Hook Bridge	2104100	WA-III-168	US 340 over Potomac R, CSX RR, C&O Canal, Sandy Hook Rd	Sandy Hook	Washington	State	1947	Eligible
Conococheague Crk Bridge	2104200	WA-I-462	MD 494 over Conococheague Crk	Fairview	Washington	State	1932	Eligible
US 522 over Potomac R, CSX RR, and C&O Canal	2104300	WA-VI-053	US 522 over Potomac R, CSX RR, and C&O Canal	Hancock	Washington	State	1939	Eligible
US 522 over MD 144 and Tonoloway Crk	2112400	WA-HAN-349	US 522 over MD 144 and Tonoloway Crk	Hancock	Washington	State	1937	Eligible
US 13 Bus over E. Branch of Wicomico R	2200400	WI 224	US 13 Bus over E. Branch of Wicomico R	Salisbury	Wicomico	State	1937	Eligible
MD 347 over Quantico Crk	2201400	WI-340	MD 347 over Quantico Crk	Quantico	Wicomico	State	1926	Eligible
US 50 WB over Herring Crk	2300604	WO-482	US 50 WB over Herring Crk	Ocean City	Worcester	State	1942	Eligible
Ocean City Bridge (US 50 over Sinepuxent Bay)	2300700	WO-461	US 50 over Sinepuxent R	Ocean City	Worcester	State	1942	Eligible
US 113 over Purnell Branch	2300800	WO-483	US 113 over Purnell Branch	Snow Hill	Worcester	State	1952	Eligible

Table 3. Non-priority Eligible Historic Bridges

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
MD 36 over Jennings Run	0100700	AL-V-B-312	MD 36 over Jennings Run	Mt Savage	Allegany	State	1929	Non-priority Eligible
MD 935 over Georges Creek	0101900	AL-VI-C-327	MD 935 over Georges Creek	Barton	Allegany	State	1932	Non-priority Eligible
MD 51 over Sawpit Run	0104600	AL-II-B-146	MD 51 over Sawpit Run	Town Creek	Allegany	State	1932	Non-priority Eligible
MD 170 over Severn Run	0204400	AA-2119	MD 170 over Severn Run	Odenton	Anne Arundel	State	1936	Non-priority Eligible
MD 25 over George's Run	0301900	BA-2783	MD 25 over George's Run	Hampstead	Baltimore	State	1932	Non-priority Eligible
MD 25 over Jones Falls	0302700	BA-2663	MD 25 over Jones Falls	Timonium	Baltimore	State	1932	Non-priority Eligible
US 40 over Gunpowder Falls	0303500	BA-2720	US 40 over Gunpowder Falls	Kingsville	Baltimore	State	1935	Non-priority Eligible
US 40 over Whitemarsh Run	0303700	BA-2666	US 40 over Whitemarsh Run	White Marsh	Baltimore	State	1935	Non-priority Eligible
MD 150 over MD 700	0309500	BA-2724	MD 150 over MD 700	Middle River	Baltimore	State	1942	Non-priority Eligible
MD 404 Alt over Tuckahoe Crk	0501700	CAR-297	MD 404 Alt over Tuckahoe Crk	Hillsboro	Caroline	State	1915	Non-priority Eligible
MD 31 over Dickerson Run	0600700	CARR-1557	MD 31 over Dickerson Run	New Windsor	Carroll	State	1924	Non-priority Eligible
MD 31 over Sams Crk	0600800	CARR-1468	MD 31 over Sams Crk	New Windsor	Carroll	State	1929	Non-priority Eligible
MD 850 over Talbot Branch	0604200	CARR-1473	MD 850 over Talbot Branch	Franklinville	Carroll	State	1930	Non-priority Eligible
MD 7 over Stoney Run	0700800	CE-1489	MD 7 over Stoney Run	North East	Cecil	State	1931	Non-priority Eligible
MD 272 SB over North East Crk	0703700	CE -1469	MD 272 SB over North East Crk	North East	Cecil	State	1944	Non-priority Eligible
MD 5 SB over Zekiah Swamp	0800200	CH-487	MD 5 SB over Zekiah Swamp Run	Bryantown	Charles	State	1931	Non-priority Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
MD 5 SB over Zekiah Swamp	0800300	CH-488	MD 5 SB over Zekiah Swamp Run	Bryantown	Charles	State	1931	Non-priority Eligible
MD 6 over Nanjemoy Crk	0801500	CH-387	MD 6 over Nanjemoy Crk	Grayton	Charles	State	1922	Non-priority Eligible
MD 224 over Reeders Run	0801800	CH-381	MD 224 over Reeders Run	Chicamuxen	Charles	State	1928	Non-priority Eligible
MD 806A over Little Hunting Crk	1000700	F-6-107	MD 806A over Little Hunting Crk	Thurmont	Frederick	State	1927	Non-priority Eligible
MD 85 over Branch of Monocacy R	1001300	F-1-81	MD 85 over Branch of Monocacy R	Buckeystown	Frederick	State	1929	Non-priority Eligible
MD 28 over Branch of Potomac R (Rocky Fountain Branch)	1001500	F-1-82	MD 28 over Branch of Potomac R (Rocky Fountain Branch)	Point of Rocks	Frederick	State	1937	Non-priority Eligible
US 40 over Branch of Little Catoctin Crk	1003300	F-4-102	US 40 over Branch of Little Catoctin Crk	Myersville	Frederick	State	1936	Non-priority Eligible
US 40 WB over Rock Crk	1003400	F-3-49	US 40 WB over Rock Crk	Frederick	Frederick	State	1936	Non-priority Eligible
MD 75 over Branch of Bennett Crk	1004600	F-7-125	MD 75 over Branch of Bennett Crk	Urbana	Frederick	State	1930	Non-priority Eligible
MD 77 over Owens Crk	1005300	F-6-115	MD 77 over Owens Crk	Rocky Ridge	Frederick	State	1932	Non-priority Eligible
MD 140 over Flat Run	1006200	F-6-111	MD 140 over Flat Run	Emmitsburg	Frederick	State	1910/1932	Non-priority Eligible
MD 140 over Middle Crk	1006300	F-6-112	MD 140 over Middle Crk	Emmitsburg	Frederick	State	1932	Non-priority Eligible
MD 478 over unnamed tributary of Potomac R	1008800	F-2-91	MD 478 over unnamed tributary of Potomac R	Knoxville	Frederick	State	1926	Non-priority Eligible
MD 478 over Branch of the Potomac R	1008900	F-2-92	MD 478 over Branch of the Potomac R	Brunswick	Frederick	State	1925	Non-priority Eligible
MD 17 over Catoctin Crk	1017600	F-4-41	MD 17 over Catoctin Crk	Myersville	Frederick	State	1928	Non-priority Eligible
MD 17 over Catoctin Crk	1017700	F-4-112	MD 17 over Catoctin Crk	Myersville	Frederick	State	1919	Non-priority Eligible
MD 828 over Youghiogheny R	1101100	G-II-A-366	MD 828 over Youghiogheny R	Friendsville	Garrett	State	1932	Non-priority Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
MD 135 over CSX RR	1101600	G-IV-B-271	MD 135 over CSX RR	Altamont	Garrett	State	1930	Non-priority Eligible
MD 136 over Big Branch	1203000	HA-1977	MD 136 over Big Branch	Harkins	Harford	State	1934	Non-priority Eligible
MD 136 over Falling Branch	1203100	HA-1866	MD 136 over Falling Branch	Pylesville	Harford	State	1930	Non-priority Eligible
MD 176 over Deep Run (aka MD 103?)	1304100	HO-650	MD 176 over Deep Run (aka MD 103?)	Dorsey	Howard	State	1937	Non-priority Eligible
MD 291 over Cypress Crk	1401500	K-675	MD 291 over Cypress Crk	Millington	Kent	State	1928	Non-priority Eligible
MD 28 over the Little Monocacy R	1500100	M:12-47	MD 28 over the Little Monocacy R	Dickerson	Montgomery	State	1925	Non-priority Eligible
MD 97 over Hawlings R	1501100	M:23-125	MD 97 over Hawlings R	Sunshine	Montgomery	State	1930	Non-priority Eligible
MD 650 over Hawlings R	1501700	M:23-127	MD 650 over Hawlings R	Ashton	Montgomery	State	1929	Non-priority Eligible
MD 117 over Bucklodge Branch	1501800	M:18-46	MD 117 over Bucklodge Branch	Bucklodge	Montgomery	State	1932	Non-priority Eligible
MD 547 over Rock Crk	1506200	M:31-16	MD 547 over Rock Crk	Kensington	Montgomery	State	1932	Non-priority Eligible
MD 978 over Collington Branch	1604800	PG:74B-21	MD 978 over Collington Branch	Bowie	Prince George’s	State	1929	Non-priority Eligible
MD 382 over Mataponi Crk	1606200	PG:86A-28	MD 382 over Mataponi Crk	Croom	Prince George’s	State	1930	Non-priority Eligible
MD 410 over Sligo Crk	1606700	PG:65-20	MD 410 over Sligo Crk	Takoma Park	Prince George’s	State	1934	Non-priority Eligible
MD 213 over Gravel Run	1702000	QA-480	MD 213 over Gravel Run	Centreville	Queen Anne’s	State	1934	Non-priority Eligible
MD 405 over Southeast Crk	1703300	QA-479	MD 405 over Southeast Crk	Church Hill	Queen Anne’s	State	1933	Non-priority Eligible
MD 456 over Branch of Wye R	1703500	QA-482	MD 456 over Branch of Wye R	Queenstown	Queen Anne’s	State	1924	Non-priority Eligible
MD 6 over Lockes Swamp Crk	1801200	SM-515	MD 6 over Lockes Swamp Crk	Huntersville	St. Mary’s	State	1930	Non-priority Eligible

Name	SHA Bridge No.	MIHP No.	Location	City/Town	County	Owner	Date	Preservation Level
MD 6 over Persimmon Crk	1801300	SM-516	MD 6 over Persimmon Crk	Cremona	St. Mary’s	State	1932	Non-priority Eligible
MD 244 over Poplar Hill Crk	1802400	SM-506	MD 244 over Poplar Hill Crk	Chingville	St. Mary’s	State	1938	Non-priority Eligible
MD 471 over St. Mary’s R	1802900	SM-514	MD 471 over St. Mary’s R	Great Mills	St. Mary’s	State	1932	Non-priority Eligible
MD 303 over Norwich Crk	2001000	T-947	MD 303 over Norwich Crk	Queen Anne	Talbot	State	1928	Non-priority Eligible
MD 662C over Potts Mill Crk	2002200	T-942	MD 662C over Potts Mill Crk	Easton	Talbot	State	1911	Non-priority Eligible
MD 62 over Little Antietam Crk	2102600	WA-I-735	MD 62 over Little Antietam Crk	Leitersburg	Washington	State	1931	Non-priority Eligible
MD 858 over Little Antietam Crk	2104700	WA-III-121	MD 858 over Little Antietam Crk	Rohrersville	Washington	State	1922/1930s	Non-priority Eligible
MD 353 over Burnt Mill Branch	2201800	WI-220	MD 353 over Burnt Mill Branch	Pittsville	Wicomico	State	1934	Non-priority Eligible
MD 354 over Tilghman Race	2301100	WO-489	MD 354 over Tilghman Race	Whiton	Worcester	State	1932	Non-priority Eligible
US 113 SB over Corkers Crk	2302300	WO-486	US 113 SB over Corkers Crk	Snow Hill	Worcester	State	1912/1930	Non-priority Eligible

Part I

Methods and Results

Methods and Results

The Maryland State Highway Administration (SHA) contracted KCI Technologies, Inc. and their subconsultant TranSystems, to develop a comprehensive Historic Bridge Management Plan for SHA's historic bridges. This management plan is a compilation of the project and an explanation of the methodology. The plan describes how the project was completed, and how decisions were made. A summary of the previous studies and discussions of the individual preservation plans, best practice treatments implementing Preservation Briefs from the National Park Service (NPS), as well as a description of the database are included as part of this report.

The project was divided into two phases. Phase I consisted of re-evaluation of the preservation levels previously assigned to 102 SHA-owned bridges. The Phase I studies were summarized in a report presented to SHA in August 2007.

Phase II involved development of guidelines and recommendations to maintain and preserve SHA's historic bridges, including an individual preservation plan for each bridge identified as a priority for preservation and best practice treatments to maintain and preserve the structures. Also as part of Phase II of the project, SHA's existing historic bridge database was modified with the information and results of the Phase I studies and some of the Phase II work. The final component of Phase II included the development and implementation of a training course to inform SHA personnel and local jurisdictions about conservation treatments appropriate for historic bridges.

Also as part of Maryland's Historic Bridge program, 79 concrete beam, concrete slab and metal girder bridges were reevaluated to determine whether they retained sufficient integrity and historic and/or engineering significance to be eligible for listing in the National Register of Historic Places. The reevaluation documentation was submitted to SHA in October 2009.

This report outlines the results of Phases I and II of the project and provides a plan for managing historic bridges owned by SHA that are identified as a priority for preservation. The management plan identifies Maryland's significant historic bridges and provides recommendations and guidance to SHA to preserve and enhance the specific materials and elements of these historic structures. The plan also presents information about applicable federal and state environmental and historic preservation guidelines and regulations as they apply to historic bridges, potential funding sources to maintain and preserve historic bridges, and public involvement opportunities to guide both SHA and local historic bridge owners in the stewardship of their historic bridges.

The preservation plan for each priority bridge, in conjunction with the best practice treatments, provide an outline of regular maintenance and treatment options to preserve the bridge for at least the next two decades, essentially taking the place of environmental and cultural resources studies and development of mitigation measures for these specific bridges.

Previous Studies

SHA prepared a historic context report and surveyed and evaluated their historic bridges across the state around 1995. In Appendix C of the historic context report, the authors detailed the character-defining elements (CDEs) of bridges. They divided the CDEs into three levels:

- Primary—"contribute in a major way to the structure's essential characteristics"
- Secondary—"those with moderate importance…are less crucial to those characteristics"
- Tertiary—"are incidental to the structure's essential characteristics" (C-28)

The CDEs are considered as part of the evaluation of integrity of National Register of Historic Places eligibility.

National Register of Historic Places eligibility determinations for most bridges were previously made in 2001 by SHA and the Maryland Historical Trust (MHT), which serves as the State Historic Preservation Officer (SHPO). The remaining bridges were evaluated and determined eligible as part of individual projects.

Methods

Phase I – Reevaluation

In Phase I of the project, 102 bridges were re-evaluated to recommend which should be a priority for preservation. This phase included three major tasks: research of previous studies, SHA plans, inspection files, and historic background; field survey of the 102 bridges; and evaluation and documentation of each bridge's preservation potential.

Research

The office research consisted of reviewing the existing bridge files and other SHA documents such as the historic context report, Historic Bridge Inventory and Database, Maryland Inventory of Historic Places (MIHP) Forms, "Highway Needs" List, Consolidated Transportation Program (CTP) List, Bridge Inspection and Remedial Engineering Division (BIRE) Worklist, bridge plans, inspection files, and Structure Inventory and Appraisal (SI&A) database. This included obtaining the following information for each of the 102 bridges:

- Historical significance, bridge type, age, and design features.
- General condition, and past repairs or alterations.
- Determination of the future repairs, rehabilitations, or other work that are currently planned.
- Current and future traffic volumes, and planned development nearby.
- Structural capacity and geometric appraisal.
- Hydraulic capacity and scour potential.
- Location within an historic district, heritage area, or park, or on the National Road, scenic byway, or scenic river.

The inspection frequency for any bridges on an inspection cycle that is more frequent than the standard, federally-mandated cycle of every two years was noted. Additionally, where the safety of a historic bridge was potentially an issue, accident information was provided.

Field Survey

Upon completion of the office research outlined above, multidisciplinary field teams including an engineer and a historian made a site visit to each of the 102 bridges to gather the following:

- Information on integrity, such as observations of current conditions, previous repairs and alterations, and current setting and use.
- Photographs including general photos, defect photos, repair photos, and photos of character-defining elements (CDE) and other details.
- Determination of any future repairs and rehabilitations that are likely to be required or will be needed to maintain the bridge as an historic bridge over the next 20 years.

Evaluation

Using the information gathered from the office and field research, the engineers and historians assessed each of the 102 bridges using these considerations:

- Whether the bridge retained integrity and its character-defining elements;
- How it fits into its current setting;
- Whether it is on a scenic byway or river, in a heritage area, or in a historic district;
- Its traffic volume and accident history;
- Its condition, likelihood of replacement, and ease of sensitive rehabilitation;
- How it compares to other bridges of its type within the state.

The recommended preservation levels were provided in an individual report for each bridge. These reports were collected into the Phase I Re-Evaluation of Preservation Levels Report (August 2007). SHA selected 17 bridges to be included as a preservation priority. These bridges are listed in Table 4 below.

Table 4. Priority-Level Historic Bridges on the Maryland Highway System

County	Bridge No.	Route	Crossing	MIHP No.	Bridge Type
Allegany	0103500	MD 144AE	Town Crk	AL-II-A-149	Reinforced Concrete Arch, Filled
Allegany	0104800	MD 51	C&O Canal	AL-I-B-075	Steel Warren Pony Truss
Allegany	0106600	MD 942	Potomac R	AL-IV-A-153	Steel Tied Thru-Arch
Anne Arundel	0205400	MD 214	Patuxent R	AA-761	Steel Parker Thru-Truss
Baltimore	0310500	MD 463	Little Falls	BA-593	Stone Arch
Baltimore	0310900	US 40	Patapsco R	BA-2557	Reinforced Concrete Arch, Open-Spandrel
Frederick	1003100	US 40	Middle Crk	F-4-116	Reinforced Concrete Arch, Filled (Stone Façade)
Garrett	1100700	US 40 Alt	Casselman R	G-II-C-101	Steel Pratt Thru-Truss
Howard	1304600	Old MD 32	Patapsco R, CSX	HO-673	Aluminum Box Girder
Talbot	2002300	MD 331	Choptank R	T-487	Movable Swing Span, Steel Subdivided Warren Thru-Truss
Washington	2100400	MD 845A	Little Antietam Crk	WA-II-1125	Reinforced Concrete Arch, Filled
Washington	2101000	US 40	Licking Crk	WA-V-416	Steel Wichert Girder
Washington	2101200	US 40	Conococheague Crk	WA-V-211	Reinforced Concrete Arch, Open-Spandrel
Washington	2103800	MD 68	Antietam Crk	WA-II-009	Stone Arch
Wicomico	2200900	MD 991	Wicomico R	WI-117	Movable Bascule, Double-Leaf Trunnion
Worcester	2300200	MD 12	Pocomoke R	WO-178	Movable Bascule, Single-Leaf Trunnion
Worcester	2300400	US 13 Bus	Pocomoke R	WO-177	Movable Bascule, Double-Leaf Trunnion

Phase II – Management Plan

Phase II of the project gathered the information from Phase I to develop a management plan on how to best preserve the 17 priority-level state-owned bridges. Phase II also includes the development of best practice treatments addressing specific materials, bridge types, and features related to these 17 state-owned bridges; development of a preservation plan for each priority-level bridge; an update of the database, and development and implementation of training for engineers, cultural resources staff and maintenance personnel. Included in the management plan are environmental requirements including applicable environmental laws, federal and state guidelines, funding opportunities for historic bridges, public involvement opportunities, and a brief discussion on non-SHA owned historic bridges in Maryland.

Preservation Plans

In deciding which bridges would be priority-level bridges, several criteria were considered:

- was the bridge a part of early state transportation legislation
- was the average daily traffic volume low
- was the bridge located along a scenic by-way
- was the bridge located within a heritage area
- was the bridge not planned for replacement within the next 20 years
- was the bridge used for local traffic only (e.g. the bridge was located on old U.S. 40) and has since been bypassed with a modern bridge
- was the bridge a good example of its type with strong integrity
- did the bridge have a high degree of preservation potential

Each preservation plan includes basic information on the bridge such as type, year constructed, number of spans, length and width, as well as information regarding each bridge's basic structural and historical elements. Each preservation plan also provides recommendations for regular maintenance and specific repairs and activities intended to preserve the bridge's historic integrity while supporting its continued use as a safe and functional structure for the next 20 years.

Each preservation plan consists of the recommended (or currently planned) future repairs or rehabilitation that will be needed in the short-term, as well as over the next few decades, in order to maintain the bridge as a priority-level bridge in its historic form. The preservation plans cross-reference the best practice treatments for bridge type and materials as appropriate.

Reevaluation of Bridges

An additional component of SHA's historic bridge program included the reevaluation in 2008 of 79 concrete beam, concrete slab and metal girder bridges that had been determined eligible for listing in the National Register of Historic Places in 2001 as part of the earlier historic bridge survey. Research was conducted to gather information and provide additional analysis of each bridge's integrity and significance to supplement the original NRHP evaluation. At SHA's Office of Structures (OOS), architectural historians and engineers reviewed Bridge Inspection Reports (BIR), repair history files, SHA Bridge Plans, the Bridge Inspection and Remedial Engineering (BIRE) Worklist, and Structure Inventory and Appraisal (SI&A) reports. An architectural historian visited each bridge to examine and document current conditions with field notes, digital photography, and black and white photography.

For evaluation of the bridge's historic significance and NRHP eligibility, the architectural historians consulted the original MIHP form, *Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report*, *A Context for Common Historic Bridge Types, NCHRP Project 25-25, Task 15*, and "NR Bulletin 15: How to Apply the National Register Criteria for Evaluation." Each bridge was documented and reevaluated on a Maryland Inventory of Historic Places Determination of Eligibility (DOE) form accompanied by black and white photographs.

MHT reviewed the DOE forms in 2009 and concurred that nine (9) of the bridges remained NR eligible, nine (9) of the bridges had lost integrity and were no longer NR eligible, and the remaining 60 bridges were considered NR eligible and placed into a category called Non-priority Historic Bridges. In March 2012, previously prepared documentation for each of the 60 Non-priority Historic Bridges was converted into the MIHP Addendum Sheet format and resubmitted to MHT to fulfill mitigation requirements included the PA.

Programmatic Agreement

A draft Programmatic Agreement (PA) that outlines mitigation and treatment of Maryland's historic highway bridges has been prepared. The PA has been reviewed by the Maryland Historical Trust (MHT), SHA, the Federal Highway Administration (FHWA), and the Advisory Council on Historic Preservation (ACHP), and currently is in draft form as of March 2012.

The PA outlines the basis for the SHA's administration of its Historic Highway Bridge Program and the FHWA and MD SHPO's involvement with the Program and individual bridge projects under the Program. Three treatment categories for SHA's owned and managed historic bridges include:

1. Preservation Priority Historic Bridges: historic bridges designated for indefinite preservation
2. Eligible Historic Bridges: historic bridges that will be maintained and preserved, when feasible, and are subject to streamlined review process
3. Non-Priority Historic Bridges: historic bridges that do not require preservation in place and are subject to a streamlined review process and standard mitigation treatments.

The PA provides stipulations for the appropriate management, coordination, and corresponding review processes for historic bridges within each of the three treatment categories. This allows the review procedures to be streamlined and provides measures for bridge stewardship and outreach efforts when resources allow.

Best Practice Treatments

SHA's priority-level bridges include stone, concrete and steel arch, pony and thru steel trusses, aluminum girders and moveable bridges. The Maryland Best Maintenance and Conservation Practices for Older Bridge Types is a guide to best practices for conserving material and keeping steel and masonry bridges in service. The guidance applies to all of Maryland's historic bridges and should be consulted when maintaining or repairing a National Register of Historic Places listed or eligible bridge regardless of whether it is a preservation priority, eligible, or non-priority eligible structure.

The best practice treatments will serve as general guidelines for engineers, historians, contractors, and maintenance personnel in designing and performing repairs, rehabilitations, treatments, and other actions that have been deemed as appropriate to preserve bridges in the study population of each bridge type/material intact. The treatment guidelines include:

- Best Practice Maintenance Treatments Common to All Bridge Types
- Reinforced Concrete Conservation and Repair
- Addressing Moisture Penetration in Stone and Reinforced Concrete Arch Bridges
- Repointing Stone Masonry – Including Stone Veneer
- Protecting Steel from Rust/Corrosion
- Strengthening of Steel Bridges/Replacement of Component Members
- Repair of Damaged Steel Bridge Components/Members
- Appropriate Railing Treatments

The best practice treatments are included at the end of this document.

Database

The Historic Bridge Database was modified to include additional useful data-fields and to be more user-friendly. Preconfigured queries and quick links to photos and bridge plans were incorporated into the updated database.

Environmental Compliance, Funding Opportunities, and Public Involvement

In establishing a management plan for each of the priority-level bridges, certain historic preservation and environmental legislative guidelines must be adhered to such as Section 106 of the National Historic Preservation Act, National Environmental Policy Act (NEPA) and Section 4(f) of the US Department of Transportation Act. Funding sources for rehabilitation are available and some specific programs are outlined in this section. Guidelines for public outreach also are an integral part of any transportation improvement project and are usually undertaken in conjunction with requirements for the federal laws described below.

Historic Bridges not Owned by SHA

While this report was developed for SHA, it is recognized that many historic bridges within the state are not owned by SHA. These bridges may include:

- Privately owned bridges by both residents and corporations (e.g. railroad companies)
- City-owned bridges
- County-owned bridges
- Federally-owned bridges
- Bridges owned by other state agencies (such as the state tolls authority - MdTA)

Although this report acknowledges the existence of these historic bridges, this report does not and cannot take jurisdiction and mandate use of this management plan for those bridges not owned by SHA. SHA encourages county Department of Public Works (DPW) and other state agencies to incorporate these treatments outlined in this document into their plans for maintaining and preserving historic bridges under their ownership.

Historic Preservation and Environmental Requirements

If a bridge project requires a federal action (money or permitting) the project would require review under one or more of the environmental and cultural resource laws outlined below. Even if the Federal Highway Administration (FHWA) is not providing funding for a project, agencies such as Maryland's Department of Natural Resources (DNR) and the United States Army Corp of Engineers (USCOE) often require permits for bridge projects.

Two important laws related to historic preservation are Section 106 of the National Historic Preservation Act (NHPA) of 1966 and Section 4(f) of the U.S. Department of Transportation Act of 1966. These two laws assist in the preservation of historic resources at the planning stage and consider resources of national significance, as well as those important at the local and state levels. The National Environmental Policy Act (NEPA) of 1969 also considers impacts to historic properties in the context of the natural, social and cultural environment. These three federal laws are often implemented together and studies for each are often interrelated. Other applicable legislation that assists historic preservation within the state of Maryland is the Maryland Historic Trust Act of 1985 as amended and the State Finance and Procurement Article §§ 5A-325 and 5A-326 of the Annotated Code of Maryland. Coordination should be undertaken with SHA's environmental and cultural resources staff to complete the appropriate studies and documentation to fulfill the requirements of Section 106, Section 4(f), NEPA, and Maryland's historic preservation laws.

Section 106

Section 106 of the National Historic Preservation Act of 1966, as amended, (Public Law 89-665; 16 U.S.C. 470 et seq.) requires that the federal agency consider the effect of its undertaking/project on resources listed in or determined eligible for listing in the NRHP and provide those concerned with the opportunity to comment. The full text of the NRHP can be found at http://www.achp.gov/docs/nhpa%202008-final.pdf.

Guidelines for the evaluation of historic properties are set forth in the regulations of the Advisory Council of Historic Preservation (ACHP) at 36 CFR Part 800. The full text of the ACHP guidelines can be found at http://www.achp.gov/regs-rev04.pdf.

The guidelines define an effect on an historic property as an alteration to the characteristics of the historic property that qualify it for inclusion in or eligibility for listing in the NRHP [36 CFR § 800.16(i)]. An adverse effect is defined in the guidelines as an alteration of

> …any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. [36 C.F.R. § 800.5(a)(1)]

Adverse effects on historic bridges could include:

- Physical destruction of or damage to all or part of the bridge;
- Alteration of the bridge, including restoration, rehabilitation, repair, maintenance, stabilization, and hazardous material remediation that is not consistent with the Secretary's Standards for the Treatment of Historic Properties (36 CFR Part 68) and applicable guidelines;
- Removal of the bridge from its historic location;
- Change in the character of the bridge's use or of physical features within the bridge's setting that contribute to the historical significance;
- Neglect of the bridge which results in its deterioration,
- Transfer, lease or sale of the bridge out of federal ownership or control without adequate and legally enforceable restrictions or conditions to ensure long-term preservation of the bridge's historic significance.

Section 4(f)

Section 4(f) of the U.S. Department of Transportation Act of 1966, as amended, and Section 6009(a) of the 2005 transportation authorization and funding bill, Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), apply only to projects that require involvement by the U.S. DOT, which includes the Federal Highway Administration (FHWA). FHWA issued a final rule on Section 4(f) on March 12, 2008 and the regulation was moved to 23 C.F.R. 774. Information about Section 4(f) along with links to the laws can be found at the FHWA Environment website http://www.environment.fhwa.dot.gov/4f/index.asp. Additional information can be found at SHA's Section 4(f) website http://www.section4f.com/home.htm.

For historic bridges, these laws require that FHWA consider whether there are alternatives, such as rehabilitation or relocation, that do not require the use of a historic bridge, and that the project should include planning to minimize harm to the bridge. Compliance with these laws will require coordination with SHA environmental, cultural resources and engineering staff to develop and consider alternatives and prepare the appropriate documentation.

NEPA

The National Environmental Policy Act of 1969 (NEPA), as amended (42 USC § 4321 et seq.) considers the impacts to historic resources throughout the project through the evaluation of project needs, evaluation of alternatives, and detailed studies. To help streamline the project, NEPA should be integrated with the Section 106. The full text of NEPA can be found at http://ceq.hss.doe.gov/nepa/regs/nepa/nepaeqia.htm.

Maryland Historic Trust Act of 1985 and the State Finance and Procurement Article §§ 5A-325 and 5A-326 of the Annotated Code of Maryland

Maryland's legislation supports the NHPA of 1966 and further details the Section 106 process within the state. Article §§ 5A-325 requires departments within the state to consult with the Maryland Historical Trust (the State Historic Preservation Office) on any state-financed capital projects that own or control properties. These departments must determine their project's effects on these properties that 50 years of age or older. Article §§ 5A-326 outlines the protection and use of historic properties. The full text of the statute can be found at http://mht.maryland.gov/documents/PDF/MHT_Statute.pdf.

Federal and State Guidelines

In preparing treatment plans for rehabilitation for potential grant programs, the Secretary of Interior has established guidelines that must be followed. For bridges, these would be beneficial for maintaining the integrity of primary CDEs. State historic contexts assist in placing the bridge in its historic context and providing information about materials and techniques that were used to construct the bridges.

Secretary of Interior's Standards for Rehabilitation

The Secretary of Interior's Standards for Rehabilitation are codified in 36 CFR Part 67 and were developed to guide preservationists and planners for Federal tax credit projects and other government grant programs. The Secretary of Interior's Standards, in conjunction with the Best Practice Treatments developed for Maryland's historic bridges as part of this Management Plan, provide guidance for rehabilitation, repair and maintenance specifically for historic properties (http://www.nps.gov/tps/standards/rehabilitation/rehab/index.htm).

Historic Context Reports

SHA has four historic contexts that apply specifically to historic bridges:

- *Historic Highway Bridges in Maryland: 1631-1960, Historic Context Report*

  The "Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report" examines the history of bridge building from the colonial period to the recent past. Ten types of construction (arch, beam, cantilever, girder, movable, rigid frame, slab, suspension, timber and truss) and four types of materials (wood, stone, concrete and metal) characterize Maryland's bridges. The context provides an overview and history of road, bridge and highway development; a discussion of government agencies which controlled the roads and bridges; images and three appendices which contain a timetable; list of bridge designers who were active in Maryland; and CDEs for each bridge type. SHA uses this context to compile its historic bridge inventory and to evaluate each bridge for inclusion in the National Register. Others can use this context to assess the historical significance of a bridge. The type groupings allow a reviewer to compare a resource against a similar structure in the state or a county.

- *Small Structures on Maryland's Roadway's, Historic Context Report*

  The "Small Structures on Maryland's Roadways, Historic Context Report" contains an historical overview of the development of Maryland's roadway system, focusing on small roadway structures less than twenty feet/ 20-feet long; a discussion of the types of small structures found on Maryland's roadways; and guidance for assessing

  the state's small structures for eligibility for inclusion in the National Register. These structures may resemble a bridge, but are less than twenty feet long. The early nineteenth century is associated with early turnpikes and the National Road. The period from 1912 to 1933 is associated with the Maryland State Roads Commission's development of "Standard Plans" which allowed easy construction of concrete structures over almost any body of water in the state. The state stopped using the standard plans in 1933, which concludes the period of significance for many twentieth century small structures.

Links to these two historic contexts can be found at the Cultural Resources page of SHA's website at http://sha.md.gov/index.aspx?PageId=729.

Two other Maryland bridge contexts have been recently completed:

- "Tomorrow's Roads Today" Expressway Construction in Maryland, 1948-1965

  This historic context study and the companion piece by the URS Corporation, *Phase II State Historic Bridge Context & Inventory of Modern Bridges, Survey Report and Assessments of Significance,* Vols. I, II, and III (2004) address SHA's efforts to identify, evaluate and assess eligibility of 286 bridges built between 1948 and 1965 on Maryland highways. SHA sought to streamline the review process while complying with Section 106 of the National Historic Preservation Act of 1966, as amended and its implementing regulations at 36 CFR Part 800 by identifying and evaluating bridges that were built between 1948 and 1965 on all Maryland state highways (3).

- *Historic Context of Maryland Highway Bridges Built Between 1948 and 1960*

  An updated and expanded historic context from the *Historic Highway Bridges in Maryland: 1631-1960 Historic Context* (Paula Spero & Associates and Louis Berger & Associates, 1995) was prepared for the Maryland State Highway Association (SHA) by URS Corporation in 2011. As the Executive Summary states "the expanded context was to develop more fully the historic context for bridges built in Maryland from the 1948-1960 period to reflect the technological innovations in bridge design and construction from this period; to establish criteria for the evaluation of the significance and integrity of 1948-1960 highway bridges in Maryland for their eligibility for listing in the National Register for Historic Places (NRHP); to document and record 21 highway bridges in Maryland from the 1948-1960 period representing 12 different bridge types; and to apply this criteria in the evaluation of the 21 surveyed highway bridges for their NRHP-eligibility" (i).

A Context for Common Historic Bridge Types, a broad historic context that covers bridges built in the United States through 1955, was produced under the National Cooperative Highway Research Program, Project 25-25, Task 15 (October 2005). As stated in the Abstract, "[the study] is intended to provide assistance to practitioners with assessing the historic significance or bridge types within the context of the United States…as well as providing an assessment of the technological and historical significance of the individual types" (p. iv). The report is available online at http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(15)_FR.pdf.

Funding Opportunities for Historic Bridges

Funding for historic bridges is available through both public and private sources. Most money is available through programs sponsored by the Federal Highway Administration and requires a matching grant of usually 20 percent. Private money is partially given through federally sponsored organizations such as Save America's Treasures. Grants also may be available through the SHPO and other state and local agencies to help preserve historic bridges.

Transportation Enhancement Program

The Transportation Enhancement Program (TEP) is sponsored by the Federal Highway Administration under 23 U.S.C. §101(a)(35). This program provides 12 possible activities for funding for bridge-related projects. Typically the applicant is responsible for a percentage of the grant. Additional information about the federal Transportation Enhancement Program can be found at http://www.fhwa.dot.gov/environment/te/index.htm.

As part of the federal program, SHA supports and administers the TEP in Maryland. Project sponsors must provide a match of at least 50% of a project's total costs, and 20% of the match must include a 20% non-federal cash match which applies to the costs of reimbursable activities. Additional information and guidelines regarding Maryland's TEP program can be found at http://www.marylandroads.com and follow the links under "Environment and Community/ Community Improvement/Transportation Enhancement Program (TEP)."

Highway Bridge Replacement and Rehabilitation Program

The Highway Bridge Replacement and Rehabilitation Program (HBRRP) is sponsored by the Federal Highway Administration. The program requires each state to complete a historic bridge inventory and market those historic bridges that face demolition. If a suitable location and new owner are found, funds equal to the amount it would cost to demolish the bridge would be available under this program to move the structure. Further information about the HBRRP, other FHWA historic bridge programs and links to additional historic bridge resources can be found at http://environment.fhwa.dot.gov/histpres/bridges.asp.

Save America's Treasures

Since its founding in 1998 through a joint effort of the White House, the National Park Service, and the National Trust for Historic Preservation, Save America's Treasures has allocated over $320 million dollars in preserving historic resources important both locally and nationally in America's history. Grants are awarded annually through public/private funds. Further information about the Save America's Treasures program can be found at http://www.saveamericastreasures.org/.

National Historic Covered Bridge Preservation Program

The National Historic Covered Bridge Preservation Program (NHCBPP) was part of the TEA-21 legislation passed in 1998 and provides funding to help preserve covered bridges that are either eligible or listed on the National Register. Further information about the NHCBPP can be found at http://www.fhwa.dot.gov/bridge/covered.cfm.

Public Involvement Opportunities

When a bridge project is reviewed under Section 106 of the NHPA or under NEPA, the public is afforded the opportunity to participate and provide comments as part of the public involvement components of the legislation. Under Section 106, consulting parties, which generally include the State Historic Preservation Officer (SHPO) and local and regional historic preservation groups, review and comment on documents and recommendations prepared as part of the Section 106 studies. Consulting parties also help develop mitigation measures for projects where resources are adversely affected. Under NEPA, SHA typically holds public meetings or plans displays, where the public is invited and encouraged to comment on proposed project plans, engineering alternatives and mitigation measures.

Other public involvement opportunities may include engaging local volunteers and grass-roots campaigns, as communities are often the first to champion their local threatened historic sites. Educating the public through Boy Scout projects, school projects, and university projects can also help preserve historic bridges and can provide local manpower for those bridges where simple tasks, such as removal of debris, etc. is required. National, state and regional groups devoted to historic bridges, such as the Historic Bridge Foundation and the Historic Bridge Alliance, also provide guidance and ideas for educating the public about preserving historic bridges in their communities.

Bibliography

A Citizen's Guide to the NEPA. Revised January 2005.
http://ceq.hss.doe.gov/nepa/Citizens_Guide_Dec07.pdf. Accessed April 2, 2012.

Aesthetic Bridges Users Guide. August 1993, revised January 2005.
http://www.roads.maryland.gov/OBD/oos-aesthetics-guide.pdf. Accessed April 3, 2012.

Protecting Historic Properties: A Citizen's Guide to Section 106 Review.
http://www.achp.gov/citizensguide.html. Accessed April 2, 2012.

FHWA Environmental Toolkit. http://www.environment.fhwa.dot.gov/histpres/bridges.asp#addl. Accessed April 2, 2012.

National Historic Covered Bridge Preservation Program.
http://www.fhwa.dot.gov/bridge/covered.cfm. Accessed April 2, 2012.

National Transportation Enhancements Clearinghouse. http://www.enhancements.org/index.asp. Accessed April 2, 2012.

Save America's Treasures. http://www.saveamericastreasures.org/. Accessed April 2, 2012.

Secretary of Interior's Standards for the Treatment of Historic Properties, 1995.
http://www.nps.gov/history/local-law/arch_stnds_8_2.htm. Accessed April 2, 2012.

Preservation Plans for Priority Level Bridges

Preservation Plans for Priority Bridges

SHA Bridge No. 0103500
MD 144AE over Town Creek

Flintstone, Allegany County, MD
MIHP No. AL-II-A-149

Bridge Type: Closed-Spandrel, Filled, Reinforced Concrete Arch

Year Built: 1925

No. of Spans: 1

Total Length: 73'-0"

Roadway Width: 24'-0"

NRHP Eligibility: Criteria A and C, as a significant example of concrete arch construction during the upgrading of the National Pike.

Primary CDEs: Arch barrel, spandrel walls, and balustrades.

Other Comments: The bridge is on the National Road Scenic Byway on this nearly abandoned alignment (MD 144AE) of the original National Pike between Baltimore and Cumberland. It is a parallel alignment to the mainline portion of the current National Pike (MD 144).

This bridge is currently in satisfactory condition and carries relatively little traffic (ADT of 300 in 2002). The stone masonry portions of the wingwalls were coated with shotcrete in the 1980s.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines.
- Repair the concrete balustrades and spandrel walls, particularly along the interfaces between the spandrel walls and arch barrel. Other areas on the bridge may require similar concrete repairs.
- If the balustrades require total replacement, they should be rebuilt to resemble the original balustrades. State and federal requirements to upgrade the new balustrades to current highway traffic-barrier standards should be investigated, using the AASHTO guidance available for very low volume roads, and also considering the relatively low prevailing speeds and favorable roadway alignment.

- Replace the bituminous wearing surface. The existing wearing surface should be removed, rather than paved over, so that no additional dead load is added to the bridge. As part of the wearing surface replacement, a waterproof membrane should be installed beneath the new pavement, as well as an adequate drainage system along the curbs, to move water and de-icing salts off of the bridge.

- If a more major rehabilitation is needed beyond replacement of the wearing surface, then an acceptable treatment involves the removal of all or portions of the fill material over the arch, placing a waterproof membrane along the top of the exposed barrel, and replacing the fill with an engineered backfill. Adequate drainage should be provided, as above, and another waterproof membrane should be placed on top of the new fill prior to placing the new wearing surface.

- As the shotcrete on the wingwalls begins to fail, the loose portions of shotcrete should be removed and the stone masonry restored by repointing as needed. This may need to be done on a periodic basis, as the shotcrete deteriorates over time. It is not recommended to forcibly remove the shotcrete all at once, as this may damage the underlying stone masonry.

- As the wingwalls are restored, the plastic drain pipes in the shotcreted areas should be removed, replaced, or otherwise made more inconspicuous, while providing for adequate drainage behind the stone masonry.

- If initial movements are detected in the wingwalls, they may be stabilized by placing tie-back rods through the face of the wingwall and into the backfill. The tie-back anchorages can be countersunk on the face of each wingwall, and then covered with a non-shrink grout. However, if the movements are significant, the wingwall should be replaced in-kind.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this rural location with a very low traffic volume, little chance of future development in the vicinity of the bridge, and the adjacent parallel roadways.

- This bridge has already been bypassed twice in the past with the parallel alignments of MD 144 and I-68. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 3 – Addressing Moisture Penetration in Stone and Reinforced Concreted Arches
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 0104800
MD 51 over C&O Canal

Allegany County, MD
(near Paw Paw, WV)
MIHP No. AL-I-C-075

Bridge Type: Steel Sub-Divided Warren Camelback Pony Truss

Year Built: 1932

No. of Spans: 1

Total Length: 89'-0"

Roadway Width: 27'-0"

NRHP Eligibility: Criteria A and C, as a good example of pony truss construction during the Good Roads Movement in the 1930s.

Primary CDEs: Steel trusses, steel floorbeams, and concrete abutments.

Other Comments: The bridge is on the C&O Canal Scenic Byway and is within the C&O Canal National Historical Park. It crosses over the currently dry canal and tow-path. This bridge is currently in fair to satisfactory condition and carries an ADT of approximately 2,000. The bridge is considered fracture-critical.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation. Also, maintain the vegetation beneath the bridge.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines, truss members, and abutment seats.
- Repaint the superstructure steel.
- Repair the general deterioration (spalls and delaminations) in the concrete abutments and wingwalls.
- Repair the large vertical crack in the north abutment.
- Replace secondary structural members as needed. Repair deteriorated truss members by adding new plates or shapes. Deteriorated rivets can be replaced with high-strength bolts.
- Install roadway splash-shields along both trusses.

- Replace the existing concrete deck, including curbs, in its entirety. A reliable roadway joint system should be included at each end of the deck. A structurally and functionally adequate, yet context sensitive, traffic barrier should be incorporated into any deck replacement project.

- If additional live load capacity becomes necessary, the member(s) governing the bridge's capacity may be addressed by adding auxiliary members carefully detailed and positioned so as not to detract from the scale of the bridge or the make-up of the connections.

- Because of the construction type of this bridge, moving it to another location is a feasible preservation option if faced with demolition.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this rural location with a relatively low traffic volume.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 0106600
The "Blue Bridge"
MD 942 over Potomac River
(Johnson St. / Bridge Ave.)

Cumberland, Allegany County, MD and Ridgeley, WV
MIHP No. AL-IV-A-153

Bridge Type: Steel Tied Arch

Year Built: 1955

No. of Spans: 2

Total Length: 315'-0"

Roadway Width: 28'-0"

NRHP Eligibility: Criterion C, as a rare example of steel tied-arch construction in Maryland.

Primary CDEs: Steel arches, suspenders, and ties, and concrete pier and abutments.

Other Comments: This bridge is considered a local landmark, and is located adjacent to the Canal Place Heritage Area in downtown Cumberland, which is a "Preserve America" community. The bridge is also located near the western termini of the C&O Canal Scenic Byway and the C&O Canal National Historical Park.

This bridge is considered fracture-critical. The bridge is currently in satisfactory condition and carries an ADT of approximately 1,000. The bridge deck was rehabilitated in 1995, which included replacement of the small portions of steel open-grid deck along each gutterline with concrete. The rehabilitation also included removal of the steel curb stringers, addition of exterior steel stringers under the new portions of deck, addition of concrete curbs, in-kind replacement of the concrete sidewalks, installation of new scupper drains, installation of new utility supports under the sidewalks, and a complete repainting of the steel superstructure.

Right-of-Way: Responsibility for this bridge is shared with West Virginia. MD SHA inspects and maintains the bridge; WV DOH shares these costs.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines, sidewalks, and pier and abutment seats.
- Periodically remove debris from the river.

- Repair general deterioration (spalls and delaminations) in the concrete pier, abutments, and wingwalls as required.

- Replace missing pigeon screens throughout the bridge, and install additional screens as needed.

- Clean pigeon droppings from throughout the bridge by power-washing on a regular cycle.

- Repaint the superstructure steel.

- Replace secondary structural members as needed. Repair deteriorated superstructure members by adding new plates or shapes. Deteriorated rivets can be replaced with high-strength bolts.

- Install roadway splash-shields along both bridge railings.

- Replace the bituminous wearing surface. The existing wearing surface should be removed, rather than paved over, so that no additional dead load is added to the bridge.

- Replace the existing concrete deck, including curbs and sidewalks, in its entirety. A reliable roadway joint system should be included at the end of each span.

- Install an appropriate traffic barrier along each curbline to separate vehicular and pedestrian traffic.

- Replace or supplement the existing bridge railings along each sidewalk with fencing or additional railing to meet current pedestrian railing requirements, but to also fit the scale of the bridge.

- If additional live load capacity becomes necessary, the member(s) governing the bridge's capacity may be addressed by adding auxiliary members carefully detailed and positioned so as not to detract from the scale of the bridge or the make-up of the connections.

- Alteration of this bridge may be a viable preservation option if faced with demolition, which is not an acceptable option.

- Moving this bridge to another location is also a feasible preservation option if faced with demolition. However, moving the bridge would be very difficult because of the large scale of this bridge. Likewise, widening is possible and acceptable, but would be extremely difficult.

Applicable Best Practice Treatments:
- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 0205400
MD 214 over Patuxent River

Davidsonville, Anne Arundel &
Prince Georges Counties, MD
MIHP No. AA-761

Bridge Type: Steel Parker Through Truss

Year Built: 1935

No. of Spans: 1

Total Length: 200'-0"

Roadway Width: 30'-0"

NRHP Eligibility: Criterion A for its association with continuing advances in metal truss technology and fabrication in the early 20th century, and Criterion C as a good example of a Parker through truss.

Primary CDEs: Steel trusses, sway-bracing portals, floorbeams, and concrete abutments and wingwalls.

Other Comments: The bridge was built as part of the Good Roads Movement and was fabricated by the Roanoke Iron and Bridge Works. It is located along the Patuxent Scenic River. Five sway-bracing members were replaced in-kind, due to accident damage, in 2001.

This bridge is currently in fair condition and carries an ADT of approximately 12,000. The vertical clearance available to vehicles is just under 16'-0". The bridge is considered fracture-critical, and is on an increased (yearly) inspection cycle because of substandard load-carrying capacity.

A deck replacement was recently performed on this bridge. The rehabilitation also included the replacement of several steel members in-kind, new bridge railings, installation of fiberglass splash-shields behind the railings, and total repainting of the bridge.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation. Also, periodically cut back the vegetation beneath the bridge and overhanging the sides of the bridge.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines, truss members, and abutment seats.
- Periodically remove graffiti from the abutment areas.
- Repaint the superstructure steel.

- Repair general deterioration (spalls and delaminations) in the concrete abutments and wingwalls.

- Although a bridge rehabilitation was recently completed, additional steel deterioration may occur in the future. If so, replace secondary structural members as needed. Repair deteriorated truss members by adding new plates or shapes. Deteriorated rivets can be replaced with high-strength bolts.

- If additional live load capacity becomes necessary, the member(s) governing the bridge's capacity may be addressed by adding auxiliary members carefully detailed and positioned so as not to detract from the scale of the bridge or the make-up of the connections.

- Alteration or widening of this bridge may be a viable preservation option if faced with demolition, which is not an acceptable option.

- Moving this bridge to another location is also a feasible preservation option if faced with demolition. However, moving the bridge would be fairly difficult because of the large size of this truss.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 0310500
MD 463 over Little Falls
(Old York Road)

Parkton, Baltimore County, MD
MIHP No. BA-593

Bridge Type: Stone Masonry Arch

Year Built: 1809

No. of Spans: 2

Total Length: 62'-0"

Roadway Width: 20'-0"

NRHP Eligibility: Criterion A for its association with transportation and commerce on an early turnpike, and Criterion C as a relatively well-preserved example of a stone arch bridge.

Primary CDEs: Arch barrels, spandrel walls, parapets, pier, and wingwalls.

Other Comments: This bridge is particularly significant as the oldest known stone arch bridge still in service in Maryland. It was one of five bridges built along the Baltimore and York-Town Turnpike. The former Parkton Hotel, which is listed on the National Register of Historic Places, sits at the southwest corner of the bridge. The hotel was built in the 1850s as a stop-over point for travelers on both the Baltimore and York-Town Turnpike and the Baltimore and Susquehanna Railroad. To the southeast of the bridge is the former First National Bank of Parkton. The Northern Central Railroad Trail is located south of the bridge on the bed of the former Baltimore and Susquehanna Railroad.

This bridge is currently in satisfactory condition and carries a negligible traffic volume. The entire structure was coated with shotcrete at an unknown date.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation.
- Periodically remove debris from the stream channel at the bridge.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines.
- As the shotcrete on the bridge begins to fail, the loose portions of shotcrete should be removed and the stone masonry restored by repointing as needed. This may need to be done on a periodic basis, as the shotcrete deteriorates over time. It is not recommended to forcibly remove the shotcrete all at once, as this may damage the underlying stone masonry.

- Replace the bituminous wearing surface. The existing wearing surface should be removed, rather than paved over, so that no additional dead load is added to the bridge. As part of the wearing surface replacement, a waterproof membrane should be installed beneath the new pavement, as well as an adequate drainage system along the curblines, to move water and de-icing salts off of the bridge.

- If a more major rehabilitation is needed beyond replacement of the wearing surface, then an acceptable treatment involves temporarily shoring the arch, removing of all or portions of the fill material over the arch, repairing/repointing the exposed stone masonry, placing a waterproof membrane along the top of the exposed barrel, and replacing the fill with an engineered backfill or relieving structure. Adequate drainage should be provided, as above, and another waterproof membrane should be placed on top of the new fill prior to placing the new wearing surface.

- State and federal requirements to install approach traffic barriers meeting current highway traffic-barrier standards should be investigated, using the AASHTO guidance available for very low volume roads, and also considering the very low prevailing speeds at this bridge.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this rural location with a negligible traffic volume and the adjacent parallel roadways.

- This bridge has already been bypassed twice in the past with the parallel alignments of MD 45 (the present York Road) and I-83. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 3 – Addressing Moisture Penetration in Stone and Reinforced Concrete Arches
- Chapter 4 – Repointing Stone Masonry – Including Stone Veneer
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 0310900
US 40 over Patapsco River

Catonsville, Baltimore County, MD
Ellicott City, Howard County, MD
MIHP No. BA-2557

Bridge Type: Open-Spandrel, Ribbed, Reinforced Concrete Arch

Year Built: 1936

No. of Spans: 1

Total Length: 334'-0"

Roadway Width: Two roadways at 24'-0" each, separated by a concrete median. (4 lanes total)

NRHP Eligibility: Criterion C, as a strong example of an open-spandrel reinforced concrete arch.

Primary CDEs: Arch ribs, spandrel columns, abutments, wingwalls, and balustrades.

Other Comments: The bridge is located in the Patapsco Heritage Greenway and crosses over the Patapsco Valley State Park.

A modern concrete safety-shape barrier was installed along the center of the roadway in 1975, and metal guardrails have recently been installed along the full length of both balustrades.

This bridge is currently in satisfactory to poor condition and carries an ADT of approximately 42,000. The bridge is on an increased (yearly) inspection cycle because of substandard load-carrying capacity.

Preservation Recommendations:

- A major bridge rehabilitation that includes acceptable preservation treatments is forthcoming. The rehabilitation will include replacement of the deck and floorbeams, as well as about half of the spandrel columns (in-kind). The remaining superstructure and substructure components will be repaired with concrete. The sidewalks will be removed and the deck cantilevers widened slightly (Due to the large scale of this bridge, a minor deck widening is acceptable.). A new concrete barrier will be placed along the center of the roadway and the balustrades will be replaced with modern safety-shape concrete barriers, which will have inset panels to mimic the existing open-balustrade architectural details on the exterior faces. The important views of this bridge are from the perspective of the state park, and not from the roadway itself; therefore, this parapet treatment is acceptable.

- Modify the drainage system on the bridge so that it does not drain onto any of the concrete elements of the bridge.

- Continue routine condition inspections and regular maintenance.

- Keep bridge free of vegetation.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines.
- Periodically remove graffiti from the lower portions of the bridge. Apply an anti-graffiti coating to problem areas to facilitate easier cleaning in the future.
- Although a bridge rehabilitation is forthcoming, additional deterioration may occur in the concrete elements over time, and should be repaired.
- Install erosion protection along the embankment slopes at each end of the bridge, if it becomes necessary.
- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option. Likewise, the demolition of this bridge is not an acceptable preservation option.
- This bridge has already been bypassed with the parallel alignment of I-70. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 1003100
US 40 over Middle Creek

Myersville, Frederick County, MD
MIHP No. F-4-116

Bridge Type: Closed-Spandrel, Filled, Reinforced Concrete Arch with Stone Masonry Veneer

Year Built: 1936

No. of Spans: 2

Total Length: 144'-0"

Roadway Width: 40'-0"

NRHP Eligibility: Criteria A and C, as a significant example of concrete arch construction during the relocation and widening of US 40 in the 1930s.

Primary CDEs: Arch barrels, spandrel walls, parapets, and all of the stone veneer and architectural treatments on the wingwalls, buttresses, and parapets.

Other Comments: This bridge is one of three very similar bridges located along a short segment of US 40. The three bridges were designed to complement one another, and blend in with the context of their surroundings. These bridges are located on the Catoctin Mountain Scenic Byway, and are within the Heart of the Civil War Heritage Area. This portion of US 40 is on the current alignment of the National Pike. This bridge is currently in satisfactory condition and carries an ADT of approximately 4,800. Metal guardrail attachments have been bolted through the parapet endposts.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation. Also, periodically cut back the vegetation beneath the bridge and overhanging the sides of the bridge.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines.
- Periodically remove debris from the stream channel at the bridge.
- Perform periodic repointing of the mortar joints as needed. Reset any missing stones at that time. These can most likely be recovered on-site. Also, the efflorescence throughout the stone veneer should be removed by careful cleaning (see guidance in NPS Briefs).

- Replace the bituminous wearing surface. The existing wearing surface should be removed, rather than paved over, so that no additional dead load is added to the bridge. As part of the wearing surface replacement, a waterproof membrane should be installed beneath the new pavement, as well as an adequate drainage system along the curbs, to move water and de-icing salts off of the bridge (and eliminate further efflorescence on the veneer).

- If initial movements are detected in the wingwalls, they may be stabilized by placing tie-back rods through the face of the wingwall and into the backfill. The tie-back anchorages can be hidden behind the veneer. However, if the movements are significant, the wingwall should be replaced in-kind.

- If a more major rehabilitation is needed beyond replacement of the wearing surface, then an acceptable treatment involves the removal of all or portions of the fill material over the arch, placing a waterproof membrane along the top of the exposed barrel, and replacing the fill with an engineered backfill. Adequate drainage should be provided, as above, and another waterproof membrane should be placed on top of the new fill prior to placing the new wearing surface.

- Repair the concrete portions of the structure, particularly the curbs. Any concrete behind a stone veneer will not need to adhere to the Best Practice Treatments for matching concrete.

- When it becomes necessary, replace the existing metal guardrails and parapet anchorages with context-sensitive traffic barriers that meet current highway safety standards.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this rural location with a roadway that can already accommodate additional lanes, and with the adjacent parallel roadway.

- This bridge has already been bypassed with the parallel alignment of I-70. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 3 – Addressing Moisture Penetration in Stone and Reinforced Concrete Arches
- Chapter 4 – Repointing Stone Masonry – Including Stone Veneer
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 1100700
US 40 Alt over Casselman River

Grantsville, Garrett County, MD
MIHP No. G-II-C-101

Bridge Type: Steel Pratt Through Truss

Year Built: 1932

No. of Spans: 1

Total Length: 133'-0"

Roadway Width: 40'-0"

NRHP Eligibility: Criteria A and C, as one of a small but significant number of metal truss bridges erected in Maryland from the 1920s through the 1940s.

Primary CDEs: Steel trusses, sway-bracing portals, floorbeams, and concrete abutments and wingwalls.

Other Comments: The bridge was built as part of the Good Roads Movement and the realignment and expansion of the National Road (US 40). This bridge is located on the National Road Scenic Byway and is within the Garrett County Heritage Area. It is adjacent to the state park containing the original 1813 stone arch bridge crossing the Casselman River. The stone arch bridge is a National Historic Landmark. The truss bridge is also adjacent to the Penn Alps artisan village, a tourism destination. Additionally, this location displays three eras of bridge-building technology, from stone arch to metal truss, to the modern high-level steel multi-girder interstate bridges located just upstream.

Two sway-bracing portal elements have been replaced in-kind. The original steel channel portions of the bridge railings (a secondary CDE) have been replaced with modern metal guardrails.

This bridge is currently in poor condition and carries an ADT of approximately 4,500. The vertical clearance available to vehicles is less than 15'-0". The bridge is considered fracture-critical, and is on an increased (yearly) inspection cycle because of substandard load-carrying capacity.

A deck replacement and rehabilitation was recently completed on this bridge. The new deck incorporated a modern traffic barrier system along both sides of the bridge. The new barriers help to protect the superstructure steel from roadway splash and de-icing salts. The previous metal guardrails were removed from the trusses. The rehabilitation also included minor steel plating repairs to superstructure members and in-kind replacement of a few truss members and deteriorated gusset and batten plates. In performing the steel repairs, deteriorated rivets were replaced with high-strength bolts. Minor concrete repairs to the abutments were also completed.

Preservation Recommendations:

- Perform an analysis of the portal sway braces to determine if they can be modified and raised, and to what extent, to increase the vertical clearance available to vehicles.

- Continue routine condition inspections and regular maintenance.

- Keep bridge free of vegetation. Also, periodically cut back the vegetation overhanging the sides of the bridge.

- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines, truss members, and abutment seats.

- Repaint the superstructure steel.

- Although a recent bridge rehabilitation was performed, additional concrete deterioration may occur in the future. If so, repair general deterioration (spalls and delaminations) in the concrete abutments and wingwalls, as needed. Likewise, any future steel deterioration should be addressed accordingly.

- If additional live load capacity becomes necessary, the member(s) governing the bridge's capacity may be addressed by adding auxiliary members carefully detailed and positioned so as not to detract from the scale of the bridge or the make-up of the connections.

- Alteration or widening of this bridge may be a viable preservation option if faced with demolition, which is not an acceptable option.

- Moving this bridge to another location is also a feasible preservation option if faced with demolition. However, moving the bridge would be fairly difficult because of the large size of this truss.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 1304600
Old MD 32 over CSX Railroad, River Road, & Patapsco River

Sykesville, Howard & Carroll Counties, MD
MIHP No. HO-673

Bridge Type: Aluminum Box Girder

Year Built: 1963

No. of Spans: 3

Total Length: 296'-0"

Roadway Width: 30'-0"

NRHP Eligibility: Criterion C as a significant and rare example of an aluminum bridge in Maryland, and Criterion G for a bridge that has met historic significance within the last 50 years. The bridge is only one of six aluminum bridges built in the US between 1948 and 1963, and is the only example in Maryland.

Primary CDEs: Aluminum box girders.

Other Comments: The box girders consist of riveted built-up aluminum triangular box-stiffened sheet girders. They were designed and fabricated by the Fairchild Engine and Airplane Corp.

This bridge is currently in poor condition with extensive deterioration in the primary structural elements of the box girders, which have been determined to be irreparable. This led to the construction of a new adjacent bridge in 2006, and the permanent closure of the aluminum bridge. As a condition to permit the new bridge construction, SHA entered into a preservation agreement with MHT to close and preserve the aluminum bridge in place.

Preservation Recommendation:

In 2003 and 2004, SHA performed the following steps in accordance with the bridge's preservation agreement:

- Installed interpretive signage at the bridge.
- All spalled and delaminated areas of the concrete curbs and parapets were repaired.
- The roadway joints were sealed.
- All debris from inside the aluminum box beam and beam seat areas was removed.
- Steel post barricades at each end of the bridge were installed to close the bridge to traffic.

Additional recommendations to preserve and maintain the bridge include:

- Repeat the above work on an as-needed basis.
- Perform any other repairs to defects that are discovered during the routine biennial inspections of this bridge. Even without traffic on the bridge, the concrete substructure will deteriorate over time, and should be repaired when warranted.

- It is understood that the SHA is likely to retain ownership and maintenance responsibilities for this bridge for the foreseeable future. However, transfer of ownership of this bridge to a private organization or local jurisdiction is an acceptable preservation option, if it ensures close adherence to this Preservation Plan.

- If it is determined that the bridge can no longer be safely maintained in place, SHA should coordinate with FHWA, MHT, and any other consulting party to develop appropriate mitigation measures. One option could include dismantling the bridge and keeping a portion (cross section) of the superstructure intact so that its unique design and construction techniques are apparent. The bridge section could then be safely displayed at its current location or a venue similar to the Baltimore Museum of Industry. The existing interpretive signage at the bridge site should accompany the preserved cross-section of the bridge. Ownership of the preserved portion should transfer to a preservation organization, and the aluminum elements properly refurbished.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair

SHA Bridge No. 2002300
MD 331 over Choptank River
"Dover Drawbridge"

Talbot & Caroline Counties, MD
MIHP No. T-487

Bridge Type: Steel Sub-Divided Warren Through Truss, with a Center Swing Span, and Reinforced Concrete Slab Approach Spans

Year Built: 1933

No. of Spans: 3 Truss Spans (1 Swing)
8 Approach Spans

Total Length: 842'-0"

Roadway Width: 24'-0"

NRHP Eligibility: Criterion A for its association with bridge construction during the 1920s and 1930s to meet growing vehicular demands, and Criterion C as a strong example of a Warren truss/swing span bridge.

Primary CDEs: Steel trusses, sway-bracing portals, floorbeams, pivot girder, and the pivot, drive, and wedge mechanisms. Also, the concrete pivot pier and rest piers of the truss spans. (This is a center-bearing swing span.)

Other Comments: The bridge is located in a rural, marshy setting along the Chesapeake Country Scenic Byway and within the Stories of the Chesapeake Heritage Area.

Numerous repairs and alterations have been performed on this bridge over the years, primarily to secondary and tertiary CDEs. The work has included fender repairs, substructure concrete repairs, roadway joint replacements, approach slab repairs, steel plating repairs, replacement of some gussets and braces, and installation of fiberglass jackets on the river piers. A complete overhaul of the mechanical/electrical system was performed in 1999, followed by replacement of the swing span deck in 2003. Two swing span floorbeams were strengthened at that time, and additional mechanical/electrical upgrades were undertaken.

This bridge is currently in fair to satisfactory condition and is functionally obsolete. It carries an ADT of approximately 12,000. The vertical clearance available to vehicles is approximately 15'-0." The truss spans are considered fracture-critical, and the bridge is on an increased (yearly) inspection cycle because of substandard load-carrying capacity.

The bridge is scheduled to be bypassed within five years. It will then remain under very limited service on the SHA road system. The swing span is to be left in the open position for the vast majority of the time, to allow marine traffic to pass freely, and operated about once per year for civic functions. However, this presents the opportunity for a lack of maintenance.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance, even after the bridge is bypassed.

- Minor repairs are currently planned for this bridge, to include deck patching, fender repairs, and mechanical/electrical maintenance. These repairs should proceed. Short-term minor repairs should also include concrete repairs to the curbs along the fixed truss spans.

- Establish and adhere to a maintenance schedule, particularly for the swing span and mechanical systems. This should include regular lubrication and testing (more frequent than yearly) of the mechanical and operating systems, as well as regular maintenance of the navigational lights and electrical system, and regular maintenance and upkeep of the tender's house.

- Since the bridge will no longer carry regular vehicular traffic, safety upgrades to meet current highway standards are not necessary.

- Maintain the vegetation around the ends of the bridge, and periodically cut back the vegetation beneath and alongside the approach spans.

- Maintain a strict schedule of cleaning dirt, debris and bird droppings from the bridge, particularly the deck, truss members, and pier and abutment seats.

- Repaint the superstructure steel and mechanical components.

- Repair general deterioration (spalls and delaminations) in the concrete decks, abutments, wingwalls, and piers, as needed over time.

- Repair the timber fenders as needed over time.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this location after the bridge is bypassed.

- Moving this bridge to another location is also unlikely, but could be a feasible preservation option if faced with demolition. However, moving the bridge would be fairly difficult because of the large size of this truss.

- It is understood that the SHA is likely to retain ownership and maintenance responsibilities for this bridge for the foreseeable future. However, transfer of ownership of this bridge to a private organization or local jurisdiction is an acceptable preservation option, if it ensures close adherence to this Preservation Plan. The bridge could be left in place and transferred to an entity such as the nearby Chesapeake Bay Maritime Museum.

SHA Bridge No. 2100400 MD 845A (Main Street) over Little Antietam Creek

Keedysville, Washington County, MD
MIHP No. WA-II-1125

Bridge Type: Closed-Spandrel, Filled, Reinforced Concrete Arch

Year Built: 1927

No. of Spans: 1

Total Length: 50'-0"

Roadway Width: 24'-0"

NRHP Eligibility: Criterion A for its association with the bridge building work of the State Roads Commission in the 1920s in eliminating dangerous geometry, and Criterion C for its engineering and architecture.

Primary CDEs: Arch barrel, spandrel walls, and balustrades.

Other Comments: The bridge was built by the Luten Bridge Company, and was constructed using monies from the "Special Bridge Fund". It was built to improve the connection between the county seat and the rural countryside. The bridge is a contributing element within the Keedysville Historic District, and is located within the Heart of the Civil War Heritage Area and on the Antietam Campaign Scenic Byway (a designated Civil War Trail).

This bridge is currently in satisfactory condition and carries relatively little traffic (ADT of 600 in 2002). The original lampposts were removed from the bridge at an unknown date.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines and sidewalks.
- Install scour and erosion protection along the abutments and adjacent stream banks, if needed.
- Repair the concrete balustrades and spandrel walls, particularly along the interfaces between the spandrels and arch barrel, when it becomes necessary. Other areas on the bridge, such as the barrels and cantilevered sidewalk brackets, may require similar concrete repairs.

- If the balustrades require total replacement, they should be rebuilt to resemble the original balustrades. State and federal requirements to upgrade the new balustrades to current highway traffic-barrier standards should be investigated, using the AASHTO guidance available for low volume roads, and also considering the relatively low prevailing speeds and favorable roadway alignment. Replacement of the balustrades may include the replacement of sidewalks and cantilever brackets as well. Any attached utilities should be incorporated (hidden) within the new balustrades or sidewalks. Any historical plaques should be preserved, refurbished, and properly installed on the new balustrades.

- Re-wire the bridge for electrical service and install new lamp posts along the balustrades to replicate or closely resemble the original lamp posts and luminaires.

- Replace the bituminous wearing surface. The existing wearing surface should be removed, rather than paved over, so that no additional dead load is added to the bridge. As part of the wearing surface replacement, a waterproof membrane should be installed beneath the new pavement, as well as an adequate drainage system along the curbs, to move water and de-icing salts off of the bridge.

- If a more major rehabilitation is needed beyond replacement of the wearing surface, then an acceptable treatment involves the removal of all or portions of the fill material over the arch, placing a waterproof membrane along the top of the exposed barrel, and replacing the fill with an engineered backfill. Adequate drainage should be provided, as above, and another waterproof membrane should be placed on top of the new fill prior to placing the new wearing surface.

- If initial movements are detected in the wingwalls, they may be stabilized by placing tie-back rods through the face of the wingwall and into the backfill. The tie-back anchorages can be countersunk on the face of each wingwall, and then covered with a non-shrink grout. However, if the movements are significant, the wingwall should be replaced in-kind.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this location in a village setting with a very low traffic volume, little chance of future development in the vicinity of the bridge, and the adjacent parallel roadway.

- This bridge has already been bypassed with the parallel alignment of MD 34. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:
- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 3 – Addressing Moisture Penetration in Stone and Reinforced Concrete Arches
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 2101000
US 40 over Licking Creek

Indian Springs, Washington County, MD
MIHP No. WA-V-416

Bridge Type: Steel Wichert Girder/Truss System

Year Built: 1938

No. of Spans: 3

Total Length: 306'-0"

Roadway Width: 28'-0"

NRHP Eligibility: Criterion C, as a significant example of a metal truss and girder bridge.

Primary CDEs: Steel girder/truss system, concrete abutments and piers, and the ornamental bridge railings.

Other Comments: This bridge is located along the National Road Scenic Byway.

Although substantially rehabilitated and slightly altered in 2006, the treatment of this bridge was well done. The work included a deck replacement and minor concrete and steel repairs. The ornamental metal-and-concrete Art Deco bridge railings were preserved, replicated, and reset outside of the new concrete traffic barriers along the deck. A post-tensioning retrofit had been previously added to the girder/truss system over each pier.

This bridge is currently in very good to satisfactory condition and carries an ADT of approximately 1,400. The bridge is considered fracture-critical, and is on an increased (yearly) inspection cycle because of substandard load-carrying capacity

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation. Also, periodically cut back the vegetation beneath the bridge and overhanging the sides of the bridge.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines, the pier and abutment seats, and around the bottoms of the ornamental railings.
- Repaint the superstructure steel and the metal portions of the ornamental railings.
- Periodically remove debris from the stream channel at the piers.
- Install scour and erosion protection along the bottoms of the piers, along the adjacent stream banks, and on the steep embankments in front of each abutment, as needed.

- Repair general deterioration (spalls and delaminations) in the concrete abutments, wingwalls, and piers, as needed over time.

- Although a bridge rehabilitation was recently completed, additional steel deterioration may occur in the future. If so, replace secondary structural members as needed. Repair deteriorated girder and truss members by adding new plates or shapes. Deteriorated rivets can be replaced with high-strength bolts.

- Maintain and track the monitoring system attached to the post-tensioning retrofit rods.

- If additional live load capacity becomes necessary, the member(s) governing the bridge's capacity may be addressed by adding auxiliary members carefully detailed and positioned so as not to detract from the scale of the bridge or the make-up of the connections.

- Alteration or widening of this bridge may be a viable preservation option if faced with demolition, which is not an acceptable option.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- This bridge has already been bypassed with the parallel alignment of I-70. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 2101200
US 40 over Conococheague Creek

Wilson, Washington County, MD
MIHP No. WA-V-211

Bridge Type: Open-Spandrel, Ribbed, Reinforced Concrete Arch

Year Built: 1936

No. of Spans: 3

Total Length: 370'-0"

Roadway Width: 44'-0"

NRHP Eligibility: Criteria A and C, as a significant example of a reinforced concrete open-spandrel arch bridge constructed by the State Roads Commission as part of the Good Roads Movement.

Primary CDEs: Arch ribs, spandrel columns, abutments, wingwalls, piers, and balustrades.

Other Comments: The bridge is located along the National Road Scenic Byway, adjacent to the Wilson Bridge Park which contains the historic Wilson stone arch bridge.

The only questionable alteration to the bridge occurred in 1952 and included the destruction of small portions of the parapet walls to install modern light poles. The current tall aluminum mast-arm light poles were installed in 2001.

This bridge is currently in satisfactory to fair condition and carries an ADT of approximately 13,000.

Preservation Recommendations:

- General concrete repairs throughout the bridge, roadway joint modifications, and installation of drainage trough downspouts are currently planned for this bridge. These repairs should proceed in accordance with the Best Practice Treatments.
- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines and sidewalks.
- Periodically remove graffiti from the lower portions of the bridge. Apply an anti-graffiti coating to problem areas to facilitate easier cleaning in the future.
- Periodically remove debris from the stream channel at the piers.

- If a major bridge rehabilitation becomes necessary, the work could include replacement of the surface of the concrete deck, or complete replacement of the deck and floorbeams (in-kind). The remaining superstructure and substructure components would be repaired with concrete. Because of the generous roadway width for only two lanes of traffic, a new traffic barrier can be constructed along the curblines, to meet current highway safety standards, and to separate pedestrian and vehicular traffic.

- If the balustrades require total replacement, they should be rebuilt to resemble the original balustrades. State and federal requirements to upgrade the new balustrades to current highway traffic-barrier standards should be investigated, using the AASHTO guidance available, and also considering the favorable roadway alignment.

- A balustrade replacement may include the sidewalks and cantilever brackets as well. Widening of the sidewalks (toward the center of the bridge, rather than outward) would be acceptable and practical at this bridge. Any attached utilities should be incorporated (hidden) within the new balustrades or sidewalks, or installed beneath the new deck. Any historical plaques should be preserved, refurbished, and properly installed on the new balustrades.

- Remove the tall mast-arm light poles from the bridge when the balustrades are replaced. New lamp posts and luminaires that closely resemble lamp posts of the period of original bridge construction, but that provide the necessary roadway lighting in accordance with current highway safety standards, should then be installed along the balustrades.

- Modify the drainage system on the bridge so that it does not drain onto any of the concrete elements of the bridge, and is not visually obtrusive.

- Although concrete repairs may soon be completed, additional concrete deterioration may occur in the future. If so, repair general deterioration (spalls and delaminations) throughout the bridge, as needed.

- Install scour protection around the piers, and erosion protection along the embankment slopes at each end of the bridge, as it becomes necessary.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this location with a roadway that is already accommodating more lanes than needed, and with the adjacent parallel roadway.

- This bridge has already been bypassed with the parallel alignment of I-70. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 2103800
MD 68 over Antietam Creek
"Booth's Mill Bridge"

Lappans, Washington County, MD
MIHP No. WA-II-009

Bridge Type: Stone Masonry Arch

Year Built: 1833

No. of Spans: 3

Total Length: 133'-0"

Roadway Width: 20'-0"

NRHP Eligibility: Criterion C, for its stone arch engineering and architectural design.

Primary CDEs: Arch barrels, spandrel walls, parapets, piers, abutments, and wingwalls.

Other Comments: The bridge is situated within the Heart of the Civil War Heritage Area and is located in Devil's Backbone County Park.

In 1996, the bridge underwent a major rehabilitation and reconstruction, which included a partial structural bypass of the masonry arch with a rigid concrete arch. Nonetheless, the work was completed in a historically sensitive manner, incorporating nearly all of the material from the original bridge. More recent repairs have included fixing damage at the ends of the parapets, which is being repeatedly caused by trucks with long trailers. The alignment of the most often damaged corner has already been adjusted slightly to reduce the frequency of impacts, but this has not solved the problem.

This bridge is currently in satisfactory condition, but is functionally obsolete. It carries an ADT of approximately 2,250. The bridge is currently posted for a vehicle weight restriction of 27,000 lbs and a vehicle length restriction of 50 feet.

Preservation Recommendations:

- Continue routine condition inspections and regular maintenance.
- Keep bridge free of vegetation.
- The bridge requires major repointing of the mortar joints throughout the structure, which are currently failed or failing. The bond and mortar joints should match the original design. Perform subsequent periodic repointing of the mortar joints as needed. Delaminated or cracked stones should be repaired or replaced in-kind where possible.
- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines.

- Periodically remove debris from the stream channel at the piers and abutments.

- Replace the bituminous wearing surface. The existing wearing surface should be removed, rather than paved over, so that no additional dead load is added to the bridge. As part of the wearing surface replacement, a waterproof membrane should be installed beneath the new pavement, as well as an adequate drainage system along the curblines, to move water and de-icing salts off of the bridge.

- If a more major rehabilitation is needed beyond replacement of the wearing surface, work similar to the 1996 rehabilitation should be undertaken, which involves temporarily shoring the arch, removing of all or portions of the fill material over the arch, repairing/repointing the exposed stone masonry, placing a waterproof membrane along the top of the exposed barrel, and replacing the fill with an engineered backfill or relieving structure. Adequate drainage should be provided, as above, and another waterproof membrane should be placed on top of the new fill prior to placing the new wearing surface.

- Repair the damaged ends of the parapets in-kind when damaged by trucks. Serious consideration should be given to making the existing vehicle weight and length restrictions more stringent on this bridge (and enforcing those restrictions more diligently).

- Replace the existing context-sensitive timber traffic barriers along the approaches in-kind when deteriorated or damaged beyond serviceable limits.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option.

- Although the widening or alteration of this bridge may be a viable preservation option if faced with demolition, neither of these options is very likely to become a consideration at this rural location within county parkland.

- Likewise, a change in bridge use or setting as a result of a bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 3 – Addressing Moisture Penetration in Stone and Reinforced Concrete Arches
- Chapter 4 – Repointing Stone Masonry – Including Stone Veneer
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 2200900
MD 991 (Main Street) over Wicomico River

Salisbury, Wicomico County, MD
MIHP No. WI-117

Bridge Type: Steel Double-Leaf Trunnion Bascule

Year Built: 1928

No. of Spans: 1

Total Length: 83'-0"

Roadway Width: 26'-0"

Eligibility: Criterion A for its association with the development of vehicular traffic, which began to take over as the primary means of transport on the Eastern Shore, and Criterion C as a significant example of a Chicago trunnion-style bascule bridge and for the architectural aspects of the tender's tower.

Primary CDEs: Bascule girders, trunnions, counterweights, drive machinery, tender's tower, and bascule piers.

Other Comments: The tender's tower was built in the Classical Revival style and is considered to be one of the most notable buildings in the Salisbury Historic District (MIHP No. WI-145). The bridge is located within the Lower Eastern Shore Heritage Area and is on the Blue Crab Scenic Byway.

The bridge has had several rehabilitations in the past. Major repairs in 1981 included replacing a large number of floorbeams, stringers, sidewalk brackets, lateral bracing, and trunnion supports in-kind. In 1996, the bulkhead and fender system was replaced. New timber sidewalks were installed in 1998. The tender's tower had been altered in the past; however, the exterior was restored in 2001 to nearly its original appearance. The original lamp posts on the bridge were removed at an unknown date. The original timber deck was replaced with a steel grid deck in 1938, which in turn was replaced in-kind in 2005. Other major repairs in 2005 included replacement of the electrical/control system, restoration of the interior of the tender's tower, repairs to the bascule girders, replacement of some bracing and connection steel, minor concrete repairs to the piers, and replacement of the nose locks and brakes.

This bridge is currently in good condition, but is functionally obsolete. It carries an ADT of approximately 12,650. The bascule span is considered fracture-critical.

Preservation Recommendations:

- Concrete repairs to the bascule piers and various repairs to the fender system are currently being planned. These repairs should proceed as planned.

- Continue routine condition inspections and regular maintenance.

- Repaint the entire bridge (superstructure steel, tender's tower, parapets, railings, piers, mechanical components, fender and bulkhead, etc.).

- Install ornamental lamp posts and luminaires, which replicate the originals, at the original lamp post locations.

- Establish and adhere to a maintenance schedule for the mechanical and control systems. This should include regular lubrication and testing of the mechanical and operating systems, as well as regular maintenance of the navigational lights, traffic safety system, and electrical system, and regular maintenance and upkeep of the tender's tower.

- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the sidewalks, the curblines on top of the counterweights, the machinery and counterweight pits, and the bascule superstructure.

- Although concrete repairs may soon be completed, additional concrete deterioration may occur in the future. If so, repair general deterioration (spalls and delaminations) in the concrete counterweights, parapets, approach sidewalks, and bascule piers, as needed.

- Likewise, repair any future deterioration in the timber and steel fenders and bulkheads, as needed.

- Replace the top concrete riding surface of each counterweight as it ages and deteriorates. This work should include replacement of the curbs. Likewise, the steel grid deck and flooring system will require partial or total replacement after a few decades of service, as well as the timber sidewalk.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option. Likewise, the widening, alteration, or demolition of this bridge are not acceptable preservation options.

- This bridge has already been bypassed twice in the past with the parallel alignments of US 50 and US 50 Business. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 2300200
MD 12 over Pocomoke River
"Snow Hill Drawbridge"

Snow Hill, Worcester County, MD
MIHP No. WO-178

Bridge Type: Steel Single-Leaf Trunnion Bascule

Year Built: 1932

No. of Spans: 2

Total Length: 100'-0"

Roadway Width: 30'-0"

Eligibility: Criterion A for its association with the development of vehicular traffic, which replaced steam boats as the primary transport of local agricultural and maritime goods on the Eastern Shore. The bridge is also eligible under Criterion C as a significant example of a Chicago trunnion-style bascule bridge, and for the architectural aspect of the tender's house.

Primary CDEs: Bascule girders, trunnions, counterweights, drive machinery, and tender's house.

Other Comments: The tender's house was built in the Neo-classical style. The bridge is located in and contributes to the Snow Hill Historic District and is within the Lower Eastern Shore Heritage Area. It is also situated on the Blue Crab Scenic Byway and the Pocomoke Scenic River. The concrete open-balustrades, steel railings, and ornamental lights are not considered primary CDEs, but they add to the aesthetic appeal of the bridge.

Some rehabilitation has been performed on the bridge in the past. The original timber deck on the bascule span was replaced with a steel grid deck in 1955. The steel purlins supporting the grid deck were replaced in 1984, and new concrete curbs were constructed. In 1990, one steel floorbeam was replaced in-kind. Major mechanical and electrical maintenance was performed in 2004. In 2007, the timber sidewalk planks were replaced, repairs were made to the railings and fenders, and mechanical/electrical maintenance was completed

This bridge is functionally obsolete and in fair to satisfactory condition. It carries an ADT of approximately 6,500. The bascule span is considered fracture-critical.

Preservation Recommendations:

- Major structural, mechanical, and electrical rehabilitation is currently scheduled, to include: concrete repairs, structural steel repairs, replacement of the span lock system, complete replacement of the electrical and control systems, repainting of the entire bridge, and installation of a safety barrier at the west end which will deploy when the draw-span is raised. This work should proceed as planned.

- Routine minor structural, mechanical, and electrical maintenance items have also been scheduled and should proceed as planned in the interim.

- Continue routine condition inspections and regular maintenance.

- Establish and adhere to a maintenance schedule for the mechanical and control systems. This should include regular lubrication and testing of the mechanical and operating systems, as well as regular maintenance of the navigational lights, traffic safety system, and electrical system, and regular maintenance and upkeep of the tender's house.

- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly from the movable span bearings on the rest pier, the bascule superstructure, and the machinery and counterweight pit.

- Although concrete repairs may soon be completed, additional concrete deterioration may occur in the future. If so, repair general deterioration (spalls and delaminations) in the concrete counterweight, parapets, approach sidewalks, and bascule piers, as needed.

- Likewise, repair any future deterioration in the timber and steel fenders and bulkheads, as needed.

- The steel grid deck and flooring system will require partial or total replacement after a few decades of service, as well as the timber sidewalk.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option. Likewise, the widening, alteration, or demolition of this bridge are not acceptable preservation options.

- No future expansion is planned for this roadway, and no significant development is anticipated in the vicinity of the bridge. Therefore, a change in bridge use or setting as a result of a bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

SHA Bridge No. 2300400
US 13 Business over
Pocomoke River
"Pocomoke Drawbridge"

Pocomoke City,
Worcester & Somerset Counties, MD
MIHP No. WO-177

Bridge Type: Steel Double-Leaf Trunnion Bascule, with Steel Beam Approach Spans

Year Built: 1920

No. of Spans: 1 Bascule Span, 6 Approach Spans

Total Length: 308'-0"

Roadway Width: 24'-0"

NRHP Eligibility: Criterion A for its association with the development of vehicular traffic, which replaced steam boats as the primary transport of local agricultural and maritime goods on the Eastern Shore, and Criterion C as a significant example of a bascule bridge and for the architectural aspects of the tender's house and end pylons.

Primary CDEs: Bascule girders, trunnions, counterweights, drive machinery, tender's house, bascule piers, and end pylons.

Other Comments: The bridge is a contributing element to the Pocomoke City Historic District (MIHP No. WO-187) and is located within the Lower Eastern Shore Heritage Area. It is also on the Blue Crab Scenic Byway and the Pocomoke Scenic River.

The bridge has had several rehabilitations in the past, particularly on the approach spans. In 1942, a sidewalk was added to the north side of the bridge, and a new steel grid deck was placed on the bascule span. Major mechanical upgrades were made in 1981. In 1988, a section of the approach spans collapsed into the river. As a result, all of the original reinforced concrete T-beam approach spans were replaced with steel beam spans, the bascule stringers were repaired, the bascule piers were underpinned, the counterweights were repaired, and new ornamental lamp posts were installed along the parapets. In 1998, the grid deck and stringers were partially replaced on the bascule span, while the remaining stringers and floorbeams were repaired. Upgrades to the electrical/control system were made at that time as well. Around 2005, machinery supports were repaired, and new windows and doors were installed on the tender's house.

This bridge is currently in satisfactory condition, but is functionally obsolete. It carries an ADT of approximately 4,200. The bascule span is considered fracture-critical, and it is on an increased (yearly) inspection cycle because it has a posted weight restriction of 25 tons for single-unit vehicles and 30 tons for combination vehicles.

Preservation Recommendations:

- A major rehabilitation is currently proposed for the bascule span, to include replacement of the grid deck and stringers, repair of steel curbs and steel railings, concrete repairs on the bascule piers, a complete overhaul of the mechanical/electrical system, and replacement of the nose locks, trunnion bearings, counterweights, and fender system. This rehabilitation should proceed as planned.

- Continue routine condition inspections and regular maintenance.

- Repaint the entire bridge (superstructure steel, tender's house, parapets, mechanical components, piers, etc.).

- Install additional ornamental lamp posts and luminaires, which match the existing lamp posts, where there are bare wires exposed at several original (removed) lamp post locations.

- Establish and adhere to a maintenance schedule for the mechanical and control systems. This should include regular lubrication and testing of the mechanical and operating systems, as well as regular maintenance of the navigational lights, traffic safety system, and electrical system, and regular maintenance and upkeep of the tender's house.

- Maintain a strict schedule of cleaning dirt and debris from the bridge, particularly the curblines on the deck, the pier and abutment seats, the bascule pier areas, and the bascule superstructure. Also, the scupper drains along the deck should be kept free of debris.

- Although concrete repairs may soon be completed, additional concrete deterioration may occur in the future. If so, repair general deterioration (spalls and delaminations) in the concrete decks, parapets, abutments, wingwalls, piers, and end pylons, as needed.

- Likewise, repair any future deterioration in the timber fenders and sidewalks as necessary.

- Replace the concrete surfacing on the approach span decks as they age and deteriorate. However, total replacement of the approach span decks and parapets may become necessary in the future.

- Because of the construction type of this bridge, moving it to another location would not be a feasible preservation option. Likewise, the widening, alteration, or demolition of this bridge are not acceptable preservation options.

- This bridge has already been bypassed with the parallel alignment of the US 13 mainline. Therefore, a change in bridge use or setting as a result of another bypass is unlikely and is not a concern for this bridge.

Applicable Best Practice Treatments:

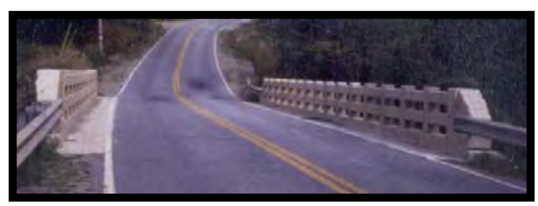
- Chapter 1 – Best Practice Maintenance Treatments Common to All Bridge Types
- Chapter 2 – Reinforced Concrete Conservation and Repair
- Chapter 5 – Protecting Steel from Rust/Corrosion
- Chapter 6 – Strengthening of Steel Bridges/Replacement of Components/Members
- Chapter 7 – Repair of Damaged Steel Bridge Components/Members
- Chapter 8 – Appropriate Railing Treatments

Part II

Part II

Best Practice Treatments

MARYLAND BEST MAINTENANCE & CONSERVATION PRACTICES FOR OLDER BRIDGE TYPES



Prepared for the Maryland State Highway Agency

Prepared by TranSystems
One Oxford Valley, Suite 818, Langhorne, PA

in association with KCI Technologies

Final, April 2012

MARYLAND BEST MAINTENANCE AND CONSERVATION PRACTICES FOR OLDER BRIDGE TYPES

<u>Table of Contents</u>

Appendices

MARYLAND BEST MAINTENANCE AND CONSERVATION PRACTICES FOR OLDER BRIDGE TYPES

Introduction

A successful maintenance/conservation strategy is one where preventive maintenance is performed and then, when problems are identified, the source(s) of the problem, not just the manifestations of the problem, are addressed. For example, patching an eroded section of a concrete pier will not be a long-term solution if the deck joint that leaked and caused the deterioration is not also addressed. Likewise, application of *shotcrete* to spalling reinforced concrete that has chloride infiltration and corroded reinforcing bars does little more than cover up the real problems.

Successful maintenance/conservation strategies include routine maintenance activities that are obvious but sometimes are not routinely performed. The best strategy remains to perform routine maintenance activities and to address problems when they first manifest themselves. It is a time-honored truism that lack of proper maintenance results in more extensive and expensive rehabilitation work that could have been avoided. Fortunately, there are many effective and sometimes very economical procedures that, when performed regularly or when problems first develop, can prolong the useful life of a bridge.

1. Best Practice Maintenance Treatments Common to All Bridge Types

Best practices for preservation of historic bridges start with the same maintenance and conservation strategies used for all bridges – performing routine maintenance and addressing problems when they first appear. In many instances, this proactive approach stops deterioration before it becomes so pervasive that it adversely affects the bridge. Routine maintenance activities are effective and seemingly obvious yet are sometimes not performed. This includes tasks such as ensuring that all drains are kept open and in good repair, seasonally removing accumulated debris, and washing the bridge.

1.1 Remove Accumulated Debris by Regularly Washing Bridge

Washing a bridge with potable water is one of the simplest yet most cost-effective preventative treatments. Debris accumulates on exposed horizontal surfaces, such as the deck joints and abutment seats at the bearings of most bridges and on the lower chords of truss bridges. Accumulated debris can act like a poultice to accelerate material deterioration, and its presence greatly reduces the evaporation of water thus providing favorable conditions for metal to rust and concrete and mortar joints to deteriorate. It should be removed using a low-pressure washing at least annually. In locations where deicing salts are used, a wash each spring is recommended.

1.2. Keep Concrete Decks in Good Condition

The most effective maintenance/conservation strategy for any bridge with a reinforced concrete deck is to keep it in good repair and watertight. Moisture penetration from a failing deck can start with cracked or deteriorated deck pavement, depressions that collect and retain water, roadway drains that are clogged or not functioning properly, or failed expansion joints. Leaking utility pipes buried within the fill of a closed spandrel arch are also a source of damaging moisture.

Keeping a deck watertight is accomplished by making sure that the pavement on the bridge and where it joins the curb are not so deteriorated that there is water infiltration. Any detected deck cracks should be patched, and scuppers and bridge drainage systems should be cleaned and kept open. Any expansion joints should also be cleaned and kept in good repair or replaced as needed.

If not already in place, adequate means of draining water away from the bridge should be installed. Depending on the type of bridge, scuppers can be installed at the deck level either on or adjacent to the bridge. Weep holes or pipes wrapped in filter fabric can be installed into cored holes placed inconspicuously at the bottom of a closed spandrel arch to drain any moisture that gets into the fill.

1.3 Enforce Load Limits

Enforcing posted load restrictions protects the bridge from structural damage and prolongs its useful life. Many older bridges were designed for lighter loads. They are often posted for restricted loads, but the posted restrictions may be ignored. Repeatedly exceeding the posted load limits results in the eventual loss of the bridge. Some jurisdictions have adopted programs to protect their posted historic bridges enforcing weight restrictions by deputizing public works employees who then use a portable scale. Violators are then ticketed and fined. Others use vertical clearance barriers on approaches to the bridge to prevent overloaded vehicles on the bridge.

2. Reinforced Concrete Conservation and Repair

Most deterioration of reinforced concrete is caused by moisture that leads to corrosion of the embedded reinforcing steel and degradation of the concrete itself. Other problems can arise from a variety of reasons, like use of improper material at time of construction or structural issues. Understanding the cause(s) of deterioration is central to identifying an effective conservation and rehabilitation plan. Excellent explanations of the cumulative deterioration that affects reinforced concrete and its manifestations are found in *Preservation Briefs 15* (Appendix C). Of particular interest are the problems related to concrete used before air-entrained concrete was introduced in the 1930s.

2.1 Keep Vegetation Off Bridge Elements

Keeping bridges free of vegetation prolongs the useful life of all types of concrete and reinforced-concrete bridge components, from mortar joints to piers, wingwalls, and railings/parapets. Vegetation such as lichen, moss, or trees can break down concrete resulting in moisture penetration and deterioration that when severe enough can cause movement of walls. All vegetation should be killed (in order to destroy the root system) and then removed from concrete before it has the opportunity to grow and become well established.

2.2 Have a Maintenance Plan

Having and implementing a maintenance plan to prevent water-related deterioration is the most effective conservation treatment for avoiding deterioration associated with moisture penetration. The plan should begin with an in-depth inspection that establishes the baseline condition information and then continues with careful, periodic inspection and monitoring of the structure.

2.3 Make Repairs with Compatible Material that Matches the Existing Concrete

Use of prepackaged concrete materials is never appropriate for the repair of historic concrete bridges. Any new concrete or repair material needs to visually match the existing material as closely as possible and also match its physical properties. And while it is acceptable to use air-entrained or polymer-modified material, it is important that the properties of the historic and new materials, such as the coefficient of thermal expansion, modulus of elasticity, and strength, are compatible so that the old and new material will bond well. The new material should be applied only to a properly prepared substrate where all deteriorated concrete has been removed exposing sound concrete. Rusted or lost reinforcing steel must be cleaned or replaced. Removal of concrete will typically extend beyond the level of the reinforcing steel so that the patch encapsulates it and thus provides the mechanical attachment for the repair. Failure to address the soundness of the substrate often results in the failure of the repair and continued deterioration of the bridge.

15 Preservation Briefs: Preservation of Historic Concrete: Problems and General Approaches (Appendix C) describes the proper strategy for planning and executing concrete repairs, including laboratory testing. Test patches, including finishing techniques, on inconspicuous parts of the structure should be done and allowed to cure completely before being evaluated. The new material should match the existing in color, composition, and finish. Finish is often the hardest to replicate and requires understanding of the original finishing techniques and skill. This may require rubbing or a mild pressure wash to achieve the "weathered" appearance. The techniques described in *2 Preservation Briefs: Repointing Mortar Joints in Historic Masonry Buildings* (see Appendix A) should be followed to achieve a proper patch. The *Briefs* should also be consulted for the suitable strategy for repairing or replacing lost mortar joints on railings and any architectural detailing on the bridge.

Hiding problems under a pneumatically or troweled application of cementitious materials, including *shotcrete* and bagged masonry cement, does not address the cause(s) of the problems or contribute to their solution, and it is not a suitable strategy. With proper substrate preparation, shotcrete can be used to repair reinforced concrete, but it should never be used to "solve" moisture penetration problems without first making sure that the structure is watertight.

All repairs should be done in a manner that reproduces original detailing, like scoring or cornices/string courses.

2.4 Use Waterproof and Water-Repellent Coatings Only When and Where Necessary

While coatings and sealers are common for non-historic concrete, waterproof and water-repellent coatings as well as anti-graffiti coatings are not recommended for historic concrete because of the visual change they cause and the fact that they are not reversible. Clear or opaque waterproof coatings seal the surface from liquid water and water vapor and make it impervious to water. Water-repellent coatings keep liquid water from penetrating the surface but allow water vapor to enter and leave through "pores" that are part of the concrete. Once water vapor is inside the material, however, it can condense into liquid water and then cannot get back out through the water-repellent coating. These coatings seldom stop the source(s) of moisture penetration, and they can trap moisture and salts resulting in efflorescence and spalling. If conditions are severe enough to require a coating, only the affected areas of the bridge should be treated, not the whole structure. A test patch that is allowed to go through a freeze-thaw cycle is recommended.

2.5 Clean Bridge Only When Necessary and with the Gentlest Means Possible

Cleaning is a highly technical and specialized process that should be undertaken only under professional direction and after a test patch has been prepared and permitted to weather for an extended period. The proper strategy for cleaning is first to define the reason for cleaning. If it is determined to be necessary, then define what is to be cleaned. Is it to remove dirt and discoloration, or rust stains or mold stains? The nature and source of what is to be removed should drive selection of the gentlest means possible for cleaning. Chemical and abrasive cleaning can change the appearance of the bridge and can damage the concrete. The same considerations should also apply to stone masonry.

There are various water, chemical, poulticing, and mildly abrasive cleaning processes. Water tends to soften the deposits and eventually washes them from the surface. Chemical cleaners react with the deposits to hasten the removal process; the deposits, reaction products, and excess chemicals are then washed away from the surface with water. Poulticing is a technique used for removing stains by drawing them out of the material. Abrasive methods include all techniques that physically abrade the surface; they can be particularly destructive to architectural detailing.

The advantages and appropriateness of masonry cleaning are thoroughly described in several National Park Service publications including *A Glossary of Historic Masonry Deterioration Problems and Preservation Treatments* and *6 Preservation Briefs: Dangers of Abrasive Cleaning to Historic Buildings* (see Appendix B). These and other publications on the conservation of historic masonry are available online at nps.gov or from the SHPO office.

2.6 Increasing Load-Carrying Capacity

Increasing the load-carrying capacity of a closed-spandrel arch bridge should be done in an unobtrusive manner and should preferably be performed internally to avoid an adverse visual effect.

Saddle or Relieving Slabs. Relieving slabs are used to relieve the existing arch from some or all of its live load. One method to accomplish this is to construct a reinforced concrete saddle directly over the extrados of the existing arch. Another method is to construct the reinforced concrete slab on the fill at the roadway level thereby more evenly distributing the live load away from the arch. Since installing a saddle or relieving slab may require excavation of some fill, replacement of unsuitable fill with a properly draining material and an adequate drainage system should be done at the same time.

Construct a New Bridge Within the Confines of the Spandrel Walls. When there is sufficient fill above the arch crown to fit the depth of a new superstructure, a new bridge can be constructed over the existing arch. This is accomplished by constructing abutments and piers, in the case of multi-span arches, behind or at the base of the existing arch and then spanning the distance between these units with a new superstructure (usually reinforced or prestressed concrete slab or box beams). If there is not sufficient depth of fill, it is sometimes possible to re-profile the existing roadway slightly in order to accommodate the depth of the new member. A reconstruction or modification of the existing bridge railings may also be required.

Replace Earth Fill With Flowable Backfill. Flowable fill, the excavational backfill material that is frequently used in utility trenches, can be used to replace fill material. When used in a closed spandrel arch bridge, it creates a “solid” structure where the fill, spandrel walls and arch ring act together allowing for better load distribution. Replacement of fill material has no effect on historic bridges.

3. Addressing Moisture Penetration in Stone and Reinforced Concrete Arches

3.1 Routinely Remove Vegetation

Keeping bridges free of vegetation prolongs the useful life of all types of masonry components from mortar joints to wingwalls and parapets. Vegetation such as lichen, moss, or trees can break down both the masonry and the bond between the masonry units. This permits moisture penetration, deterioration, and when severe enough, movement of walls, and if on the arch itself, moisture penetration into the fill. All vegetation should be killed and removed from masonry bridges, including load-bearing masonry spandrel walls, parapets, and wingwalls, before it has the opportunity to grow and become established.

If vegetation has established itself on or adjacent to a stone or brick bridge or the wingwalls, it should be killed and then removed. Attempting to remove vegetation that has established its root structure in the masonry can dislodge or loosen the units and affect structural integrity. Trees of any size should be cut as close to the ground or wall as possible, and the root system should be left to decompose. Holes can be drilled in the stumps and an approved herbicide used to accelerate decomposition. Any voids caused by vegetation should be repaired in accordance with sections 4.1 and 4.3

Additionally, the seasonal accumulation of natural debris on and adjacent to the structure should be routinely removed. The build up of debris, including leaves and branches, holds moisture and prevents the structure from drying out. All roadway and structure drains should also be cleared of debris.

3.2 Keep Deck in Good Condition

Keep the deck watertight. This is accomplished by making sure that the pavement on the bridge and where it joins the curbs or railings/parapets is not so cracked that there is water infiltration, that there is adequate means of draining water away from the bridge, and that any utility pipes buried within the fill are not leaking. Deck cracks should be patched, and scuppers and bridge drainage systems should be cleaned and kept open. If not already in place, adequate means of draining water away from the bridge should be installed. Weep holes or pipes wrapped in filter fabric can be installed into cored holes placed inconspicuously at the bottom of the arch ring to accommodate draining moisture. Expansion joints should also be cleaned and kept in good repair or replaced as needed.

3.3 Provide Good Waterproofing and Proper Drainage

When moisture penetration has fouled the fill and failed the waterproofing, the saturated fill material should be removed and a new waterproofing membrane installed along with an adequate means for drainage. Fill is not a significant feature of any arch bridge. The replacement of the existing fill with a solid engineered backfill material or flowable fill will decrease the dead load on the structure and increase the live load capacity of the bridge and minimize water infiltration. If solid fill is placed, the waterproofing membrane should be placed between the pavement and the new fill. Proper drains direct the water to either storm drains or through drains in the abutment into a stream. Weep holes need to be installed in the spandrel walls and arch ring of stone arch bridges.

During the excavation to install any of these options, extreme care must be exercised to avoid uneven excavation of the fill which may cause the arch to lose its shape and therefore its load carrying capabilities. This situation can be avoided by providing temporary centering below the arch during the operation. Additional information on excavation is outlined in the Construction Division section of the AASHTO Standard Specifications. Also, there may be utilities present in the fill that could be the source of the problem, such as leaks from a water main.

3.4 Keep Mortar Joints Watertight

Mortar bonds masonry units together, and whether a bridge is stone or brick, the most effective maintenance strategy is to keep all mortar joints in good condition. This will keep moisture from penetrating into the structure. Watertightness is achieved by replacing lost and failing mortar joints with an appropriate mortar before moisture penetration damage affects the masonry units, and thereby the structural integrity of the bridge.

4. Repointing Stone Masonry – Including Stone Veneer

Repointing is the process of removing failing mortar, preferably by hand, from joints and replacing it, as well as filling open joints, with new mortar. When properly done, repointing restores the visual appearance and ensures the structural integrity of the masonry. The new mortar should be compatible with the historic mortar in physical properties; compressive strength, texture, color, and style (size and finish of joint). Improperly done repointing can be unsightly, can adversely affect the historical significance of the bridge, and can cause damage to the masonry units.

Before repointing, the cause of the failure of the joints must be determined and corrected. Joints may have failed for reasons other than age-related deterioration. Open joints may be providing relief of hydraulic pressure for moisture trapped behind the wall. Closing the joints will only worsen the problem of improper drainage of the bridge deck.

It should be noted that filling failing or lost mortar joints with a modern masonry cement (premixed, bagged mixture) is not considered repointing, and the practice is not a suitable strategy for historic masonry. Modern masonry cement does not bond well with the historic mortar because it is too hard, and it never matches the historic mortar in color or properties. Consequently, application of masonry cement is generally irreversible. It is also a common error to assume that hardness or high-strength in repointing mortar is appropriate for historic masonry, particularly lime-based mortars. Stresses will, and do, occur in a masonry structure, and if the mortar is too hard, the stress will be relieved by cracking the softer masonry units rather than the too-hard mortar joints. While stresses can also break the bond between the mortar and the masonry units, it is much easier to correct the problem by repointing the joints than by replacing cracked bricks and stones or rebuilding the structure.

4.1 Proper Repointing

It is important to use accepted conservation standards when repointing historic masonry, and this starts with understanding the physical make-up of the old mortar. The setting and pointing mortars used before World War I are different from modern, portland cement-based mortar and premixes, and have many advantages over their modern counterparts. Lime-based mortars are generally and purposely softer/weaker than the masonry units. New mortar with high lime content bonds well with old mortar, is porous, and changes little in volume during temperature fluctuations. It is slightly water soluble and thus able to re-seal any hairline cracks that may develop. Portland cement, on the other hand, can be extremely hard, is resistant to movement of water, shrinks upon setting, and undergoes relatively large thermal movements.

An appropriate mortar mix is composed of sand, a small part of portland cement, and lime, which are then mixed with water to make a paste. A commonly used mix ratio is not greater than one part white, nonstaining portland cement (to achieve workability and plasticity), two parts lime, and six to eight parts sand for setting mortar and up to 12 parts sand for pointing mortar. Pointing mortar is usually softer than the setting mortar. While mortar analysis by a qualified laboratory can provide useful information about the historic mortar, it is not always crucial to success. The most useful information that can come out of laboratory analysis is the identification of the sand gradation and color. This information is useful in achieving a match of color and texture. A fracture test will identify the compressive strength of the historic mortar.

The color and texture of the new mortar will usually fall into place if the sand is successfully matched, but it is important to understand that if the bridge is not being cleaned (see below), the new mortar should match the existing mortar, which is usually weathered. Matching the original mortar in color and texture rather than the existing appearance of the mortar can result in mortar that is too light in color. There are many appropriate finishing techniques to match the existing texture of weathered concrete, including rubbing or a mild water blast to expose the sand. Crushed or manufactured sand is generally not the appropriate type of sand to use. Rounded or natural sand is preferred because (1) it is usually similar to the original sand and is thus a better match, and (2) it has better working qualities or plasticity and can be forced into joints more easily. Test patches to determine how well a mortar mix will match the existing mortar should always be done in an inconspicuous part of the structure.

The proper methodology for repointing historic masonry is clearly and thoroughly explained in the National Park Service's *Preservation Briefs 2: Repointing Mortar Joints in Historic Masonry Buildings* (see Appendix A). The guidance is directly applicable to historic bridges as well as buildings.

4.2 Install Weep Holes

Any repointing, especially on the barrel of an arch or intrados, should include installation of weep holes. Strategically located weep holes will ensure relief of water pressure and provide a drainage path for any moisture that does penetrate the fill.

4.3 Stone Spandrel Wall Rehabilitation

Bulging of stone spandrel walls and wingwalls must be addressed by remedial action or the failing component will eventually collapse. The failing sections need to be dismantled, the cause of the problem (usually moisture penetration, lateral pressure from live loads, or roots dislodging the stonework) addressed, and the stone then re-laid in the same bond/pattern with a mortar mix that matches the existing mortar in texture, color, and composition in accordance with proper repointing described above.

Replacing damaged or missing masonry units with concrete patches is not appropriate. All damaged and lost units should be replaced in-kind. Lost stones that have fallen from the structure may well be nearby or in the stream bed. They can be reset using a stronger setting mortar and mechanical connections (rock anchors) when necessary.

If the bulging is minor, consideration can be given to addressing the source of the bulging and then installing metal tie rods through the structure and anchor plates. This will stabilize the wall or section of wall without reconstructing it. The technique has successfully been used on buildings and bridges for centuries.

5. Protecting Steel from Rust/Corrosion

5.1. Keep Bridge Free of Debris to Prevent Moisture Penetration and Rust

The best maintenance and conservation strategy for preservation of iron and steel bridges of all types is to keep them free from accumulated debris, which is frequently found on exposed horizontal surfaces such as abutment seats at the bearings, top flanges of stringers and floorbeams, and at lower chord panel points. Rust also occurs at the interface of rivet- and bolt-connected members, a condition known as impacted rust. Routinely removing accumulated debris and cleaning bridges with a low-pressure, potable-water wash after the danger of frost has passed is an easy and cost-effective methodology. It eliminates conditions that promote rust and markedly increases the longevity of metal bridge members, including stringers, bearings, and members at lower chord panel points on metal truss bridges. This has proven to be the single most effective practice for preventing rust.

5.2 Keep Bridge Paint or Coating System in Good Condition

The paint or coating system is the most significant mechanical tool for preservation of all types of steel bridges, so its initial application should be done properly with careful attention to surface preparation and then maintained. Paint and coating failures should be addressed on a spot basis, and all touch ups should be applied only after proper surface preparation.

Even with increased understanding of capturing hazardous materials and the development and availability of cost-effective and long-lived coating systems, painting/coating is still the biggest issue related to metal truss bridges. It is frequently the most expensive factor associated with their maintenance, rehabilitation, and preservation. On a large truss bridge, the painting/coating cost alone, which will include all environmental considerations for containment of lead-based paint, can drive the decision on the prudence of preserving it. Much of the expense, as much as 85 to 90 percent of the total cost, is associated with the containment system that must be erected to capture and contain the removed paint and blast medium, protect the workers, and address proper disposal of the collected waste.

Because of the singular importance of paint and coatings, any maintenance and conservation activities related to them should be done in a manner to ensure maximum benefit to the structure. Research should be done to determine the best coating system for a given bridge and the most cost-effective way to clean and coat the structure. For a small bridge, moving it to an offsite location for cleaning and coating is often a cost-effective strategy. There is a great deal of technical assistance on paint and coating systems available from sources such as FHWA, state departments of transportation, and paint/coating system manufactures and contractors.

5.3 Keep Concrete Deck Components of Steel Bridges in Good Condition

It is important to keep deck components, including the deck itself, curbs, drains, and expansion joints, in good repair and sufficiently crack free in order to prevent water infiltration that can affect the structural steel components below the deck. Deck cracks should be patched, and scuppers and bridge drainage systems should be periodically cleaned and kept open. If not already in place, adequate means of draining water away from the bridge should be installed in a manner that does not mar the elevation view.

Expansion joints should also be cleaned and kept in good repair or replaced as needed. Deck joints should be replaced or rehabilitated to eliminate leakage through the joints. There are various deck joint systems available that can be adapted successfully to the various types of structures and the full range of expansion and contraction that must be accommodated. The type chosen should be properly sized and based on performance and adaptability and not on historic issues because expansion joints do not affect historical significance.

6. Strengthening of Steel Bridges/Replacement of Components/Members

There are many cost-effective approaches to increasing the load-carrying capacity of old bridges that do not have an adverse effect on what makes them historic. Generally accepted preservation guidance, including the National Park Service's *The Secretary of the Interior's Standards for Rehabilitation (1977, rev. 1983, 1990)*, allows for in-kind replacement of deteriorated fabric/members and adding new members, so there are a variety of successful methodologies ranging from replacing decks with lighter ones to post- tensioning longitudinal beams or tension truss members.

Truss members that have deteriorated or need to be strengthened can be replaced with higher strength steel equivalents as long as the connections are done in the original manner. Bolts are an acceptable substitute for rivets and have been since the 1960s. It is also acceptable to use bolts to attach new material to existing members and to weld plate to existing cover plates, upper chords, end posts, and beam flanges in order to strengthen the bridge, if it is known for certain that the coverplate and beams are steel. Field welding, however, is generally discouraged due to its lack of a controlled environment. If welding is performed, then a full understanding of fatigue design issues is an absolute must.

Most post-1895 truss bridges are steel, but the transition from wrought iron to steel in the middle to late 1890s was gradual. There are two low-cost, non-destructive tests that can be performed to characterize ferrous material as to whether it is wrought iron, mild steel, or steel. These include the spark test and field metallography where the metal is polished, etched and then its microstructure is replicated for examination in the laboratory. Iron and steel each have a distinctive microstructure that reveals which material it is (Figure 1).

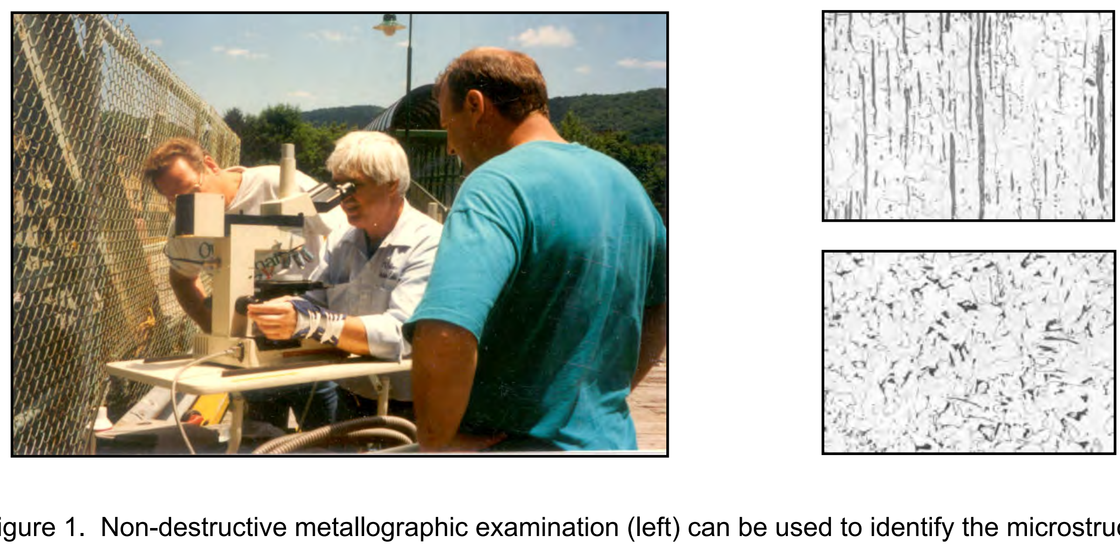


Figure 1. Non-destructive metallographic examination (left) can be used to identify the microstructure of wrought iron (top right) versus steel (bottom right). Note the distinctive elongated slag fibres in the wrought iron.

6.1 Deck Replacement to Reduce Dead Load and Increase Live Load Capacity

Decks, wearing surfaces, and pavements on fill are generally not historically significant features of a bridge. Therefore replacing them with lighter concrete decks, timber, fiber reinforced plastic (FRP), or grid decks is often an effective way to reduce dead load, as is removing layers of overlay on the bridge and corresponding approach roadways, and thus increasing load-carrying capacity. Such work should not be considered an adverse effect, or even an effect, on a historic bridge. Before any decisions can be made about the extent of the replacement or repair of an existing deck, if its condition is not already obvious, a deck condition survey must be conducted. The survey will indicate whether partial or full deck replacement is required.

6.2 Use of Higher Strength Steel for Flooring Systems

The floorbeams and stringers (flooring system) on truss, girder-floorbeam, and steel through arch bridges are generally not historically significant features, although they are considered primary historic elements in Maryland. In many instances, these members can be upgraded to increase load-carrying capacity as long as the members are replaced in-kind (steel with steel even if the replacement steel is a higher strength). The floorbeams should be connected in the original manner, meaning with eye heads or pin plates at pin connections or with bolts at gusset plates at rigid connections. Stringer-to-floorbeam connections are not as critical, which means that angle shelves or notching does not necessarily need to be reproduced. In-kind replacement of flooring system members with higher strength steel is an appropriate way to increase load-carrying capacity, again, as long as the type of connection of the floorbeam is maintained.

Another way to increase capacity of floorbeams or indeed any beam is to weld or bolt coverplate to beam flanges. Welding has been a common means of attachment since the development of arc-welding equipment in the late 1920s. Care needs to be taken to never weld the connection, pinned or riveted, just the attachment of the coverplate to the flanges of the floorbeam. From both the historical and the structural perspectives, it is important to not change the original manner of connection at the panel point or gusset plate. Again, any field welding needs to be carefully controlled.

When adequacy of the waterway opening permits, longitudinal stringers and transverse floorbeams can also be post-tensioned using rods or strands to add load-carrying capacity into the member and the bridge.

6.3 Add Auxiliary Members

This option involves the placement of additional members to help increase load capacity. Methodologies will vary with bridge type. A good rule-of-thumb, which is also in accordance with *The Secretary of the Interior's Standards,* is to sensitively add material but not to take historical material away. For stringer bridges or bridges with stringer/floorbeam flooring systems, this can include placing new beams between the interior beams and retaining the existing fascia beams (i.e., not a bridge/deck widening). This treatment should have no adverse effect. The same members can also be post-tensioned with rods or strands (see 6.7 Post-Tensioning below).

When analysis reveals that some of the truss bridge members require strengthening, consideration should be given to adding new members to take all or part of the load. For increasing the capacity of tension members, post-tensioning has proven to be cost effective when there is enough room at the panel points to accommodate the additional material. Additional material can be added to compression members, but, as with post-tensioning, the members must be large enough in the first place for this approach to be appropriate. Additional members can generally be added without shoring the bridge, but then the new members will only support live loads. One way for additional members to support dead load is to add them prior to the placement of a new deck so that the dead load is now shared by the existing and new members. The new members should be positioned in the least conspicuous location and not be visually intrusive. For truss bridges, it is also important to remember that new members must structurally tie into the existing joint/panel point connections. To install auxiliary members, a temporary means of supporting the existing trusses may be necessary.

6.4 Add Section to Existing Members

Shapes built-up from angles and plates (i.e., members like floorbeams, girders, and verticals, chords, and end posts on truss bridges) lend themselves well to being strengthened by using the conventional method of adding material to the flanges and webs. Adding section is a way to keep historic fabric in place, but it can also involve the removal of existing rivets and their subsequent replacement with high-strength bolts. If the rivets are visually prominent and it is important to preserve the historic appearance and mechanical connection, button-head bolts can be used. It is important to define which side will have the head and which will have the shank. If not specified, the contractor will generally do whichever is easiest, not which is best for the appearance of the bridge (Figure 2). The same treatment can be used to replacing/repairing deteriorated sections of built-up members.

6.5 In-Kind Replacement of Undersized or Deteriorated Members

Existing steel members can be replaced in-kind, wholly or in part, with steel members that have better material properties such as higher strength when the member being replaced is not the source of historical significance. This can be achieved without an adverse effect, but only when the replacement material is used in the same manner and configuration of the member it is replacing. How a particular bridge type performs, like the bending strength of a longitudinal beam resisting the live loads or how stresses are transferred at panel-point connections on a truss bridge, must be maintained since pinned and rigid connection designs handle stresses differently. Replacing a failed eye bar on a pin-connected bridge with a modern steel rod with end eyes that fit around the original pin is proper. While the appearance is different, the detail permits the bridge to continue to accommodate stresses as it was originally designed (Figure 2).

Figure 2 (below). Use of high-strength bolts to replace rivets. It is best to specify to which side to place the heads and the shanks to ensure a consistent appearance. In this example, some shanks are on the wrong side.

Figure 3 (left). Modern steel bars with end eyes that will fit around the original pins in the same manner and configuration of the members they are replacing.

6.6 Connections for In-Kind Replacement

When rivets at gusset plated panel points need to be replaced or when new section is being added to strengthen or replace deteriorated original fabric, high-strength bolts are generally an acceptable substitute, especially for bridges that remain on system and in service. Rivets do represent period technology, and they should be preserved whenever possible, but they are generally not what make a bridge historic. Selected replacement of rivets with high-strength bolts has been a generally accepted rehabilitation technique for decades. A bolt also provides a more fatigue-resistant, as well as a stronger and more reliable, connection. If appearance of the connection is important, a high-strength, button-head bolt can be used, but it is generally not necessary. What is important, however, is to define which side will have the head and which will have the shank. If not specified, the contractor will generally do whichever is easiest, not which is best for the appearance of the bridge (Figure 2).

On truss bridges, welding new or replacement members to a pin, or welding the pin itself, should never be done. It is an adverse effect, both from the historical and structural perspectives as it changes how the bridge performs. Welding will make the joint a rigid connection and will introduce bending moments for which the members were not originally designed. High residual stresses are then introduced, particularly into the tension members, and could lead to the initiation of cracks. Likewise, welding counters together to eliminate noise from vibration should not be done. Welding is seldom reversible since the base metal is permanently changed at the weld location, even if the weld itself is removed.

6.7 Post-Tensioning To Increase Load Carrying Capacity or Add Redundancy

When analysis reveals that truss bridge tension members, longitudinal beams or floorbeams require strengthening consideration should be given to adding new members to take part of the load. Post-tensioning consists of installing a post-tension cable or high-strength rod to reduce some of the dead load stress and transfer it to the post-tensioning system. It has proven to be a cost-effective means to increase load carrying capacity for undersized members or where redundancy is desired. This treatment is most appropriate for larger and heavier truss bridges (Figures 4, 5).

Figure 4 (left). Post-tensioned lower chord of pin-connected thru truss bridge. Note new members and guide placed between the eyebar packs.

Figure 5 (below). Post-tensioned floorbeam using standard high-strength rods. This increases the capacity of the floorbeam.

6.8 Strengthening by Reusing Part of Bridge and Placing New Superstructure for Live Loads

When load-carrying capacity and geometry are sufficiently low that widening or placing a new superstructure to carry live loads is warranted, there are treatments that, while not generally considered “best practices”, have gained acceptance because a high percentage of the historic metal bridge can be reused and preserved. These are treatments that the public has come to embrace as a way to balance preservation with the need to provide a safe and efficient transportation system. Often, reusing part of a historic steel bridge is the only prudent alternative given site conditions and other environmental considerations. Or, there may no prudent way to strengthen the bridge enough to meet the needs of the crossing without destroying what it is that made the bridge significant in the first place.

When approach road geometry and sight lines are adequate, there are many ways to widen a steel bridge. When the superstructure is underneath the deck, it is possible to preserve the historic beams in place and add additional beams in-kind to increase width. Stringer bridges can easily be widened by extending abutments/wingwalls and then placing additional beams. Another approach is to add cantilevered deck sections. In either of these approaches, railings may become an issue as they will need to be removed and replaced or reset (see Railings below). If possible, a parallel bridge can be constructed, leaving the historic bridge in place to carry one direction of traffic.

When widening a stringer or girder-floorbeam bridge is considered, the proposed treatment needs to be balanced against what is making the bridge historic. If, for example, the bridge is important as an early and complete example of continuous beams, it is the continuous beams that are the important feature. Consideration could be given to reusing historic beams as the fascia beams so that they are visible and reflect the original design of the historic bridge. This consideration is particularly important to continuous design and girder-floorbeam bridges.

Increasingly historic truss bridges are being reused as part of new stronger and wider stringer bridges. While this does change how the bridge supports loads and is not generally accepted as a “best practice,” it is nevertheless one that the public has come to embrace and demand as a way to “preserve” truss bridges. Consequently, it cannot be dismissed. Consideration needs to be given to ensure that any widening is still within a realistic sense of proportion for the original truss lines. Widening out a light, 60'-long pony truss from 18' to 40' by placing a new superstructure would be unrealistic where a 100'-long through truss might convincingly accommodate such a change. When widening trusses, be mindful of the original proportions and scale the widening accordingly.

In any fascia treatment, it is important for the fascia beams or truss lines to be more than decorative; they need to convey that they are load bearing, supporting at least themselves and some of the deck, whether that be sidewalks, safety walks or part of the shoulder. Relocated or reused fascia beams and truss lines need to convincingly relate to substructure units and be an integral part of the bridge. It is particularly important to retain enough of the floorbeams on truss bridges in order to make the connection to the new superstructure (Figure 6).

Figure 6. When attaching historic truss lines to a new superstructure make sure to retain a sufficient length of the floorbeams to facilitate attachment to the beams. The truss lines support themselves.

6. 9 Bearings

If the existing bearings on a steel beam or truss bridge are not functioning as designed and pose an imminent threat to the structure, they should be replaced. Bearings are not significant, and their replacement should be considered no adverse effect to the bridge. Replacement bearings, however, should function similar to the ones being replaced in how they accommodate rotation and expansion, and they should maintain the position of the superstructure.

7. Repair of Damaged Steel Bridge Components/Members

7.1 Heat Straighten Minor Damage

Over the past decades, research has demonstrated that instead of mechanical force, which can further damage a member or impose residual stresses, heat straightening can be an efficient and economical way to repair steel members that have been deformed as a result of impact damage. The technique is a procedure of applying repetitive heating and cooling cycles to produce a gradual straightening of the material. Its advantages are that it is economical as it does not require removal of the member nor temporary shoring. The work should be performed by skilled professionals as the location and the amount of heat is critical to the success of the process. Additionally, extreme care needs to be exercised to remove nicks and other defects so there is no chance of future fatigue or fracture occurring. In 2000, FHWA issued *Heat-Straightening Repairs of Damaged Steel Bridges: A Technical Guide and Manual of Practice.* More in-depth discussion of the technique can be found in the recently completed NCHRP 10-63: *Heat Straightening Repair of Damaged Steel Bridge Girders: Fatigue and Fracture Performance.*

7.2 Replace Section In Kind to Address Localized Impact Damage

In certain cases, it may be cost effective to remove damaged steel sections/members and splice in new material or to plate over a damaged section. When the affected members are not subjected to full live loading, the need for shoring is eliminated. Impact-damaged material is removed by flame cutting, and the adjacent remaining steel is ground smooth. A new steel section, similar in cross section to what was removed, can then be spliced to the existing member using bolts. Plating over damaged material typically involves adding steel plates using bolts to provide additional section to compensate for losses or holes. Refer to sections 6.5 and 6.6 for additional details on this treatment.

7.3 Raising Portal and Lateral Bracing to Increase Vertical Clearance

When analysis supports that it is structurally acceptable to do so, the lower strut and knee braces and lateral bracing can be raised to increase vertical clearance across a bridge. This is a common technique to preserve vulnerable members from impact damage, and it generally has no adverse effect on the bridge. It is also a technique that has been successfully used over the decades to resolve the very common problem of ever-increasing vertical overloading. It is also possible that the lower strut of many portal braces is already an in kind replacement of the original fabric. The raising, however, needs to be kept in scale with the overall proportions of the bridge, which means that less increase is possible on shorter and smaller spans than on longer and larger spans.

8. Appropriate Railing Treatments

8.1 Whenever Possible, Keep Original Railings Behind Crash Worthy Traffic Barriers

Railings on historic bridges are often substandard because they do not meet today's test level (TL) safety standards for crash worthiness (capability to effectively redirect an errant vehicle and to safely stop it in a controlled manner), adequacy of geometry and safety, or the guidelines for height. Most are too low and therefore do not guard against vehicle rollover. They are generally set back at less-than-the-required offset distance, increasing the probability of being struck by an errant vehicle. Some old railings can also create snagging and pocketing problems that result in excessive and unacceptable vehicular deceleration and damage.

While railings can be a visually important aspect of an old bridge, they are first and foremost a safety feature that has to meet the current safety requirements at the crossing. Safety is paramount, but that does not mean that all old railings have to be replaced. There are several effective practices for retaining original railings or placing new ones that are historically compatible and crashworthy.[1] Whenever possible, it is always preferred to leave the existing railings in place and then put a new crash-tested barrier system at the curbline in front of the old railings rather than remove and replace them. This practice works well when there are sidewalks and thus space for the traffic railing that segregates vehicular and pedestrian traffic, but any change in the width of sidewalks should comply with ADA requirements. There are many appropriate choices for crashworthy traffic railings including the TL-3 Kansas corral rails, several designs of tubular railings, and even powder-coated finish beam guide rail systems. There are also ways to achieve the desired stiffness by burying I beams in the horizontal members of architectonic railings such as Oregon DOT's "stealth" railings. Additionally, Eastern Federal Lands Highway Division has been a national leader in developing aesthetic railings that vary in TL rating (see footnote 1) (Figure 7).

8.2 Care Attaching Modern Guide Rail Systems

In many instances, there is no alternative but to attach the end of an approach guide rail system to the end posts of the old railings. Such attachments should be done in the least intrusive manner possible. Any plaques that are in the location of the attachment should be relocated to ensure their preservation and conservation (Figure 8).

---

[1] See http://www.efl.fhwa.dot.gov/technology-abs.aspx for plans, specifications, and crash test information for a variety of aesthetic railings developed or modified by Eastern Federal Lands. The TL ratings range from 1 through 3. At this point no photographs are included in the folder for each railings design, but the site is being updated. The railings are rated against FHWA requirements.

Figure 7. A crash tested traffic railing that blends well with many historic bridges is the Kansas coral railing, used here on the John Mack Bridge at Wichita, KS. Adding it to the historic bridge was no adverse effect.

Figure 8. Partridge Bridge, Maine, an example of new railings, inspired by, but not exact replicas of, the original. Note the detail for the acceptable attachment for the approach guide rails.

8.3 Consider Using Standards Other Than NCHRP 350

Replication of historic railings to meet crash test requirements is difficult because the older railings were not designed for modern design impact loads. Many configurations of railings have been crash tested, and approved railings can be found at http://www.efl.fhwa.dot.gov/technology-abs.aspx .

Some agencies use the AASHTO *Standard Specifications for Highway Bridges, 17th Edition* instead of NCHRP 350 to define safe bridge railings on historic bridges. Deficient railings on existing bridges can be replaced using designs that defer to the historic shape while meeting safety and load requirements specified in the *Standard Specifications*. States like Oregon use this approach to construct new reinforced concrete railings that resist snagging, are capable of withstanding a 10,000 pound horizontal force, and still look like the historic railings they replaced. This approach, which is used with FHWA and SHPO concurrence, provides the opportunity to design new railings that are visually historic while meeting the design load requirements for railing strength. When railings are truly an important part of the historic value of a bridge, this approach should be considered.

Figure 9. This is an appropriate, urban use of the crash-tested Texas Railing. It has proven to be a good replacement design for open balustrade railings used by many departments of transportation through the 1950s. This railing would not be appropriate for a rural setting because historically it was rarely used for non-urban bridges.

Often it is not possible to place a new traffic railing in front of an existing railing because of roadway/bridge width. In those instances, it is appropriate to construct new railings that defer to the historic ones with an aesthetically pleasing, contemporary design that is appropriate for the setting and bridge type and meets current safety requirements at the crossing. Existing reinforced concrete railings should be replaced in-kind as should open railings when that is possible. One approach is to find an appropriate crash-tested barrier, like the open balustrade Texas Railing (T411), that recalls the appearance of a commonly used historic design or to consult http://www.efl.fhwa.dot.gov/technology-abs.aspx. Another is to use inset panels on solid barriers to recall the pattern of the historic railing. Existing stone parapets can be rebuilt as reinforced concrete safety shape barriers to meet current codes and faced with a stone veneer. This approach, which is in keeping with the Secretary of the Interior's and National Park Service (NPS) guidance for working on historic structures, permits use of safer, stronger, and/or crash-tested railings. Nowhere does NPS guidance state that new work has to be an exact copy of what is being replaced (Figure 9).

The design of new railings or barriers should not create a false sense of history or rely on inappropriately applied decoration to mitigate the loss of the original treatment. Railing types should also match bridge type. For example, it is not acceptable to specify metal lattice traffic railings on an all reinforced concrete unit T beam bridge, which would have had open concrete railings or solid parapets, or the use of the Texas railing in a rural setting because it is an urban/suburban railing. Use of form liners as a way to decorate new work is not a best practice. It is better to make the new railings well proportioned and aesthetically compatible based on their intrinsic design rather than decorated.

Selected Bibliography

American Society of Civil Engineers. *Repairing and Strengthening Old Steel Truss Bridges - Procedures for Improving Bridge Behavior*.

Coney, William B. *15 Preservation Briefs: Preservation of Historic Concrete – Problems and General Approaches.* U.S. Dept. of the Interior, National Park Service, Cultural Resources, nd.

Federal Highway Administration. *Seismic Design and Retrofit Manual for Highway Bridges.* Report No. FHWA-IP-87-6. May 1987.

Federal Highway Administration. Eastern Federal Lands. "Aesthetic Barrier Systems." http://www.efl.fhwa.dot.gov/technology-abs.aspx (May, 2008).

Grimmer, Anne E., compiler. *A Glossary of Historic Masonry Deterioration Problems and Preservation Treatments*. U.S. Department of the Interior National Park Service. 1984.

Jester, Thomas, editor. *Twentieth-Century Building Materials History and Conservation.* The McGraw-Hill Companies, 1995.

Mack, Robert C. and John P. Speweik. *2 Preservation Briefs: Repointing Mortar Joints in Historic Masonry Buildings.* U.S. Department of the Interior, National Park Service, Cultural Resources, 1998. The 1998 brief updates the 1980 brief of the same name by Robert C. Mack, et al. It too is worth consulting.

Pullaro, Joe J. *Increasing the Capacity of Bridge Truss Tension Members via Post Tensioning Strands.* AREA (now AREMA) Bulletin #728, December, 1990.

Slaton, Deborah and Paul Gaudette. *15 Preservation Briefs: Preservation of Historic Concrete.* U.S. Department of the Interior, National Park Service, Historic Preservation Services, 2008.

Transportation Research Board. *Bridge Aesthetics Sourcebook*. May, 2008 (draft). Also see www.bridgeaesthetics.org.

Appendices

Appendix A.   2 Preservation Briefs: Repointing Mortar Joints in Historic Masonry Buildings

Appendix B. 6 Preservation Briefs: Dangers of Abrasive Cleaning to Historic Buildings

Appendix C. 15 Preservation Briefs: Preservation of Historic Concrete: Problems and General Approaches

Appendix A
2 Preservation Brief: Repointing Mortar Joints in Historic Masonry Buildings

2 Preservation Briefs

Technical Preservation Services
National Park Service
U.S. Department of the Interior

Repointing Mortar Joints in Historic Masonry Buildings

Robert C. Mack, FAIA, and John P. Speweik

A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

Masonry--brick, stone, terra-cotta, and concrete block--is found on nearly every historic building. Structures with all-masonry exteriors come to mind immediately, but most other buildings at least have masonry foundations or chimneys. Although generally considered "permanent," masonry is subject to deterioration, especially at the mortar joints. Repointing, also known simply as "pointing"or--somewhat inaccurately--"tuck pointing"*, is the process of removing deteriorated mortar from the joints of a masonry wall and replacing it with new mortar. Properly done, repointing restores the visual and physical integrity of the masonry. Improperly done, repointing not only detracts from the appearance of the building, but may also cause physical damage to the masonry units themselves.

The purpose of this Brief is to provide general guidance on appropriate materials and methods for repointing historic masonry buildings and it is intended to benefit building owners, architects, and contractors. The Brief should serve as a guide to prepare specifications for repointing historic masonry buildings. It should also help develop sensitivity to the particular needs of historic masonry, and to assist historic building owners in working cooperatively with architects, architectural conservators and historic preservation consultants, and contractors. Although specifically intended for historic buildings, the guidance is appropriate for other masonry buildings as well. This publication updates *Preservation Briefs 2: Repointing Mortar Joints in Historic Brick Buildings* to include all types of historic unit masonry. The scope of the earlier Brief has also been expanded to acknowledge that the many buildings constructed in the first half of the 20th century are now historic and eligible for listing in the National Register of

Historic Places, and that they may have been originally constructed with portland cement mortar.

**Tuckpointing technically describes a primarily decorative application of a raised mortar joint or lime putty joint on top of flush mortar joints.*

Historical Background

Mortar consisting primarily of lime and sand has been used as an integral part of masonry structures for thousands of years. Up until about the mid-19th century, lime or quicklime (sometimes called lump lime) was delivered to construction sites, where it had to be slaked, or combined with water. Mixing with water caused it to boil and resulted in a wet lime putty that was left to mature in a pit or wooden box for several weeks, up to a year. Traditional mortar was made from lime putty, or slaked lime, combined with local sand, generally in a ratio of 1 part lime putty to 3 parts sand by volume. Often other ingredients, such as crushed marine shells (another source of lime), brick dust, clay, natural cements, pigments, and even animal hair were also added to mortar, but the basic formulation for lime putty and sand mortar remained unchanged for centuries until the advent of portland cement or its forerunner, Roman cement, a natural, hydraulic cement.

Portland cement was patented in Great Britain in 1824. It was named after the stone from Portland in Dorset which it resembled when hard. This is a fast-curing, hydraulic cement which hardens under water. Portland cement was first manufactured in the United States in 1872, although it was imported before this date. But it was not in common use throughout the country until the early 20th century. Up until the turn of the century portland cement was considered primarily an additive, or "minor ingredient" to help accelerate mortar set time. By the 1930s, however, most masons used a mix of equal parts portland cement and lime putty. Thus, the mortar found in masonry structures built between 1873 and 1930 can range from pure lime and sand mixes to a wide variety of lime, portland cement, and sand combinations.

In the 1930s more new mortar products intended to hasten and simplify masons' work were introduced in the U.S. These included **masonry cement**, a premixed, bagged mortar which is a combination of portland cement and ground limestone, and **hydrated lime**, machine-slaked lime that eliminated the necessity of slaking quicklime into putty at the site.

Identifying the Problem Before Repointing

The decision to repoint is most often related to some obvious sign of deterioration, such as disintegrating mortar, cracks in mortar joints, loose bricks or stones, damp walls, or damaged plasterwork. It is, however, erroneous to assume that repointing alone will solve deficiencies that result from other problems. The root cause of the deterioration--leaking roofs or gutters, differential settlement of the building, capillary action causing rising damp, or extreme weather exposure--should always be dealt with prior to beginning work.

Without appropriate repairs to eliminate the source of the problem, mortar deterioration will continue and any repointing will have been a waste of time and money.

Use of Consultants. Because there are so many possible causes for deterioration in historic buildings, it may be desirable to retain a consultant, such as a historic architect or architectural conservator, to analyze the building. In addition to determining the most appropriate solutions to the problems, a consultant can prepare specifications which reflect the particular requirements of each job and can provide oversight of the work in progress. Referrals to preservation consultants frequently can be obtained from State Historic Preservation Offices, the American Institute for Conservation of Historic and Artistic Works (AIC), the Association for Preservation Technology (APT), and local chapters of the American Institute of Architects (AIA).

Masons practice using lime putty mortar to repair historic marble. Photo: NPS files.

Finding an Appropriate Mortar Match

Preliminary research is necessary to ensure that the proposed repointing work is both physically and visually appropriate to the building. Analysis of unweathered portions of the historic mortar to which the new mortar will be matched can suggest appropriate mixes for the repointing mortar so that it will not damage the building because it is excessively strong or vapor impermeable.

This late 19th century granite has recently been repointed with the joint profile and mortar color carefully matched to the original. Photo: NPS files.

Examination and analysis of the masonry units--brick, stone or terra cotta--and the techniques used in the original construction will assist in maintaining the building's historic appearance. A simple, non-technical, evaluation of the masonry units and mortar can provide information concerning the relative strength and permeability of each--critical factors in selecting the repointing mortar--while a visual analysis of the historic mortar can provide the information necessary for developing the new mortar mix and application techniques.

Although not crucial to a successful repointing project, for projects involving properties of special historic significance, a mortar analysis by a qualified laboratory can be useful by providing information on the original ingredients. However, there are limitations with such an analysis, and replacement mortar specifications should not be based solely on laboratory analysis. Analysis requires interpretation, and there are important factors which affect the condition and performance of the mortar that cannot be established through laboratory analysis. These may include: the original water content, rate of curing, weather conditions during original construction, the method of mixing and placing the mortar, and the cleanliness and condition of the sand. *The most useful information that can come out of laboratory analysis is the identification of sand by gradation and color.* This allows the color and the texture of the mortar to be matched with some accuracy because sand is the largest ingredient by volume.

In creating a repointing mortar that is compatible with the masonry units, the objective is to achieve one that matches the historic mortar as closely as possible, so that the new material can coexist with the old in a sympathetic, supportive and, if necessary, sacrificial capacity. The exact physical and chemical properties of the historic mortar are not of major significance as long as the new mortar conforms to the following criteria:

- The new mortar must match the historic mortar in **color, texture and tooling.** (If a laboratory analysis is undertaken, it may be possible to match the binder components and their proportions with the historic mortar, if those materials are available.)
- The **sand must match the sand** in the historic mortar. (The color and texture of

the new mortar will usually fall into place if the sand is matched successfully.)

- The new mortar must have **greater vapor permeability** and be **softer** (measured in compressive strength) than the masonry units.
- The new mortar must be **as vapor permeable** and **as soft or softer** (measured in compressive strength) than the historic mortar. (Softness or hardness is not necessarily an indication of permeability; old, hard lime mortars can still retain high permeability.)

This mortar is the proper consistency for repointing historic brick. Photo: John P. Speweik.

Mortar Analysis

Methods for analyzing mortars can be divided into two broad categories: **wet chemical** and **instrumental.** Many laboratories that analyze historic mortars use a simple **wet-chemical** method called acid digestion, whereby a sample of the mortar is crushed and then mixed with a dilute acid. The acid dissolves all the carbonate-containing minerals not only in the binder, but also in the aggregate (such as oyster shells, coral sands, or other carbonate-based materials), as well as any other acid-soluble materials. The sand and fine-grained acid-insoluble material is left behind. There are several variations on the simple acid digestion test. One involves collecting the carbon dioxide gas given off as the carbonate is digested by the acid; based on the gas volume the carbnate content of the mortar can be accurately determined (Jedrzejewska, 1960). Simple acid digestion methods are rapid, inexpensive, and easy to perform, but the information they provide about the original composition of a mortar is limited to the color and texture of the sand. The gas collection method provides more information about the binder than a simple acid digestion test.

Instrumental analysis methods that have been used to evaluate mortars include polarized light or thin-section microscopy, scanning electron microscopy, atomic absorption spectroscopy, X-ray diffraction, and differential thermal analysis. All instrumental methods require not only expensive, specialized equipment, but also highly-trained experienced analysts. However, instrumental methods can provide much more information about a mortar. Thin-section microscopy is probably the most commonly used instrumental method. Examination of thin slices of a mortar in transmitted light is often used to supplement acid digestion methods, particularly to look for carbonate-based aggregate. For example, the new ASTM test method, ASTM C 1324-96 "Test Method for Examination and Analysis of Hardened Mortars" which was designed specifically for the analysis of modern lime-cement and masonry cement mortars, combines a complex series of wet chemical analyses with thin-section microscopy.

The drawback of most mortar analysis methods is that mortar samples of known composition have not been analyzed in order to evaluate the method. Historic mortars were not prepared to narrowly defined specifications from materials of uniform quality; they contain a wide array of locally derived materials combined at the discretion of the mason. While a particular method might be able to accurately determine the original proportions of a lime-cement-sand mortar prepared from modern materials, the usefulness of that method for evaluating historic mortars is questionable unless it has been tested against mortars prepared from materials more commonly used in the past. **Lorraine Schnabel.**

Properties of Mortar

Mortars for repointing should be softer or more permeable than the masonry units and no harder or more impermeable than the historic mortar to prevent damage to the masonry units. It is a common error to assume that hardness or high strength is a measure of appropriateness, particularly for lime-based historic mortars. Stresses within a wall caused by expansion, contraction, moisture migration, or settlement must be accommodated in some manner; in a masonry wall, these stresses should be relieved by the mortar rather than by the masonry units. A mortar that is stronger in compressive strength than the masonry units will not "give," thus causing stresses to be relieved through the masonry units--resulting in permanent damage to the masonry, such as cracking and spalling, that cannot be repaired easily.

This early 19th century building is being repointed with lime mortar. Photo: Travis McDonald.

While stresses can also break the bond between the mortar and the masonry units, permitting water to penetrate the resulting hairline cracks, this is easier to correct in the joint through repointing than if the break occurs in the masonry units.

Permeability, or rate of vapor transmission, is also critical. High lime mortars are more permeable than denser cement mortars. Historically, mortar acted as a bedding material--not unlike an expansion joint--rather than a "glue" for the masonry units, and moisture was able to migrate through the mortar joints rather than the masonry units. When moisture evaporates from the masonry it deposits any soluble salts either on the surface as *efflorescence* or below the surface as *subflorescence.* While salts deposited on the surface of masonry units are usually relatively harmless, salt crystallization within a masonry unit creates pressure that can cause parts ofthe outer surface to spall off or delaminate. If the mortar does not permitmoisture or moisture vapor to migrate out of the wall and evaporate, theresult will be damage to the masonry units.

Components of Mortar

Sand. Sand is the largest component of mortar and the material that gives mortar its distinctive color, texture and cohesiveness. Sand must be free of impurities, such as salts or clay. The three key characteristics of sand are: particle shape, gradation and void ratios.

When viewed under a magnifying glass or low-power microscope, particles of sand generally have either rounded edges, such as found in beach and river sand, or sharp, angular edges, found in crushed or manufactured sand. For repointing mortar, rounded or natural sand is preferred for two reasons. It is usually similar to the sand in the historic mortar and provides a better visual match. It also has better working qualities or plasticity and can thus be forced into the joint more easily, forming a good contact with the remaining historic mortar and the surface of the adjacent masonry units. Although manufactured sand is frequently more readily available, it is usually possible to locate a supply of rounded sand.

The gradation of the sand (particle size distribution) plays a very important role in the durability and cohesive properties of a mortar. Mortar must have a certain percentage of large to small particle sizes in order to deliver the optimum performance. Acceptable guidelines on particle size distribution may be found in ASTM C 144 (American Society for Testing and Materials). However, in actuality, since neither historic nor modern sands are always in compliance with ASTM C 144, matching the same particle appearance and gradation usually requires sieving the sand.

A scoop of sand contains many small voids between the individual grains. A mortar that performs well fills all these small voids with binder (cement/lime combination or mix) in a balanced manner. Well-graded sand generally has a 30 per cent void ratio by volume. Thus, 30 per cent binder by volume generally should be used, unless the historic mortar had a different binder: aggregate ratio. This represents the 1:3 binder to sand ratios often seen in mortar specifications.

For repointing, sand generally should conform to ASTM C 144 to assure proper gradation and freedom from impurities; some variation may be necessary to match the original size and gradation. Sand color and texture also should match the original as closely as possible to provide the proper color match without other additives.

Lime. Mortar formulations prior to the late-19th century used lime as the primary binding material. Lime is derived from heating limestone at high temperatures which burns off the carbon dioxide, and turns the limestone into quicklime. There are three types of limestone--calcium, magnesium, and dolomitic--differentiated by the different levels of magnesium carbonate they contain which impart specific qualities to mortar. Historically, calcium lime was used for mortar rather than the dolomitic lime (calcium magnesium carbonate) most often used today. But it is also important to keep in mind the fact that the historic limes, and other components of mortar, varied a great deal because they were natural, as opposed to modern lime which is manufactured and, therefore, standardized. Because some of the kinds of lime, as well as other components of mortar, that were used historically are no longer readily available, even when a conscious effort is made to replicate a "historic" mix, this may not be achievable due to the differences between modern and historic materials.


Caulking was inappropriately used here in place of mortar on the top of the wall. As a result, it has not been durable. Photo: NPS files.

Lime, itself, when mixed with water into a paste is very plastic and creamy. It will remain workable and soft indefinitely, if stored in a sealed container. Lime (calcium hydroxide) hardens by carbonation absorbing carbon dioxide primarily from the air, converting itself to calcium carbonate. Once a lime and sand mortar is mixed and placed in a wall, it begins the process of carbonation. If lime mortar is left to dry too rapidly, carbonation of the mortar will be reduced, resulting in poor adhesion and poor durability. In addition, lime mortar is slightly water soluble and thus is able to re-seal any hairline cracks that may develop during the life of the mortar. Lime mortar is soft, porous, and changes little in volume during temperature fluctuations thus making it a good choice for historic buildings. *Because of these qualities, high calcium lime mortar may be considered for many repointing projects, not just those involving historic buildings.*

For repointing, lime should conform to ASTM C 207, Type S, or Type SA, Hydrated Lime for Masonry Purposes. This machine-slaked lime is designed to assure high plasticity and water retention. The use of quicklime which must be slaked and soaked by hand may have advantages over hydrated lime in some restoration projects if time and money allow.

Lime putty. Lime putty is slaked lime that has a putty or paste-like consistency. It should conform to ASTM C 5. Mortar can be mixed using lime putty according to ASTM C 270 property or proportion specification.

Portland cement. More recent, 20th-century mortar has used portland cement as a primary binding material. A straight portland cement and sand mortar is extremely hard, resists the movement of water, shrinks upon setting, and undergoes relatively large thermal movements. When mixed with water, portland cement forms a harsh, stiff paste that is quite unworkable, becoming hard very quickly. (Unlike lime, portland cement will harden regardless of weather conditions and does not require wetting and drying cycles.) Some portland cement assists the workability and plasticity of the mortar without adversely affecting the finished project; it also provides early strength to the mortar and speeds setting. Thus, it may be appropriate to add some portland cement to an essentially lime-based mortar even when repointing relatively soft 18th or 19th century brick under some circumstances when a slightly harder mortar is required. The more portland cement that is added to a mortar formulation the harder it becomes--and the faster the initial set.

For repointing, portland cement should conform to ASTM C 150. White, non- staining portland cement may provide a better color match for some historic mortars than the more commonly available grey portland cement. But, it should not be assumed, however, that white portland cement is always appropriate for all historic buildings, since the original mortar may have been mixed with grey cement. The cement should not have more than 0.60 per cent alkali to help avoid efflorescence.

Masonry cement. Masonry cement is a preblended mortar mix commonly found at hardware and home repair stores. It is designed to produce mortars with a compressive strength of 750 psi or higher when mixed with sand and water at the job site. It may contain hydrated lime, but it always contains a large amount of portland cement, as well as ground limestone and other workability agents, including air-entraining agents. Because masonry cements are not required to contain hydrated lime, and generally do not contain lime, they produce high strength mortars that can damage historic masonry. *For this reason, they generally are not recommended for use on historic masonry buildings.*

Lime mortar (pre-blended). Hydrated lime mortars, and pre-blended lime putty mortars with or without a matched sand are commercially available. Custom mortars are also available with color. In most instances, pre-blended lime mortars containing sand may not provide an exact match; however, if the project calls for total repointing, a pre-blended lime mortar may be worth considering as long as the mortar is compatible in strength with the masonry. If the project involves only selected, "spot" repointing, then it may be better to carry out a mortar analysis which can provide a custom pre-blended lime mortar with a matching sand. In either case, if a preblended lime mortar is to be used, it should contain Type S or SA hydrated lime conforming to ASTM C 207.

Water. Water should be potable--clean and free from acids, alkalis, or other dissolved organic materials.

Other Components

Historic components. In addition to the color of the sand, the texture of the mortar is of critical importance in duplicating historic mortar. Most mortars dating from the mid-19th century on--with some exceptions--have a fairly homogeneous texture and color. Some earlier mortars are not as uniformly textured and may contain lumps of partially burned lime or "dirty lime", shell (which often provided a source of lime, particularly in coastal areas), natural cements, pieces of clay, lampblack or other pigments, or even animal hair. The visual characteristics of these mortars can be duplicated through the use of similar materials in the repointing mortar.

Replicating such unique or individual mortars will require writing new specifications for each project. If possible, suggested sources for special materials should be included. For example, crushed oyster shells can be obtained in a variety of sizes from poultry supply dealers.

Pigments. Some historic mortars, particularly in the late 19th century, were tinted to match or contrast with the brick or stone. Red pigments, sometimes in the form of brick dust, as well as brown, and black pigments were commonly used. Modern pigments are available which can be added to the mortar at the job site, but they should not exceed 10 per cent by weight of the portland cement in the mix, and carbon black should be limited to 2 per cent. Only synthetic mineral oxides, which are alkali-proof and sun-fast, should be used to prevent bleaching and fading.

Modern components. Admixtures are used to create specific characteristics in mortar, and whether they should be used will depend upon the individual project. *Air entraining agents*, for example, help the mortar to resist freeze-thaw damage in northern climates. *Accelerators* are used to reduce mortar freezing prior to setting while *retarders* help to extend the mortar life in hot climates. Selection of admixtures should be made by the architect or architectural conservator as part of the specifications, not something routinely added by the masons.

Generally, modern chemical additives are unnecessary and may, in fact, have detrimental effects in historic masonry projects. The use of antifreeze compounds is not recommended. They are not very effective with high lime mortars and may introduce salts, which may cause efflorescence later. A better practice is to warm the sand and water, and to protect the completed work from freezing. No definitive study has determined whether air-entraining additives should be used to resist frost action and enhance plasticity, but in areas of extreme exposure requiring high-strength mortars with lower permeability, air-entrainment of 10-16 percent may be desirable (see formula for "severe weather exposure" in **Mortar Type and Mix**). Bonding agents are not a substitute for proper joint preparation, and they should generally be avoided. If the joint is properly prepared, there will be a good bond between the new mortar and the adjacent surfaces. In addition, a bonding agent is difficult to remove if smeared on a masonry surface.

Mortar Type and Mix

Mortars for repointing projects, especially those involving historic buildings, typically are custom mixed in order to ensure the proper physical and visual qualities. These materials can be combined in varying proportions to create a mortar with the desired performance and durability. The actual specification of a particular mortar type should take into consideration all of the factors affecting the life of the building including: current site conditions, present condition of the masonry, function of the new mortar, degree of weather exposure, and skill of the mason.

Here, a hammer and chisel are being correctly

Thus, no two repointing projects are exactly the same. Modern materials specified for use in repointing mortar should conform to specifications of the American Society for Testing and Materials (ASTM) or comparable federal specifications, and the resulting mortar should conform to ASTM C 270, Mortar for Unit Masonry.

Specifying the proportions for the repointing mortar for a specific job is not as difficult as it might seem. Five mortar types, each with a corresponding recommended mix, have been established by ASTM to distinguish high strength mortar from soft flexible mortars. The ASTM designated them in decreasing order of approximate general strength as Type M (2,500 psi), Type S (1,800 psi), Type N (750 psi), Type O (350 psi) and Type K (75 psi). (The letters identifying the types are from the words MASON WORK using every other letter.) Type K has the highest lime

used to prepare a joint for repointing. Photo: John P. Speweik.

content of the mixes that contain portland cement, although it is seldom used today, except for some historic preservation projects. The designation "L" in the accompanying chart identifies a straight lime and sand mix. Specifying the appropriate ASTM mortar by proportion of ingredients, will ensure the desired physical properties. Unless specified otherwise, measurements or proportions for mortar mixes are always given in the following order: cement-lime-sand. Thus, a Type K mix, for example, would be referred to as 1-3-10, or 1 part cement to 3 parts lime to 10 parts sand. Other requirements to create the desired visual qualities should be included in the specifications.

The strength of a mortar can vary. If mixed with higher amounts of portland cement, a harder mortar is obtained. The more lime that is added, the softer and more plastic the mortar becomes, increasing its workability. A mortar strong in compressive strength might be desirable for a hard stone (such as granite) pier holding up a bridge deck, whereas a softer, more permeable lime mortar would be preferable for a historic wall of soft brick. Masonry deterioration caused by salt deposition results when the mortar is less permeable than the masonry unit. A strong mortar is still more permeable than hard, dense stone. However, in a wall constructed of soft bricks where the masonry unit itself has a relatively high permeability or vapor transmission rate, a soft, high lime mortar is necessary to retain sufficient permeability.

Budgeting and Scheduling

Repointing is both expensive and time consuming due to the extent of handwork and special materials required. It is preferable to repoint only those areas that require work rather than an entire wall, as is often specified. But, if 25 to 50 per cent or more of a wall needs to be repointed, repointing the entire wall may be more cost effective than spot repointing.

Total repointing may also be more sensible when access is difficult, requiring the erection of expensive scaffolding (unless the majority of the mortar is sound and unlikely to require replacement in the foreseeable future). Each project requires judgement based on a variety of factors. Recognizing this at the outset will help to prevent many jobs from becoming prohibitively expensive.

When repairing this stone wall, the mason matched the raised profile of the original tuckpointing. Photo: NPS files.

In scheduling, seasonal aspects need to be considered first. Generally speaking, wall temperatures between 40 and 95 degrees F (8 and 38 degrees C) will prevent freezing or excessive evaporation of the water in the mortar. Ideally, repointing should be done in shade, away from strong sunlight in order to slow the drying process, especially during hot weather. If necessary, shade can be provided for large-scale projects with appropriate modifications to scaffolding.

The relationship of repointing to other work proposed on the building must also be recognized. For example, if paint removal or cleaning is anticipated, and if the mortar joints are basically sound and need only selective repointing, it is generally better to postpone repointing until after completion of these activities. However, if the mortar has eroded badly, allowing moisture to penetrate deeply into the wall, repointing should be accomplished before cleaning. Related work, such as structural or roof repairs, should be scheduled so that they do not interfere with repointing and so that all work can take maximum advantage of erected scaffolding.

Building managers also must recognize the difficulties that a repointing project can create.

A mechanical grinder improperly used to cut out the horizontal joint and incompatible repointing have seriously damaged the 19th century brick. Photo: NPS files.

The process is time consuming, and scaffolding may need to remain in place for an extended period of time. The joint preparation process can be quite noisy and can generate large quantities of dust which must be controlled, especially at air intakes to protect human health, and also where it might damage operating machinery. Entrances may be blocked from time to time making access difficult for both building tenants and visitors. Clearly, building managers will need to coordinate the repointing work with other events at the site.

Contractor Selection

The ideal way to select a contractor is to ask knowledgeable owners of recently repointed historic buildings for recommendations. Qualified contractors then can provide lists of other repointing projects for inspection. More commonly, however, the contractor for a repointing project is selected through a competitive bidding process over which the client or consultant has only limited control. In this situation it is important to ensure that the specifications stipulate that masons must have a minimum of five years' experience with repointing historic masonry buildings to be eligible to bid on the project. Contracts are awarded to the lowest responsible bidder, and bidders who have performed poorly on other projects usually can be eliminated from consideration on this basis, even if they have the lowest prices.

The contract documents should call for unit prices as well as a base bid. Unit pricing forces the contractor to determine in advance what the cost addition or reduction will be for work which varies from the scope of the base bid. If, for example, the contractor has fifty linear feet less of stone repointing than indicated on the contract documents but thirty linear feet more of brick repointing, it will be easy to determine the final price for the work. Note that each type of work--brick repointing, stone repointing, or similar items--will have its own unit price. The unit price also should reflect quantities; one linear foot of pointing in five different spots will be more expensive than five contiguous linear feet.

Execution of the Work

Test Panels. These panels are prepared by the contractor using the same techniques that will be used on the remainder of the project. Several panel locations--preferably not on the front or other highly visible location of the building--may be necessary to include all types of masonry, joint styles, mortar colors, and other problems likely to be encountered on the job.

If cleaning tests, for example, are also to be undertaken, they should be carried out in the same location. Usually a 3 foot by 3 foot area is sufficient for brickwork, while a somewhat larger area may be required for stonework. These panels establish an acceptable standard of work and serve as a benchmark for evaluating and accepting subsequent work on the building.

Joint Preparation. Old mortar should be removed to a minimum depth of 2 to 2-1/2 times the width of the joint to ensure an adequate bond and to prevent mortar "popouts." For most brick joints, this will require removal of the mortar to a depth of approximately ½ to 1 inch; for stone masonry with wide joints, mortar may need to be removed to a depth of several inches. Any loose or disintegrated mortar beyond this minimum depth also should be removed.

Although some damage may be inevitable, careful joint preparation can help limit damage to masonry units. The traditional manner of removing old mortar is through the use of hand chisels and mash hammers. Though labor-intensive, in most instances this method poses the least threat for damage to historic masonry units and produces the best final product.


Unskilled repointing has negatively impacted the character of this late-19th century building. Photo: NPS files.

The most common method of removing mortar, however, is through the use of power saws or grinders. The use of power tools by unskilled masons can be disastrous for historic masonry, particularly soft brick. Using power saws on walls with thin joints, such as most brick walls, almost always will result in damage to the masonry units by breaking the edges and by overcutting on the head, or vertical joints.

However, small pneumatically-powered chisels generally can be used safely and effectively to remove mortar on historic buildings as long as the masons maintain appropriate control over the equipment. Under certain circumstances, thin diamond-bladed grinders may be used to cut out *horizontal* joints only on hard portland cement mortar common to most early-20th century masonry buildings. Usually, automatic tools most successfully remove old mortar without damaging the masonry units when they are used in combination with hand tools in preparation for repointing. Where horizontal joints are uniform and fairly wide, it may be possible to use a power masonry saw to assist the removal of mortar, such as by cutting along the middle of the joint; final mortar removal from the sides of the joints still should be done with a hand chisel and hammer. Caulking cutters with diamond blades can sometimes be used successfully to cut out joints without damaging the masonry. Caulking cutters are slow; they do not rotate, but vibrate at very high speeds, thus minimizing the possibility of damage to masonry units. Although mechanical tools may be safely used in limited circumstances to cut out horizontal joints in preparation for repointing, they should never be used on vertical joints because of the danger of slipping and cutting into the brick above or below the vertical joint. Using power tools to remove mortar without damaging the surrounding masonry units also necessitates highly skilled masons experienced in working on historic masonry buildings. Contractors should demonstrate proficiency with power tools before their use is approved.

Using any of these power tools may also be more acceptable on hard stone, such as quartzite or granite, than on terra cotta with its glass-like glaze, or on soft brick or stone. The test panel should determine the acceptability of power tools. If power tools are to be permitted, the contractor should establish a quality control program to account for worker fatigue and similar variables.

Mortar should be removed cleanly from the masonry units, leaving square corners at the back of the cut. Before filling, the joints should be rinsed with a jet of water to remove all loose particles and dust. At the time of filling, the joints should be damp, but with no standing water present. For masonry walls--limestone, sandstone and common brick--that are extremely absorbent, it is recommended that a continual mist of water be applied for a few hours before repointing begins.

Mortar Preparation. Mortar components should be measured and mixed carefully to assure the uniformity of visual and physical characteristics. Dry ingredients are measured by volume and thoroughly mixed before the addition of any water. Sand must be added in a damp, loose condition to avoid over sanding. Repointing mortar is typically pre-hydrated by adding water so it will just hold together, thus allowing it to stand for a period of time before the final water is added. Half the water should be added, followed by mixing for approximately 5 minutes. The remaining water should then be added in small portions until a mortar of the desired consistency is reached. The total volume of water necessary may vary from batch to batch, depending on weather conditions. It is important to keep the water to a minimum for two reasons: first, a drier mortar is cleaner to work with, and it can be compacted tightly into the joints; second, with no excess water to evaporate, the mortar cures without shrinkage cracks. Mortar should be used within approximately 30 minutes of final mixing, and "retempering," or adding more water, should not be permitted.

Using Lime Putty to Make Mortar. Mortar made with lime putty and sand, sometimes referred to as roughage or course stuff, should be measured by volume, and may require slightly different proportions from those used with hydrated lime. No additional water is usually needed to achieve a workable consistency because enough water is already contained in the putty. Sand is proportioned first, followed by the lime putty, then mixed for five minutes or until all the sand is thoroughly coated with the lime putty. But mixing, in the familiar sense of turning over with a hoe, sometimes may not be sufficient if the best possible performance is to be obtained from a lime putty mortar. Although the old practice of chopping, beating and ramming the mortar has largely been forgotten, recent field work has confirmed that lime putty and sand rammed and beaten with a wooden mallet or ax handle, interspersed by chopping with a hoe, can significantly improve workability and performance. The intensity of this action increases the overall lime/sand contact and removes any surplus water by compacting the other ingredients. It may also be advantageous for larger projects to use a mortar pan mill for mixing. Mortar pan mills which have a long tradition in Europe produce a superior lime putty mortar not attainable with today's modern paddle and drum type mixers.

For larger repointing projects the lime putty and sand can be mixed together ahead of time and stored indefinitely, on or off site, which eliminates the need for piles of sand on the job site. This mixture, which resembles damp brown sugar, must be protected from the air in sealed containers with a wet piece of burlap over the top or sealed in a large plastic bag to prevent evaporation and premature carbonation. The lime putty and sand mixture can be recombined into a workable plastic state months later with no additional water.

If portland cement is specified in a lime putty and sand mortar--Type O (1:2:9) or Type K (1:3:11)--the portland cement should first be mixed into a slurry paste before adding it to the lime putty and sand. Not only will this ensure that the portland cement is evenly distributed throughout the mixture, but if dry portland cement is added to wet ingredients it tends to "ball up," jeopardizing dispersion. (Usually water must be added to the lime putty and sand anyway once the portland cement is introduced.) Any color pigments should be added at this stage and mixed for a full five minutes. The mortar should be used within 30 minutes to 1½ hours and it should not be retempered. Once portland cement has been added the mortar can no longer be stored.

Filling the Joint. Where existing mortar has been removed to a depth of greater than 1 inch, these deeper areas should be filled first, compacting the new mortar in several layers. The back of the entire joint should be filled successively by applying approximately 1/4 inch of mortar, packing it well into the back corners. This application may extend along the wall for several feet. As soon as the mortar has reached thumb-print hardness, another 1/4 inch layer of mortar--approximately the same thickness--may be applied. Several layers will be needed to fill the joint flush with the outer surface of the masonry. It is important to allow each layer time to harden before the next layer is applied; most of the mortar shrinkage occurs during the hardening process and layering thus minimizes overall shrinkage.

When the final layer of mortar is thumb-print hard, the joint should be tooled to match the historic joint. Proper timing of the tooling is important for uniform color and appearance. If tooled when too soft, the color will be lighter than expected, and hairline cracks may occur; if tooled when too hard, there may be dark streaks called "tool burning," and good closure of the mortar against the masonry units will not be achieved.

If the old bricks or stones have worn, rounded edges, it is best to recess the final mortar slightly from the face of the masonry. This treatment will help avoid a joint which is visually wider than the actual joint; it also will avoid creation of a large, thin featheredge which is easily damaged, thus admitting water. After tooling, excess mortar can be removed from the edge of the joint by brushing with a natural bristle or nylon brush. Metal bristle brushes should never be used on historic masonry.

Curing Conditions. The preliminary hardening of high-lime content mortars--those mortars that contain more lime by volume than portland cement, i.e., Type O (1:2:9), Type K (1:3:11), and straight lime/sand, Type "L" (0:1:3)--takes place fairly rapidly as water in the mix is lost to the porous surface of the masonry and through evaporation. A high lime mortar (especially Type "L") left to dry out too rapidly can result in chalking, poor adhesion, and poor durability. Periodic wetting of the repointed area after the mortar joints are thumb-print hard and have been finish tooled may significantly accelerate the carbonation process. When feasible, misting using a hand sprayer with a fine nozzle can be simple to do for a day or two after repointing. Local conditions will dictate the frequency of wetting, but initially it may be as often as every hour and gradually reduced to every three or four hours. Walls should be covered with burlap for the first three days after repointing. (Plastic may be used, but it should be tented out and not placed directly against the wall.) This helps keep the walls damp and protects them from direct sunlight. Once carbonation of the lime has begun, it will continue for many years and the lime will gain strength as it reverts back to calcium carbonate within the wall.

***Aging* the Mortar.** Even with the best efforts at matching the existing mortar color, texture, and materials, there will usually be a visible difference between the old and new work, partly because the new mortar has been matched to the unweathered portions of the historic mortar. Another reason for a slight mismatch may be that the sand is more exposed in old mortar due to the slight erosion of the lime or cement. Although spot repointing is generally preferable and some color difference should be acceptable, if the difference between old and new mortar is too extreme, it may be advisable in some instances to repoint an entire area of a wall, or an entire feature such as a bay, to minimize the difference between the old and the new mortar. If the mortars have been properly matched, usually the best way to deal with surface color differences is to let the mortars age naturally. Other treatments to overcome these differences, including cleaning the non-repointed areas or staining the new mortar, should be carefully tested prior to implementation.

This 18th century pediment and surrounding wall exhibit distinctively different mortar joints. Photo: NPS files.

Staining the new mortar to achieve a better color match is generally not recommended, but it may be appropriate in some instances. Although staining may provide an initial match, the old and new mortars may weather at different rates, leading to visual differences after a few seasons. In addition, the mixtures used to stain the mortar may be harmful to the masonry; for example, they may introduce salts into the masonry which can lead to efflorescence.

Cleaning the Repointed Masonry. If repointing work is carefully executed, there will be little need for cleaning other than to remove the small amount of mortar from the edge of the joint following tooling. This can be done with a stiff natural bristle or nylon brush after the mortar has dried, but before it is initially set (1-2 hours). Mortar that has hardened can usually be removed with a wooden paddle or, if necessary, a chisel.

Further cleaning is best accomplished with plain water and natural bristle or nylon brushes. If chemicals must be used, they should be selected with extreme caution. Improper cleaning can lead to deterioration of the masonry units, deterioration of the mortar, mortar smear, and efflorescence. New mortar joints are especially susceptible to damage because they do not become fully cured for several months. Chemical cleaners, particularly acids, should never be used on dry masonry. The masonry should always be completely soaked once with water before chemicals are applied. After cleaning, the walls should be flushed again with plain water to remove all traces of the chemicals.

Several precautions should be taken if a freshly repointed masonry wall is to be cleaned. First, the mortar should be fully hardened before cleaning. Thirty days is usually sufficient, depending on weather and exposure; as mentioned previously, the mortar will continue to cure even after it has hardened. Test panels should be prepared to evaluate the effects of different cleaning methods. Generally, on newly repointed masonry walls, only very low pressure (100 psi) water washing supplemented by stiff natural bristle or nylon brushes should be used, except on glazed or polished surfaces, where only soft cloths should be used.**

New construction "bloom" or efflorescence occasionally appears within the first few months of repointing and usually disappears through the normal process of weathering. If the efflorescence is not removed by natural processes, the safest way to remove it is by dry brushing with stiff natural or nylon bristle brushes followed by wet brushing. Hydrochloric (muriatic) acid, is generally ineffective, and it should not be used to remove efflorescence. It may liberate additional salts, which, in turn, can lead to more efflorescence.

Surface Grouting is sometimes suggested as an alternative to repointing brick buildings, in particular. This process involves the application of a thin coat of cement-based grout to the mortar joints and the mortar/brick interface. To be effective, the grout must extend slightly onto the face of the masonry units, thus widening the joint visually. The change in the joint appearance can alter the historic character of the structure to an unacceptable degree. In addition, although masking of the bricks is intended to keep the grout off the remainder of the face of the bricks, some level of residue, called "veiling," will inevitably remain. Surface grouting cannot substitute for the more extensive work of repointing, and it is not a recommended treatment for historic masonry.

***Additional information on masonry cleaning is presented in Preservation Briefs 1: Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings, Robert C. Mack, FAIA, and Anne Grimmer, Washington, D.C.: Technical Preservation Services, National Park Service, U.S. Department of the Interior, 2000; and Keeping it Clean: Removing Exterior Dirt, Paint, Stains & Graffiti from Historic Masonry Buildings, Anne E. Grimmer, Washington, D.C.: Technical Preservation Services, National Park Service, U.S. Department of the Interior, 1988.*

Visually Examining the Mortar and the Masonry Units

A simple *in situ* comparison will help determine the hardness and condition of the mortar and the masonry units. Begin by scraping the mortar with a screwdriver, and gradually tapping harder with a cold chisel and mason's hammer. Masonry units can be tested in the same way beginning, even more gently, by scraping with a fingernail. This relative analysis which is derived from the 10-point hardness scale used to describe minerals, provides a good starting point for selection of an appropriate mortar. It is described more fully in "The Russack System for Brick & Mortar Description" referenced in **Selected Reading** at the end of this Brief.

Mortar samples should be chosen carefully, and picked from a variety of locations on the building to find unweathered mortar, if possible. Portions of the building may have been repointed in the past while other areas may be subject to conditions causing unusual deterioration. There may be several colors of mortar dating from different construction periods or sand used from different sources during the initial construction. Any of these situations can give false readings to the visual or physical characteristics required for the new mortar. Variations should be noted which may require developing more than one mix.

1) Remove with a chisel and hammer three or four unweathered samples of the mortar to be matched from several locations on the building. (Set the largest sample aside--this will be used later for comparison with the repointing mortar). Removing a full representation of samples will allow selection of a "mean" or average mortar sample.

2) Mash the remaining samples with a wooden mallet, or hammer if necessary, until they are separated into their constituent parts. There should be a good handful of the material.

3) Examine the powdered portion--the lime and/or cement matrix of the mortar. Most particularly, note the color. There is a tendency to think of historic mortars as having white binders, but grey portland cement was available by the last quarter of the 19th century, and traditional limes were also sometimes grey. Thus, in some instances, the natural color of the historic binder may be grey, rather than white. The mortar may also have been tinted to create a colored mortar, and this color should be identified at this point.

4) Carefully blow away the powdery material (the lime and/or cement matrix which bound the mortar together).

5) With a low power (10 power) magnifying glass, examine the remaining sand and other materials such as lumps of lime or shell.

6) Note and record the wide range of color as well as the varying sizes of the individual grains of sand, impurities, or other materials.

Other Factors to Consider

Color. Regardless of the color of the binder or colored additives, the sand is the primary material that gives mortar its color. A surprising variety of colors of sand may be found in a single sample of historic mortar, and the different sizes of the grains of sand or other materials, such as incompletely ground lime or cement, play an important role in the texture of the repointing mortar. Therefore, when specifying sand for repointing mortar, it may be necessary to obtain sand from several sources and to combine or screen them in order to approximate the range of sand colors and grain sizes in the historic mortar sample.

Pointing Style. Close examination of the historic masonry wall and the techniques used in the original construction will assist in maintaining the visual qualities of the building. Pointing styles and the methods of producing them should be examined. It is important to look at both the horizontal and the vertical joints to determine the order in which they were tooled and whether they were the same style. Some late-19th and early-20th century buildings, for example, have horizontal joints that were raked back while the vertical joints were finished flush and stained to match the bricks, thus creating the illusion of horizontal bands. Pointing styles may also differ from one facade to another; front walls often received greater attention to mortar detailing than side and rear walls. **Tuckpointing** is not true repointing but the application of a raised joint or lime putty joint on top of flush mortar joints. **Penciling** is a purely decorative, painted surface treatment over a mortar joint, often in a contrasting color.

Masonry Units. The masonry units should also be examined so that any replacement units will match the historic masonry. Within a wall there may be a wide range of colors, textures, and sizes, particularly with hand-made brick or rough-cut, locally-quarried stone. Replacement units should blend in with the full range of masonry units rather than a single brick or stone.

Matching Color and Texture of the Repointing Mortar

New mortar should match the unweathered interior portions of the historic mortar. The simplest way to check the match is to make a small sample of the proposed mix and allow it to cure at a temperature of approximately 70 degrees F for about a week, or it can be baked in an oven to speed up the curing; this sample is then broken open and the surface is compared with the surface of the largest "saved" sample of historic mortar.

If a proper color match cannot be achieved through the use of natural sand or colored aggregates like crushed marble or brick dust, it may be necessary to use a modern mortar pigment.

During the early stages of the project, it should be determined how closely the new mortar should match the historic mortar. Will "quite close" be sufficient, or is "exactly" expected? The specifications should state this clearly so that the contractor has a reasonable idea how much time and expense will be required to develop an acceptable match.

The same judgment will be necessary in matching replacement terra cotta, stone or brick. If there is a known source for replacements, this should be included in the specifications. If a source cannot be determined prior to the bidding process, the specifications should include an estimated price for the replacement materials with the final price based on the actual cost to the contractor.

Mortar Types (Measured by volume)			
Designation	Cement	Hydrated Lime or Lime Putty	Sand
M	1	1/4	3 - 3 3/4
S	1	1/2	4 - 4 1/2
N	1	1	5 - 6
O	1	2	8 - 9
K	1	3	10 - 12
"L"	0	1	2 1/4 - 3

Suggested Mortar Types for Different Exposures			
	Exposure		
Masonry Material	Sheltered	Moderate	Severe
Very durable: granite, hard-cored brick, etc.	O	N	S
Moderately durable: limestone, durable stone, molded brick	K	O	N
Minimally durable: soft hand-made brick	"L"	K	O

Summary

For the Owner/Administrator. The owner or administrator of a historic building should remember that repointing is likely to be a lengthy and expensive process. First, there must be adequate time for evaluation of the building and investigation into the cause of problems. Then, there will be time needed for preparation of the contract documents. The work itself is precise, time-consuming and noisy, and scaffolding may cover the face of the building for some time. Therefore, the owner must carefully plan the work to avoid problems. Schedules for both repointing and other activities will thus require careful coordination to avoid unanticipated conflicts. The owner must avoid the tendency to rush the work or cut corners if the historic building is to retain its visual integrity and the job is to be durable.

For the Architect/Consultant. Because the primary role of the consultant is to ensure the life of the building, a knowledge of historic construction techniques and the special problems found in older buildings is essential. The consultant must assist the owner in planning for logistical problems relating to research and construction. It is the consultant's responsibility to determine the cause of the mortar deterioration and ensure that it is corrected before the masonry is repointed. The consultant must also be prepared to spend more time in project inspections than is customary in modern construction.

For the Masons. Successful repointing depends on the masons themselves. Experienced masons understand the special requirements for work on historic buildings and the added time and expense they require. The entire masonry crew must be willing and able to perform the work in conformance with the specifications, even when the specifications may not be in conformance with standard practice. At the same time, the masons should not hesitate to question the specifications if it appears that the work specified would damage the building.

Conclusion

A good repointing job is meant to last, at least 30 years, and preferably 50- 100 years. Shortcuts and poor craftsmanship result not only in diminishing the historic character of a building, but also in a job that looks bad, and will require future repointing sooner than if the work had been done correctly. The mortar joint in a historic masonry building has often been called a wall's "first line of defense." Good repointing practices guarantee the long life of the mortar joint, the wall, and the historic structure. Although careful maintenance will help preserve the freshly repointed mortar joints, it is important to remember that mortar joints are intended to be sacrificial and will probably require repointing some time in the future. Nevertheless, if the historic mortar joints proved durable for many years, then careful repointing should have an equally long life, ultimately contributing to the preservation of the entire building.

Selected Reading

Ashurst, John & Nicola. *Practical Building Conservation. Vol. 3: Mortars, Plasters and Renders.* New York: Halsted Press, a Division of John Wiley & Sons, Inc., 1988.

Cliver, E. Blaine. "Tests for the Analysis of Mortar Samples." *Bulletin of the Association for Preservation Technology.* Vol. 6, No. 1 (1974), pp. 68-73.

Coney, William B., AIA. *Masonry Repointing of Twentieth-Century Buildings.* Illinois Preservation Series. Number 10. Springfield, IL: Division of Preservation Services, Illinois Historic Preservation Agency, 1989.

Davidson, J.I. "Masonry Mortar." *Canadian Building Digest.* CBD 163. Ottawa, ONT: Division of Building Research, National Research Council of Canada, 1974.

Ferro, Maximillian L., AIA, RIBA. "The Russack System for Brick and Mortar Description: A Field Method for Assessing Masonry Hardness." *Technology and Conservation.* Vol. 5, No. 2 (Summer 1980), pp. 32-35.

Hooker, Kenneth A. "Field Notes on Repointing." *Aberdeen's Magazine of Masonry Construction.* Vol. 4, No. 8 (August 1991), pp. 326-328.

Jedrzejewska, H. "Old Mortars in Poland: A New Method of Investigation." Studies in Conservation. Vol. 5, No. 4 (1960), pp. 132-138.

"Lime's Role in Mortar." Aberdeen's Magazine of Masonry Construction. Vol. 9, No. 8 (August 1996), pp. 364-368.

Phillips, Morgan W. "Brief Notes on the Subjects of Analyzing Paints and Mortars and the Recording of Moulding Profiles: The Trouble with Paint and Mortar Analysis." *Bulletin of the Association for Preservation Technology.* Vol. 10, No. 2 (1978), pp. 77-89.

Preparation and Use of Lime Mortars: An Introduction to the Principles of Using Lime Mortars. Scottish Lime Centre for Historic Scotland. Edinburgh: Historic Scotland, 1995.

Schierhorn, Carolyn. "Ensuring Mortar Color Consistency." *Aberdeen's Magazine of Masonry Construction.* Vol. 9, No. 1 (January 1996), pp. 33-35.

"Should Air-Entrained Mortars Be Used?" *Aberdeen's Magazine of Masonry Construction.* Vol. 7, No. 9 (September 1994), pp. 419-422.

Sickels-Taves, Lauren B. "Creep, Shrinkage, and Mortars in Historic Preservation." *Journal of Testing and Evaluation, JTEVA.* Vol. 23, No. 6 (November 1995), pp. 447-452.

Speweik, John P. *The History of Masonry Mortar in America*, 1720-1995. Arlington, VA: National Lime Association, 1995.

Speweik, John P. "Repointing Right: Why Using Modern Mortar Can Damage a Historic House." *Old-House Journal.* Vol. XXV, No. 4 (July-August 1997), pp. 46-51.

Technical Notes on Brick Construction. Brick Institute of America, Reston, VA.

"Moisture Resistance of Brick Masonry: Maintenance." 7F. February 1986.

"Mortars for Brick Masonry." 8 Revised II. November 1989.

"Standard Specification for Portland Cement-Lime Mortar for Brick Masonry." 8A Revised. September 1988.

"Mortar for Brick Masonry-Selection and Controls." 8B Reissued. September 1988. (July/August 1976).

"Guide Specifications for Brick Masonry, Part V Mortar and Grout." 11E Revised. September 1991.

"Bonds and Patterns in Brickwork." 30 Reissued. September 1988.

Useful Addresses

Brick Institute of America
11490 Commerce Park Drive
Reston, VA 22091

National Lime Association
200 N. Glebe Road, Suite 800

Arlington, VA 22203

Portland Cement Association
5420 Old Orchard Road
Skokie, IL 60077

Acknowledgments

Robert C. Mack, FAIA, is a principal in the firm of MacDonald & Mack, Architects, Ltd., an architectural firm that specializes in historic buildings in Minneapolis, Minnesota. **John P. Speweik, CSI,** Toledo, Ohio, is a 5th-generation stonemason, and principal in U.S. Heritage Group, Inc., Chicago, Illinois, which does custom historic mortar matching. **Anne Grimmer,** Senior Architectural Historian, Heritage Preservation Services Program, National Park Service, was responsible for developing and coordinating the revision of this Preservation Brief, incorporating professional comments, and the technical editing.

The authors and the editor wish to thank the following for the professional and technical review they provided: Mark Macpherson and Ron Peterson, Masonry Restoration Contractors, Macpherson-Towne Company, Minneapolis, MN; Lorraine Schnabel, Architectural Conservator, John Milner Associates, Inc., Philadelphia, PA; Lauren B. Sickels-Taves, Ph.D., Architectural Conservator, Biohistory International, Huntington Woods, MI; and the following National Park Service professional staff, including: E. Blaine Cliver, Chief, Historic American Buildings Survey/Historic American Engineering Record; Douglas C. Hicks, Deputy Superintendent, Historic Preservation Training Center, Frederick, MD; Chris McGuigan, Supervisory Exhibits Specialist, Historic Preservation Training Center, Frederick, MD; Charles E. Fisher, Sharon C. Park, FAIA, John Sandor, Technical Preservation Services Branch, Heritage Preservation Services, and Kay D. Weeks, Heritage Preservation Services.

The original version of this brief, *Repointing Mortar Joints in Historic Brick Buildings*, was written by Robert C. Mack in 1976, and was revised and updated in 1980 by Robert C. Mack, de Teel Patterson Tiller, and James S. Askins.

Washington, D.C. October, 1998

Home page logo: Soft mortar for repointing. Photo: John P. Speweik.

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), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

Questions

Appendix B
6 Preservation Brief: Dangers of Abrasive Cleaning to Historic Buildings

6 Preservation Briefs

Technical Preservation Services
National Park Service
U.S. Department of the Interior

Dangers of Abrasive Cleaning to Historic Buildings

Anne E. Grimmer

A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

"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

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

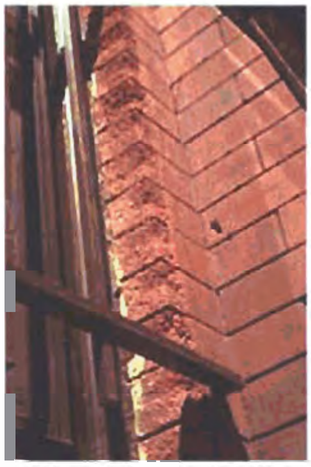
of grit material. However, any of the following materials may be substituted for sand, and all can be classified as abrasive substances: ground slag or volcanic ash, crushed (pulverized) walnut or almond shells, rice husks, ground corncobs, ground coconut shells, crushed eggshells, silica flour, synthetic 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.

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.

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.



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

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


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

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.

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.

Nonhistoric/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 Methods

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

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 he 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.

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

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

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 he 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.

Historic Interiors That Should Not Be Cleaned Abrasively

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

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.

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, whiting 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 he 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 he 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 he 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

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."

Selected Reading List

Ashurst, John. *Cleaning Stone and Brick*. Technical Pamphlet 4. London: Society for the Protection of Ancient Buildings. 1977.

Asmus, John F. "Light Cleaning: Laser Technology for Surface Preparation in the Arts." *Technology and Conservation*. 3:3 (Fall 1978), pp. 14-18.

"The Bare-Brick Mistake." *The Old House Journal*. I:2 (November 1973). p 2.

Brick Institute of America. Colorless Coatings for Brick Masonry. *Technical Notes on Brick Construction*. Number 7E (September/October 1976).

Gilder, Cornelia Brooke. *Property Owner's Guide to the Maintenance and Repair of Stone Buildings*. Technical Series/ No. 5. Albany, New York: The Preservation League of New York State, 1977.

Prudon, Theodore H.M. "The Case Against Removing Paint from Brick Masonry." *The Old House Journal*, III:2 (February 1975). pp. 6-7.

___________. "Removing Stains from Masonry." *The Old House Journal*. V:5 (May 1977), pp. 58-59.

Stambolov. T . and J.R.J. Van Asperen de Boer. *The Deterioration and Conservation of Porous Building Material in Monuments: A Review of the Literature*. Second enlarged edition. Rome: International Centre for Conservation, 1976.

Weiss, Norman R. "Cleaning of Building Exteriors: Problems and Procedures of Dirt Removal." *Technology and Conservation*, 2/76 (Fall 1976), pp. 8-13.

___________. *Exterior Cleaning of Historic Masonry Buildings*. Draft. Washington, D.C.: Office of Archeology and Historic Preservation, Heritage Conservation and Recreation Service, U.S. Department of the Interior, 1976.

Acknowledgements

This Preservation Brief was written by **Anne E. Grimmer**, Architectural Historian, Technical Preservation Services Division. Valuable suggestions and comments were made by Hugh C. Miller, AIA, Washington, D.C.; Martin E. Weaver, Ottawa, Ontario, Canada; Terry Bryant, Downers Grove, Illinois; Daniel C. Cammer, McLean, Virginia; and the professional staff of Technical Preservation Services Division. Deborah Cooney edited the final manuscript.

The illustrations for this brief not specifically credited are from the files of the Technical Preservation Services Division.

Washington, D.C. June, 1979

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

Appendix C
15 Preservation Brief: Preservation of Historic Concrete: Problems and General Approaches

Appendix C

15 PRESERVATION BRIEFS

Preservation of Historic Concrete

Paul Gaudette and Deborah Slaton

National Park Service
U.S. Department of the Interior

Heritage Preservation Services

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.

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

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.

Figure 2. Chatterton House was the home of the post trader at Fort Fred Steel 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.

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 (Fig. 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 (Fig. 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.

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

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.

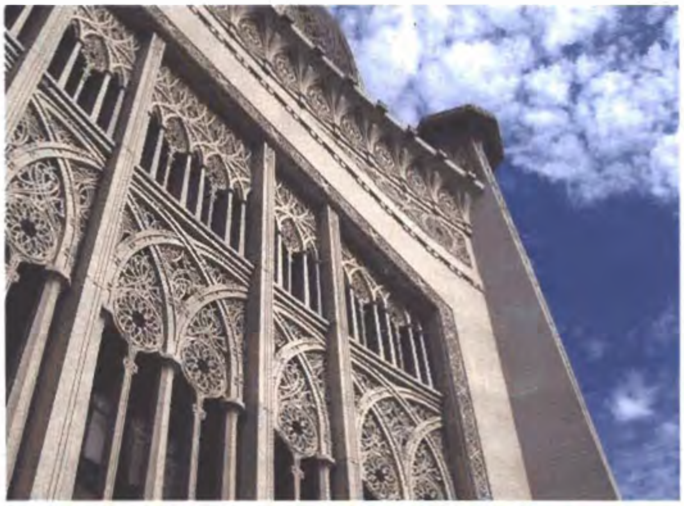


Figure 4. The highly ornamental concrete panels on the exterior facade of the Baha'i House of Worship in Wilmette, Illinois, illustrate the work of fabricator John J. Earley, known as "the man who made concrete beautiful."

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.

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 (Fig. 3).

During the early twentieth century, Ernest Ransome in Beverly, Massachusetts, Albert 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 (Fig. 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 (Fig. 5).

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.

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.

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 (Fig. 8), and the Ira C. Keller Fountain in Portland Oregon, designed by Lawrence Halprin in 1969 (Fig. 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 in sidebar).

Historic Interiors

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 (Fig. 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.

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 historic character of a building's interior can also be conveyed in a more utilitarian manner in terms of concrete features and finishes (Fig. 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.

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.

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.

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 (Fig. 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,

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).

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 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 (Fig. 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

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.

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.

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 (Fig. 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.

Figures 14. Layers of architectural concrete that have debonded (spalled) from the surface were removed from a historic water tank during the investigation performed to assess existing conditions. Photos: Anita Washko, Wiss, Janney, Elstner Associates, Inc.

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 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 (Fig. 15).

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.

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.

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 (Fig. 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 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.

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.

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.

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.

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.

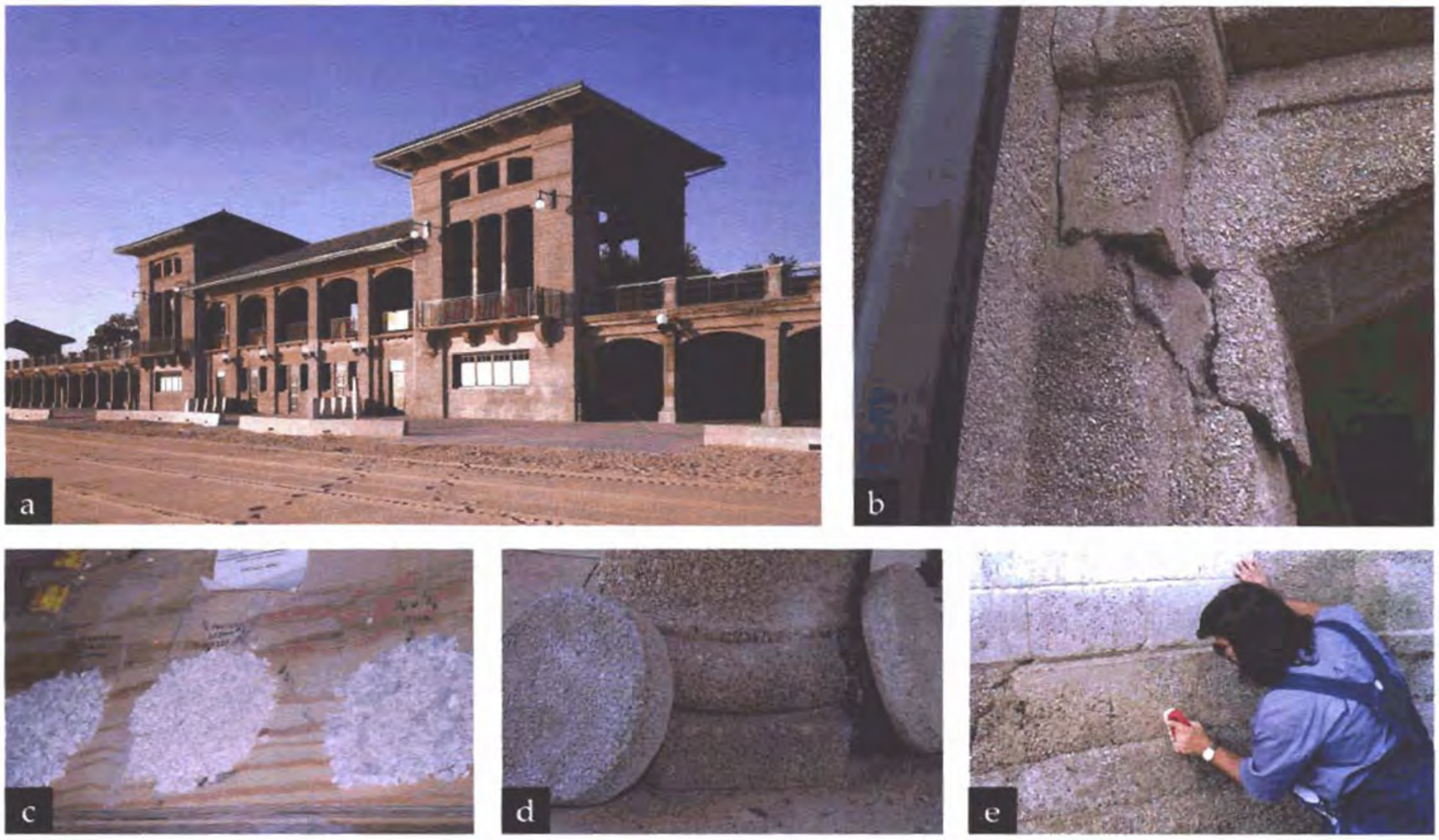


Figure 17. (a) The 63rd Street Beach House was constructed on the shoreline of Chicago in 1919. The highly exposed aggregate concrete of the exterior walls of the beach house was used for many buildings in the Chicago parks as an alternative to more expensive stone construction. Photo: Leslie Schwartz 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.

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.

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 (Fig. 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 can 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

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.

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 (Fig. 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.

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 (Fig. 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.

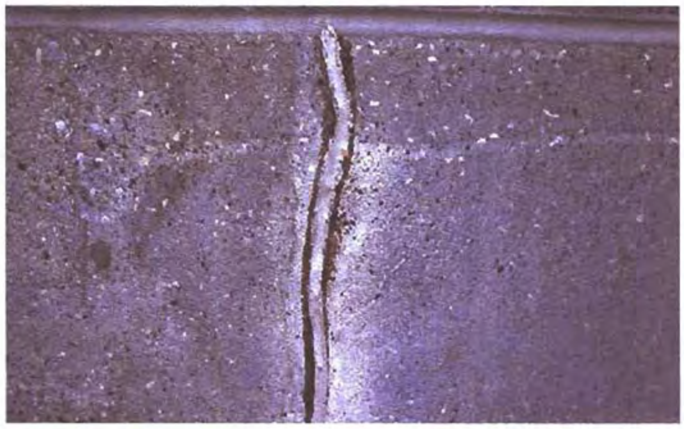


Figure 19. A high-speed grinder ia used to widen a crack in preparation for installation of a sealant. This process is called "routing." After the crack is prepared, the sealant is installed to prevent moisture infiltration through the crack. Although sealant repairs can provide a durable, watertight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

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

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.

concrete. 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.

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.

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. Like impressed-current cathodic protection methods, it is costly. Other corrosion methods are also available but have a somewhat shorter history of use.

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

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.

Selected Reading

American Concrete Institute. *Guide for Making a Condition Survey of Concrete in Service*. ACI Committee 201, ACI 201.1R-92.

American Concrete Institute. *Guide to Evaluation of Concrete Structures before Rehabilitation*. ACI Committee 364, ACI 364.1R-07.

American Concrete Institute. *Concrete Repair Guide*. ACI Committee 546, ACI 546R-04.

American Concrete Institute. *Guide for Evaluation of Existing Concrete Buildings*. ACI Committee 437, ACI 437R-03.

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

Collins, Peter. *Concrete: The Vision of a New Architecture*. New York, New York: Faber and Faber, 1959.

Cowden, Adrienne B., comp. *Historic Concrete: An Annotated Bibliography*. Washington, D.C.: National Park Service, 1993.

Komandant, August E. *Contemporary Concrete Structures*. New York, New York: McGraw Hill, 1972.

Erlemann, Gustav G. "Steel Reinforcing Bar Specification in Old Structures." *Concrete International*, April 1999, 49–50.

Federal Highway Administration. *Guide to Nondestructive Testing of Concrete*. FHWA Publication Number FHWA-SA-97-105.

Gaudette, Paul E. "Special Considerations in Repair of Historic Concrete." *Concrete Repair Bulletin*, January/February 2000, 12–13.

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

Johnson, Arne P., and Seung Kyoung Lee. "Protection Methods for Historic Concrete at Soldier Field." *Preserve and Play: Preserving Historic Recreation and Entertainment Sites*. Washington, D.C.: Historic Preservation Education Foundation, National Council for Preservation Education, and National Park Service, 2006.

Macdonald, Susan, ed. *Concrete: Building Pathology*. Osney Mead, Oxford, U.K.: Blackwell Science, 2003.

McGovern, Martin S. "A Clear View of Sealers." *Concrete Construction*, January 2000, 53–58.

Morton, W. Brown III, Gary L. Hume, Kay D. Weeks, H. Ward Jandl, and Anne E. Grimmer. *The Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines for Rehabilitating Historic Buildings*. Washington, D.C.: National Park Service, 1983, reprinted 1997.

"Repairing Cracks." *Concrete Repair Digest*, August/September 1992, 160–164. Condensed from ACI document 224.1R-93.

Slaton, Deborah. "Cleaning Historic Concrete." *Concrete Repair Bulletin*, January/February 2000, 14–15.

Acknowledgements

Paul Gaudette is an engineer with Wiss, Janney, Elstner Associates, Inc., in Chicago, Illinois. Deborah Slaton is an architectural conservator with Wiss, Janney, Elstner Associates, Inc., in Northbrook, Illinois. All photographs by Paul Gaudette unless otherwise stated. Front cover image: Kyle Normandin, Wiss, Janney, Elstner Associates, Inc.

The authors wish to thank William Bing Coney, author of the first edition of this preservation brief, who served as a peer reviewer for the current edition. In addition, the authors gratefully acknowledge the assistance of the following individuals as peer reviewers of this brief: Arne Johnson and Una Gilmartin, Wiss, Janney, Elstner Associates, Inc.; Robert Joyce, Quality Restorations, Inc.; Susan Macdonald, New South Wales Heritage Office; Miles T. Murray, Restruction Corporation; and Jack Pyburn, OJP/Architect, Inc. Anne E. Grimmer, Chad Randl, and former staff Sharon C. Park, FAIA, of the Technical Preservation Services, National Park Service, offered valuable comments during development of the brief. Charles E. Fisher of the National Park Service was the technical editor for this publication project.

ISBN: 978-0-16-078946-5
U.S. Government Printing Office Stock Number: 024-005-01253-2

2007

Part III

Programmatic Agreement

PROGRAMMATIC AGREEMENT
AMONG
THE FEDERAL HIGHWAY ADMINISTRATION,
THE MARYLAND STATE HIGHWAY ADMINISTRATION,
THE ADVISORY COUNCIL ON HISTORIC PRESERVATION AND
THE MARYLAND STATE HISTORIC PRESERVATION OFFICER
REGARDING
SHA's HISTORIC HIGHWAY BRIDGES IN MARYLAND

WHEREAS, the Federal Highway Administration (FHWA) administers the Federal Aid Highway Program (FAHP) in Maryland authorized by 23 U.S.C. 101 et seq. through the Maryland State Highway Administration (SHA) (23 U.S.C. 315); and

WHEREAS, the FHWA has determined that the FAHP may be used to rehabilitate or replace SHA-owned or controlled highway bridges listed in or eligible for listing the National Register of Historic Places (National Register) (hereafter referred to as "historic bridges"); and

WHEREAS, the FHWA has consulted with the Advisory Council on Historic Preservation (Council) and the Maryland State Historic Preservation Officer (MD SHPO) pursuant to the Council's regulations found at 36 CFR §800.14(c) implementing Section 106 of the National Historic Preservation Act (NHPA) (16 U.S.C. §470f); and

WHEREAS, the Maryland State Highway Administration (SHA) has participated in the consultation, has responsibilities under this agreement, and has been invited to be a signatory to this Programmatic Agreement (PA); and

WHEREAS, the FHWA and SHA have identified and invited the following parties to consult in the Section 106 process for the development of this PA: Maryland County Historic Preservatin and Historic District Commission, Maryland Certified Heritage Areas, Maryland Scenic Byways Commission, Preservation Maryland and the National Park Service – National Capital Region; and

WHEREAS, the SHA administers state funded bridge projects as defined in Section 2-103.1 of the Transportation Article, and the SHA and MD SHPO agree that the fulfillment of the terms of this PA for state funded projects will satisfy the SHA's responsibilities under the requirements of the Maryland Historical Trust Act of 1985, as amended, State Finance and Procurement Article §§ 5A-325 and 5A-326 of the Annotated Code of Maryland (Act); and

WHEREAS, the SHA has a staff of cultural resource specialists who meet the professional qualifications in 36 CFR Part 61 Appendix A in the fields of architectural history, history and archeology, to carry out its historic preservation programs and responsibilities, including the implementation of the provisions of this PA; and,

WHEREAS, the provisions of the PA only apply to projects involving SHA-owned or controlled historic bridges in Maryland;

NOW, THEREFORE, the FHWA, Council, MD SHPO and SHA agree that the rehabilitation or replacement of SHA-owned and controlled historic bridges shall be administered in accordance with the following stipulations, exercising reasonable judgment and good faith, to satisfy the FHWA's Section 106 responsibilities for all individual undertakings of the program.

STIPULATIONS

FHWA will ensure that the following measures are carried out:

I. Purpose

A. This PA sets forth the process by which the FHWA will meet its responsibilities under Sections 106, 110(d), and 110(f) of the NHPA with the assistance of the SHA, for SHA-owned or controlled historic highway bridge projects assisted by the FAHP. Furthermore, the PA institutes the process by which the SHA will meet its responsibilities under the Act for certain state funded activities. This PA establishes the basis for SHA's administration of its Historic Highway Bridge Program and establishes how the FHWA and the MD SHPO will be involved in both the Program and individual bridge projects under the Program.

B. The SHA proposes to administer its Historic Highway Bridge Program in accordance with this PA, in order to manage its assets and ensure that SHA's engineering heritage is preserved and protected for the benefit of Maryland's citizens. This PA identifies the program's key components including designation of three treatment categories for SHA-owned and managed historic bridges:
   1. Preservation Priority Historic Bridges (Listed in Attachment A): historic bridges designated for indefinite preservation;
   2. Eligible Historic Bridges (Listed in Attachment B): historic bridges that will be maintained and preserved, when feasible, and are subject to a streamlined review process; and
   3. Non-Priority Historic Bridges (Listed in Attachment C): historic bridges that do not require preservation in place and are subject to a streamlined review process and standard mitigation treatments.

C. The PA addresses provisions for the appropriate management and corresponding review processes for historic bridges in each of the three treatment categories. It provides streamlined review procedures under certain circumstances, standardized mitigation treatments for Non-Priority Historic Bridges, measures for coordination with Maryland Heritage Areas and Scenic Byways, and use of design exceptions and variances. In addition, the PA includes measures for bridge stewardship and outreach efforts, as resources allow.

II. Applicability

A. <u>Applicability</u>: This PA applies to any FHWA assisted and state funded work conducted on SHA-owned or controlled eligible historic bridges including, but not necessarily limited to, bridge maintenance, preservation, rehabilitation, restoration, reconstruction, relocation, and/or replacement projects, and projects containing any or all elements of the above project types. This PA also applies to any SHA state-funded bridge projects and/or state funded bridge projects requiring a US Army Corps of Engineers (COE) permit on SHA-owned or controlled historic bridges. For SHA's non-FHWA funded bridge replacement projects requiring a COE permit, the COE is the lead federal agency for Section 106 purposes and SHA must coordinate with the COE.

B. Effect on Existing Agreements: The measures contained in this PA do not supersede stipulations contained in previously executed Memoranda of Agreement regarding the rehabilitation or replacement of individual historic bridges in Maryland. Furthermore, this PA does not replace those provisions for minor bridge and small structure work established in SHA's 2008 Amended Programmatic Agreement for Minor Highway Projects (or any subsequent amendment).

C. Non-SHA Owned Historic Bridges in Maryland: The provisions of this PA do not apply to historic bridges in Maryland owned by local governments, federal agencies, or other entities. Nonetheless, the signatory parties to this PA agree that the treatment principles, guidance, and review considerations contained herein may be relevant to non-SHA owned historic bridges. FHWA, SHA and the MD SHPO will promote the appropriate stewardship of non-SHA owned historic bridges in Maryland through their respective agency programs, where appropriate.

III. Identification of SHA Historic Bridges

A. Inventory Efforts: In 1995, SHA began its comprehensive efforts to identify bridges eligible for the National Register on Maryland's state and county highways, in consultation with the MD SHPO. These initial efforts resulted in the preparation of the *Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report* (Spero & Company and Berger & Associates, 1995), which included an inventory of SHA owned bridges constructed between 1809 and 1947. SHA evaluated the National Register eligibility of the identified bridges under Criterion C, at a state level of significance, and obtained concurrence from the MD SHPO with its determinations on July 27, 2001. SHA has continued to identify and evaluate individual bridges on a case by case basis, in consultation with the MD SHPO. SHA completed a second comprehensive evaluation of SHA owned bridges constructed between 1948-1965 that resulted in the preparation of the *Phase II State Historic Bridge Context & Inventory of Modern Bridges, Survey Report and Assessments of Significance* (URS 2004) and *"Tomorrow's Roads Today," Expressway Construction in Maryland 1948-1965* (Bruder 2010). SHA coordinated its inventory efforts with the MD SHPO, FHWA, and other relevant parties (such as local governments, historic preservation commissions and heritage areas).

B. Historic Bridges Subject to the PA: The attachments to this PA include SHA-owned bridges that SHA, with concurrence by the MD SHPO, determined eligible for the National Register based on consultation through September 2010. Those bridges that are not individually eligible but may be eligible as contributing elements to a historic district may not be included in the attachments. Attachments A-C list all the SHA-owned and controlled historic bridges determined eligible for the National Register by SHA in consultation with the MD SHPO, organized by treatment category:

1. Attachment A: Preservation Priority Historic Bridges - 17 historic bridges designated for long term preservation;
2. Attachment B: Eligible Historic Bridges - 91 historic bridges that may be preserved when feasible; and
3. Attachment C: Non-Priority Historic Bridges - 60 historic bridges that do not require preservation.

C. Inventory Updates and Revisions to Attachments A-C: SHA shall continue to identify and evaluate the National Register eligibility of its bridges on a comprehensive or case by case basis as need arises, in consultation with the MD SHPO and any other relevant parties. The SHA may modify Attachments A-C to reflect the results of any inventory updates based on consultation and mutual agreement between SHA and the MD SHPO. SHA shall provide copies of any revised attachments to this PA to the signatory parties with its annual report produced pursuant to Stipulation XIII of the PA.

IV. Responsibilities of the FHWA, the SHA and the MD SHPO

A. In compliance with its responsibilities under the NHPA, and as a condition of its award to SHA of any assistance for bridge rehabilitation or replacement projects under the FAHP, the FHWA shall require the SHA to carry out the provisions of this PA to meet the requirements of 36 CFR Part 800, and the applicable Council standards and guidelines, for all of SHA's historic bridge projects included in Attachments A-C that receive Federal assistance. The SHA shall implement the terms of this PA, where applicable, to fulfill its responsibilities under the Act for state funded actions. The FHWA and the MD SHPO will participate in the process as specified in subsequent stipulations.

B. SHA cultural resource professionals will be responsible for implementing the requirements of this PA that are delegated to SHA.

C. SHA will strive to maintain in-house engineering expertise related to the treatment of historic bridges either on its staff or through consultant services, whose responsibilities will include overseeing work on its historic bridges in accordance with this PA.

D. The SHA will include information about National Register eligibility status of inventoried bridges in its internal databases used by its cultural resources, project planning and structures personnel.

V. Guidelines, Standards, Regulations, Contexts and Management Plans

Guidelines, standards, regulations, contexts and management plans relevant to this PA and its purposes include:

- 36 CFR Part 800: *Protection of Historic Properties* (2004);
- *Exemption Regarding Historic Preservation Review Process for Effects to the Interstate Highway System (Federal Register,* 11928-11931);
- *Secretary of Interior's Standards for Treatment of Historic Properties (36 CFR Part 68);*
- *Historic Highway Bridges in Maryland: 1631-1960: Historic Context Report* (Spero & Company and Berger & Associates, 1995);
- *Phase II State Historic Bridge Context & Inventory of Modern Bridges, Survey Report and Assessments of Significance* (URS 2004);
- *'Tomorrow's Roads Today,' Expressway Construction in Maryland 1948-1965* (Bruder 2010);
- *Management Plan for Historic Highway Bridges* (KCI Technologies, Inc. & Tran|Systems/Lichtenstein, April 2010);

- *Standards and Guidelines for Architectural and Historical Investigations in Maryland* (Maryland Historical Trust 2000); and
- *Standards and Guidelines for Archeological Investigations in Maryland* (Shaffer and Cole, 1994).

VI. Treatment of Preservation Priority Historic Bridges

SHA has selected seventeen (17) historic bridges, listed in Attachment A, for its treatment category, *Preservation Priority Historic Bridges*, for preservation in perpetuity to the maximum extent possible. SHA completed the *Management Plan for Historic Highway Bridges* (KCI Technologies, Inc. & Tran|Systems/Lichtenstein, April 2010) (*Management Plan*), which includes individual management plans for the preservation of the priority bridges, as well as general guidance for best practices.

A. Preservation and Maintenance: SHA will maintain and preserve the Preservation Priority Historic Bridges listed in Attachment A. In accordance with the specific bridge management plan developed for each of these bridges, SHA will incorporate measures that may involve repair, strengthening or replacement of bridge components and/or design exceptions directed at keeping the preservation priority historic bridges in long-term use. For practical purposes, "long-term" is taken to mean 20 years into the future. A 20-year window was chosen as an upper limit of how far reasonable predictions can be made regarding how any given bridge will react to its existing and proposed environment with the information that is available at the time preservation activities are planned. All repair, strengthening or replacement of bridge components will follow the recommended approaches of the *Secretary of Interior's Standards for Treatment of Historic Properties,* as well as the guidance contained in the individual management plans that will be found in the *Management Plan*.

B. Bi-Annual Inspection: In order to determine if any of the Preservation Priority Historic Bridges listed in Attachment A require repair or rehabilitation, SHA will inspect each bridge on a two-year cycle and report the inspection results to the Office of Structures (OOS) Structures Remedial Engineer in charge of the bridge.

C. Training for SHA Structures Maintenance Personnel: Within one (1) year of the signing of this PA and annually thereafter, SHA's Office of Planning and Preliminary Engineering (OPPE) and OOS will provide training to SHA structures engineers, structures inspectors and district maintenance workers as well as cultural resources professionals in order to ensure that appropriate maintenance treatments are being applied to the 17 bridges identified for preservation priority. The training will be provided either during the annual bridge inspection training class or other appropriate training and scheduled through the Learning Management System for SHA employees.

D. Funding for Preservation Priority Historic Bridges: Recognizing that individual bridge projects will occur on different schedules depending on available funding sources and individual bridge needs, SHA will begin actively seeking funds for preservation and rehabilitation of the 17 bridges using traditional funding sources on an as-needed basis within one (1) year of the signing of this PA. If needed, additional state and federal funding sources will be sought.

E. Considerations for Replacement of Preservation Priority Bridges:

1. If SHA determines that preservation of a Preservation Priority Historic Bridge is no longer feasible, SHA will thoroughly investigate all prudent and feasible alternatives, including the following options, before selecting the replacement alternative:
   - No build;
   - Minor structural rehabilitation to the existing bridge for continued vehicular use;
   - Reducing traffic volumes on the existing bridge, including one-way pair;
   - Bypassing and preserving the existing bridge in place; and
   - Relocating the existing bridge to another site.

2. If a Preservation Priority Historic Bridge is bypassed or relocated, SHA will develop an alternative management plan for the bridge's continued use as an integral part of a pedestrian or other type of facility.

3. If a Preservation Priority Historic Bridge needs to be replaced, appropriate additional efforts will be determined by the signatories of this PA to mitigate the loss of that bridge, through the consultation process noted in Stipulation VI.E.7 below. Examples of appropriate mitigation may be the development of a bridge design that would reflect both the state of twenty-first century bridge design and SHA's engineering heritage (e.g., a concrete arch bridge), or providing funding to improve another preservation priority historic bridge or identifying an eligible historic bridge listed in Attachment B which can be designated as a Preservation Priority Historic Bridge.

4. If an Eligible Historic Bridge is made a Preservation Priority Historic Bridge, SHA will develop an individual management plan for that bridge in consultation with the MD SHPO as part of the mitigation for the loss of the other bridge.

5. If a proposed project subject to this PA includes work on any bridge listed in Attachment A, the SHA will review the project in order to determine if it may have an adverse effect on the bridge or any other historic and archeological properties in the area of potential effects, applying the Criteria of Adverse Effect set forth in 36 CFR §800.5(a)(1).

6. Status Report: SHA will provide annual updates to FHWA and MD SHPO on the status of the bridge preservation efforts in conjunction with the annual review pursuant to Stipulation XIII of this PA.

7. Review Process for Preservation Priority Historic Bridges: Considering the prominent status of the Preservation Priority Historic Bridges, SHA, FHWA and the MD SHPO shall review all undertakings involving Preservation Priority Historic Bridges in accordance with the standard review process established in 36 CFR Part 800 and the Act (where applicable) and shall include appropriate consulting parties as defined at 36 CFR §800.2 in the consultation process.

VII. Treatment of Eligible Historic Bridges

SHA has assigned ninety-one (91) historic bridges, listed in Attachment B, to the treatment category *Eligible Historic Bridges*. SHA will continue to maintain and preserve these bridges, in accordance with relevant guidance contained in the *Management Plan*, as feasible. Since these bridges may not be ideal candidates for long-term preservation in place, SHA will manage these structures on a case-by-case basis. Rehabilitation, adaptive use, relocation, demolition and replacement are all possible treatment options for this bridge category. The signatory parties to this PA agree that a streamlined approach to the review of projects that result in no adverse effects to Eligible Historic Bridges is appropriate, as established below.

A. <u>Review Process for Eligible Historic Bridges</u>:

1. If a proposed project subject to this PA includes work on any bridge listed in Attachment B, the SHA will review the project in order to determine if it may have an adverse effect on the bridge or any other historic and archeological properties in the area of potential effects (APE),, applying the Criteria of Adverse Effect set forth in 36 CFR §800.5(a)(1).

2. SHA will use the *Secretary of the Interior's Standards for the Treatment of Historic Properties* and the guidance contained in the *Management Plan* in order to assess whether or not the proposed work would constitute an adverse effect.

3. If SHA determines that the project may constitute an adverse effect, they will seek to avoid such effects by incorporating the treatments and guidance contained in the *Management Plan*. SHA shall consider a full range of project alternatives, including: no action; construct a new structure at a different location without affecting the historic integrity of the old bridge; and rehabilitate the historic bridge without affecting the historic integrity of the structure.

4. The FHWA, MD SHPO, SHA and the Council agree that following the Review Process for Eligible Historic Bridges includes all possible planning to minimize effects to the historic bridge.

B. <u>No Adverse Effects</u>:

1. If SHA determines that the proposed undertaking will have no adverse effect on historic properties, no further consultation with the MD SHPO is required.

2. SHA shall document its review and no adverse effect determination on a SHA Historic Bridge Review Form (Attachment E). SHA does not need to provide the MD SHPO with a copy of its SHA Historic Bridge Review Forms, but will provide a list of all such forms it handles in a given calendar year as part of its annual report, pursuant to Stipulation XIII.

3. SHA *may* request written concurrence from the MD SHPO for its determination of no adverse effect for any project subject to this Stipulation, if desired.

4. For projects SHA reviews under this Stipulation, it will provide notification and opportunities for input from interested parties by copying the relevant local government Planning and Zoning Office, Certified Heritage Area, Scenic Byway, or other appropriate entity on its SHA Historic Bridge Review Form. SHA may copy other organizations at its discretion or upon request.

5. If SHA receives comments from the other parties, SHA will provide a copy of the documentation to the MD SHPO and consult with all relevant parties to resolve any issues or handle the individual project review under the standard 36 CFR Part 800 process.

C. Resolution of Adverse Effects:

1. If SHA determines that the undertaking will have an adverse effect on an Eligible Historic Bridge, and that that there are no viable alternatives that would avoid causing adverse effects, it will consult with the MD SHPO, FHWA, and any other identified consulting parties, pursuant to 36 CFR §800.6 to resolve the adverse effects.

2. SHA will develop and implement a Memorandum of Agreement (MOA) in coordination with the consulting parties outlining a mitigation plan for the Eligible Historic Bridge. Mitigation plans may include, but are not limited to, developing information about types of technology and engineering data related to the affected eligible bridge(s); providing copies of original plans, photographs, and new MIHP forms to the MD SHPO or other appropriate repository; Historic American Engineering Record (HAER) recordation; salvage of elements for curation, public education, reuse or incorporation into a new bridge; design review of the replacement bridge, where applicable; or other appropriate measure.

VIII. Treatment of Non-Priority Historic Bridges

SHA has assigned sixty (60) historic bridges, listed in Attachment C, to the treatment category *Non-Priority Historic Bridges*. SHA will continue to maintain these bridges, in accordance with relevant guidance contained in the *Management Plan*, as feasible. Since these bridges are representative examples of their type and not ideal candidates for long-term preservation in place, demolition and replacement are possible treatment options for this bridge category, when maintenance and rehabilitation are no longer feasible and cost effective options for these bridges. The signatory parties to this PA agree that a streamlined approach to the review of projects that result in no adverse effects to Non-Priority Historic Bridges is appropriate, as established below. Furthermore, since SHA has generated sufficient documentation regarding these bridges as part of its historic bridge inventory efforts, the signatory parties agree to resolve any adverse effects to these resources through the use of standard mitigation treatments.

A. Review Process for Non-Priority Historic Bridges:

1. If a proposed project for the type of undertakings listed in the Applicability section of this PA includes work on any bridge in Attachment C, the SHA will review the project in order to determine if it may have an adverse effect on the bridge or any

other historic and archeological properties in the APE, applying the Criteria of Adverse Effect set forth in 36 CFR §800.5(a)(1).

2. SHA will use the *Secretary of the Interior's Standards for the Treatment of Historic Properties* and the guidance contained in the *Management Plan* in order to assess whether or not the proposed work would constitute an adverse effect. If SHA determines that the project may constitute an adverse effect, they will seek to avoid such effects by incorporating the treatments and guidance contained in the *Management Plan*.

B. <u>No Adverse Effects</u>:

1. If SHA determines that the proposed undertaking will have no adverse effect on historic properties, no further consultation with the MD SHPO is required.

2. SHA shall document its review and no adverse effect determination on a SHA Historic Bridge Review Form (Attachment E). SHA does not need to provide the MD SHPO with a copy of its SHA Historic Bridge Review Forms, but will provide a list of all such forms it handles in a given calendar year as part of its annual report, pursuant to Stipulation XIII.

3. SHA *may* request written concurrence from the MD SHPO for its determination of no adverse effect for any project subject to this Stipulation, if desired.

4. For projects SHA reviews under this Stipulation, it will provide notification and opportunities for input from interested parties by copying the relevant local government Planning and Zoning Office, Certified Heritage Area, Scenic Byway, or other appropriate entity on its SHA Historic Bridge Review Form. SHA may copy other organizations at its discretion or upon request.

5. If SHA receives comments from the other parties, SHA will provide a copy of the documentation to the MD SHPO and consult with all relevant parties to resolve any issues or handle the individual project review under the standard 36 CFR Part 800 process.

C. <u>Resolution of Adverse Effects Through Standard Mitigation Treatments</u>:

1. If SHA determines that the undertaking will have an adverse effect on a Non-Priority Historic Bridge, and that there are no viable alternatives that would avoid causing adverse effects, SHA will notify the MD SHPO, FHWA, and any other identified consulting parties, of its intent to resolve the adverse effect by implementing the Standard Mitigation Treatment for Non-Priority Historic Bridges.

2. When using a Standard Mitigation Treatment, execution of a MOA to resolve the adverse effect is not warranted for this bridge category, unless the MD SHPO, FHWA or other consulting party object to the use of Standard Mitigation Treatments within thirty (30) days of SHA's notification.

3. If SHA receives comments from the other parties, SHA will provide a copy of the documentation to the MD SHPO and consult with all relevant parties to resolve any

issues or handle the individual project review under the standard 36 CFR Part 800 process.

4. SHA shall ensure that the mitigation, either a Standard Mitigation Treatment or other negotiated measure under a MOA, is completed prior to demolition of the historic bridge.

D. Standard Mitigation Treatment for Non-Priority Historic Bridges: The signatory parties to this PA agree that SHA may employ the following standard treatment to mitigate the adverse effect of an undertaking on a Non-Priority Historic Bridge.

1. SHA shall prepare a recordation package to mitigate an undertaking's adverse effect on a Non-Priority Historic Bridge listed in Attachment C.

2. SHA prepared Determination of Eligibility (DOE) Forms for all 60 Non-Priority Historic Bridges in October 2009. This documentation includes a full description of the bridge, a brief historic context, mapping and photographs. To serve as the Standard Mitigation Treatment recordation package, SHA shall convert the existing DOE forms into the MD SHPO's Addendum Sheet format, as illustrated in Attachment D. This documentation shall fulfill SHA's mitigation requirement for all Non-Priority Historic Bridges.

3. SHA may provide the MD SHPO with a single recordation package for all 60 Non-Priority Historic Bridges or may prepare and submit the documentation on a project-by-project basis. SHA shall ensure that all recordation packages for the bridges listed in Attachment C are provided to the MD SHPO within five (5) years from the execution of this PA.

4. SHA shall include a list of all the bridges it handled through Standard Mitigation Treatment for Non-Priority Historic Bridges for each given calendar year in its Annual Report produced pursuant to Stipulation XIII of this PA.

IX. Coordination with Maryland Heritage Areas and Maryland Scenic Byways

SHA shall identify if an undertaking subject to this PA includes work within in a Certified Heritage Area or along a Maryland Scenic Byway. SHA shall make sure that any such undertaking supports the objective and mission of the affected heritage area and/or scenic byway and that the project is designed in a manner that acknowledges the area's unique history, culture, natural resources and heritage tourism goals. SHA shall coordinate with and take into consideration the views of heritage area authorities, tourism agencies and any other consulting parties during project planning and implementation.

X. Potential Effects to Other Historic Properties from Bridge Projects

A. SHA will review all undertakings subject to this PA in order to determine if the undertaking has the potential to affect other historic properties, including archeological sites, or has unanticipated effects on historic properties for any project. If there are other historic properties within the APE that may be affected by the undertaking, SHA will follow the standard consultation requirements of 36 CFR Part 800.

B. At SHA's discretion, or upon the written request of FHWA, the MD SHPO, or other relevant party, SHA may review any project subject to this PA in accordance with the standard review process established in 36 CFR Part 800 and the Act (where applicable) and shall include appropriate consulting parties as defined at 36 CFR §800.2 in the consultation process.

XI. Use of Design Exceptions and Variances

A. FHWA and SHA strongly encourage the development of historic bridge projects in a context sensitive manner, including the use of design exceptions and variances when practical.

B. SHA will work with FHWA to investigate incorporating design exceptions for each project affecting the 17 Preservation Priority Historic Bridges. Design exceptions that would be investigated and applied to on a case-by-case basis include sight distances, vertical and horizontal curve clearances, shoulder widths, and geometric improvements.

C. For projects that meet the requirements for Highway Bridge Replacement and Rehabilitation Program (HBRRP) funding, FHWA will work with SHA on a project-by-project basis to maintain the historic integrity of the bridge while keeping it in service using exceptions to the standards when deemed appropriate.

XII. Bridge Stewardship and Outreach Efforts

SHA appreciates that the historic bridges under its ownership and control embody significant structures reflecting Maryland's rich history, technology, engineering, and transportation accomplishments and these bridges are important to the interests of the State and its citizens. SHA will promote awareness and appropriate stewardship of Maryland's historic bridges through the measures listed below, as funding and resources allow.

A. <u>National Register of Historic Places Nominations</u>: SHA will nominate the Preservation Priority Historic Bridges to the National Register. SHA will submit at least two bridge nominations per year to the MD SHPO, as funds are available for the nomination work. SHA shall develop the nomination package(s) in accordance with the National Register Bulletin *How to Complete the National Register Form* and all other applicable guidance from the National Park Service and the MD SHPO. SHA shall submit the completed National Register nomination(s) to the MD SHPO for review and approval. SHA shall revise the nomination package(s) in accordance with any MD SHPO comments. Once approved by the MD SHPO, the MD SHPO shall forward the nomination(s) to the Keeper of the National Register of Historic Places for listing.

B. <u>Updating SHA's Historic Bridges Web Pages and Creation of a Maryland National Register Historic Bridges Web Page</u>: Within one (1) year of the signing of this PA, SHA will work with FHWA, and MD SHPO, to update its Maryland Historic Bridges portion of its web site. Updates will include but are not limited to the following items: a copy of the executed PA, the *Management Plan*, the individual bridge management plans, historic bridge contexts, guidance for best practices, high resolution scanned images of Maryland Inventory of Historic Properties (MIHP) bridge forms performed for FHWA funded projects, and high resolution digital images of documented bridges. In addition, SHA will post new bridge studies or documentation to the Historic Bridges Web Pages, as appropriate. The MD SHPO will ensure that the listed bridges are included in the National Register web page that it maintains.

C. Public Outreach: SHA will seek opportunities to make presentations, publish articles, create posters, and/or implement other outreach measures about its Historic Highway Bridge Program during annual meetings or training sessions such as the Maryland Annual Preservation and Revitalization Conference, the County Engineers Association of Maryland's Annual Meeting, the Maryland Association of Historic District Commissions (MAHDC) meetings, and other relevant events, as resources allow.

D. Historic Bridge Plaques: SHA will install the metal plaques created for the Preservation Priority Historic Bridges listed in Attachment A within one (1) year of executing this PA.

XIII. Annual Reporting

A. Beginning June 30, 2013 and on or about the end of Maryland's fiscal year for the duration of this PA, the SHA will prepare an annual report, addressing the topics listed below as relevant to the preceding calendar year, and provide it to the MD SHPO and FHWA:
- List of project reviews completed for the Preservation Priority Historic Bridges;
- List of project reviews completed for the Eligible Historic Bridges, noting relevant effect determinations and outcomes;
- List of project reviews completed for the Non-Priority Historic Bridges, noting relevant effect determinations and outcomes;
- Status of preparing the standard mitigation treatment for the 60 Non-Priority Historic Bridges;
- Progress in developing and distributing design exceptions for historic bridges;
- Progress in nominating the Preservation Priority Historic Bridges to the National Register;
- Progress in updating the SHA Historic Bridge Web Pages;
- Progress in outreach efforts;
- Status of installing the plaques on the preservation priority historic bridges;
- Updates on SHA's Annual Bridge Candidates for New/Replacement Structure List;
- Any problems or unexpected issues encountered during the year;
- Any revisions to Attachments A – C; and
- Any changes that SHA believes should be made in implementing the PA or the need for formal amendments to the agreement.

B. At the request of any signatory party to this PA, SHA shall hold a meeting or meetings with the signatory parties to facilitate review and comment, to address questions, or to resolve any outstanding issues related to the implementation of the PA.

XIV. Coordination with Other Federal and State Review Processes

For those projects covered by this PA that are also subject to coordination through other federal and state review processes that include the MD SHPO (such as joint federal/state permit applications to the Maryland Department of the Environment/Corps of Engineers and submittals to the Maryland State Clearinghouse for Intergovernmental Assistance), the SHA shall make a good faith effort to provide copies of the relevant SHA Historic Bridge Review Form as part of its joint permit application or State Clearinghouse notification. Inclusion of this form as part of these other federal and state review processes will document the SHA's compliance with Section 106 and the Act for the associated activities and facilitate the MD SHPO's review and processing of these activities under other federal and state review processes.

XV. Dispute Resolution

A. Should the MD SHPO or Council object within 30 days to any documentation submitted or actions proposed pursuant to this PA, the FHWA will ensure that the SHA consults with the objecting party to resolve the objection. If the objection cannot be resolved, the FHWA will comply in accordance with 36 CFR §800.4 through 36 CFR §800.6. FHWA's responsibility to comply with the stipulations of this PA for all other projects that are not the subject of the dispute will remain unchanged.

B. When requested by any consulting party, the Council will consider FHWA's findings under this PA. The provisions of 36 CFR §800.9(a) on public requests to the Council will apply.

XVI. Amendment

Any signatory to this PA may request that it be amended, whereupon the parties shall consult to consider the proposed amendment.

XVII. Termination

Any party to this PA may terminate it by providing thirty days notice to the other signatories, provided that the parties will consult during the period prior to termination to seek agreement on amendments or other actions that would avoid termination. In the event of termination, the FHWA and MD SHA will comply with 36 CFR §800.4 through 36 CFR §800.6 with regard to individual undertakings covered by this PA.

XVIII. Failure to Comply with Agreement

In the event the FHWA or SHA do not carry out the terms of this PA, the FHWA or SHA will comply with 36 CFR §800.4 through 36 CFR §800.6 with regard to individual undertakings covered by this PA.

XIX. Duration

This PA shall become effective upon execution by FHWA, MD SHPO, the Council, and SHA and shall remain in effect for ten years or until December 31, 2022. No later than December 31, 2021, FHWA will consult with the signatories to this PA to determine interest in renewing this PA. The PA may be extended for additional terms upon the written agreement of the signatories.

Execution and implementation of this PA evidences that the FHWA has afforded the Council a reasonable opportunity to comment on its programs and their effects on historic bridge properties.

FEDERAL HIGHWAY ADMINISTRATION

BY: ____ Date: _______________
Gregory Murrill, Division Administrator

MARYLAND STATE HIGHWAY ADMINISTRATION

BY: ______________________________________ Date: _______________
Melinda B. Peters, Administrator

MARYLAND STATE HISTORIC PRESERVATION OFFICER

BY: ____ Date: _______________
J. Rodney Little, State Historic Preservation Officer

ADVISORY COUNCIL ON HISTORIC PRESERVATION

BY: ______________________________________ Date: _______________
John M. Fowler, Executive Director

LIST OF ATTACHMENTS

Attachment A: Preservation Priority Historic Bridges

Inventory							
Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Date	Preservation Level
MD 144E (Nat'l Pike) over Town Creek	0103500	AL-II-A-149	MD 144E (Nat'l Pike) over Town Creek	Flintstone	Allegany	1925	Priority
MD 51 over C & O Canal	0104800	AL-I-C-075	MD 51 over C & O Canal	Keifars	Allegany	1932	Priority
Blue Bridge (MD 942 over N. Br. Potomac River)	0106600	AL IV-A-153	MD 942 over North Branch	Cumberland	Allegany	1955	Priority
MD 214 over the Patuxent River	0205400	AA-761	MD 214 over the Patuxent River	Davidsonville	Anne Arundel	1935	Priority
Parkton Stone Arch Bridge (MD 463 over Little Gunpowder	0310500	BA-593	MD 463 over Little Gunpowder Falls	Parkton	Baltimore	1809	Priority
Patapsco River Bridge (US 40, Edmondson Ave Extended)	0310900	BA-2557	US 40 (Nat'l Pike, Edmondson Ave Extended) over Patapsco River	Catonsville	Baltimore	1936	Priority
US 40 (National Pike) over Middle Creek	1003100	F-4-116	US 40 (National Pike) over Middle Creek	Myersville	Frederick	1936	Priority
US 40 Alternate over Casselman River	1100700	G-II-C-101	US 40 Alt over Casselman River	Grantsville	Garrett	1932	Priority
MD 32 over River Rd, Patapsco River and B&O RR	1304600	HO-673	MD 32 over River Rd, Patapsco River and B&O RR	Sykesville	Howard	1963	Priority
Dover Bridge (MD 331 over Choptank River)	2002300	T-487	MD 331over Choptank River	Tanyard	Talbot	1933	Priority
Little Antietam Creek Bridge (MD 845A)	2100400	WA-II-1125	MD 845 A (Main Street)over Little Antietam Creek	Keedysville	Washington	1927	Priority
US 40 over Licking Creek	2101000	WA-V-418	US 40 over Licking Creek	Big Pool	Washington	1938	Priority
US 40 (National Pike) over Conococheague Creek	2101200	WA-V-211	US 40 (National Pike) over Conococheague Creek	Wilson	Washington	1936	Priority
Booth's Mill Bridge (Delemere Bridge)	2103800	WA-II-0009	MD 68 over Antietam Creek	Boonsboro	Washington	1833	Priority
Wicomico River Bridge (MD 991 over Wicomico River)	2200900	WI-117	MD 991 over Wicomico River	Salisbury	Wicomico	1928	Priority
Snow Hill Bridge (MD 12	2300200	WO-178	MD 12 over Pocomoke River	Snow Hill	Worcester	1932	Priority

Inventory							
Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Date	Preservation Level
over Pocomoke River)							
Pocomoke City Bridge (US 13 Business over Pocomoke River	2300400	WO-177	MD 675 across the Pocomoke River	Pocomoke City	Worcester	1920	Priority

Attachment B: Eligible Historic Bridges

Inventory								
Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 36 over Jennings Run	0100800	AL-V-A-314	MD 36 over Jennings Run	Mount Savage	Allegany	State	1929	Eligible
US 40 Alt (Nat'l Pike) over Wills Creek	0102800	AL-V-B-316	US 40 Alt (Nat'l Pike) over Wills Creek	Cumberland	Allegany	State	1932	Eligible
MD 144 (Nat'l Pike) over Flintstone Creek	0103300	AL-II-A-043	MD 144 (Nat'l Pike) over Flintstone Creek	Flintstone	Allegany	State	(c) 1900/1925	Eligible
MD 51 over Town Creek	0104700	AL-II-B-130	MD 51 (Old Town Road) over Town Creek	Town Creek	Allegany	State	1932	Eligible
US 40 Scenic over Sideling Hill Creek	0106400	AL-I-B-084	US 40 Scenic (McFarland Rd.) over Sideling Hill Creek	Bellegrove	Allegany	State	1925	Eligible
Stony Creek Bridge (MD 173 over Stony Creek)	0204500	AA-2196	MD 173 (Fort Smallwood Rd) over Stony Creek	Riviera Beach/Orchard Beach	Anne Arundel	State	1947	Eligible
Annapolis Eastport Bridge (MD 181 over Spa Creek)	0205300	AA-2195	MD 181(Compromise St.) over Spa Creek	Annapolis	Anne Arundel	State	1946	Eligible
MD 174 over AMTRAK	0207500	AA-2125	MD 174 over AMTRAK	Severn	Anne Arundel	State	1931	Eligible
US 1 Alt. NB, AMTRAK, and Herberts Run	0301100	BA-2782	Alt. US 1 (Washington Blvd)	Halethorpe	Baltimore	State	Yes	Eligible
Little Gunpowder Bridge (MD 7 over Little Gunpowder)	0301200	BA-2857	MD 7 (Philadelphia Road) over Little Gunpowder Falls	Bradshaw	Baltimore	State	1927	Eligible
MD 45 (York Rd.) over Western Run	0304200	BA-2858	MD 45 (York Rd.) over Western Run	Hunt Valley	Baltimore	State	1917	Eligible
MD 45 (York Rd) over Little Gunpowder Falls	0304700	BA-2859	MD 45 (York Rd) over Little	Parkton	Baltimore	State	1930	Eligible

Inventory

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
			Gunpowder Falls					
Gunpowder Falls Bridge (MD 45 over Gunpowder Fall)	0304800	BA-2860	MD 45 (York Rd) over Gunpowder Falls	Hereford	Baltimore	State	1924	Eligible
Old Court Road Bridge (MD 125 over Brice Run)	0306600	BA-2861	MD 125 (Old Court Road)over Brice Run	Randallstown	Baltimore	State	1930	Eligible
Gwynns Falls Bridge (MD 126 over Gwynns Falls)	0306700	BA-2862	MD 126 (Gwynn Oak Ave.) over Gwynns Falls	Woodlawn	Baltimore	State	1903/1930	Eligible
MD 128 over Piney Run	0306800	BA-2723	MD 128 over Piney Run	Dover	Baltimore	State	1945	Eligible
Glyndon Bridge (MD 128 over WMRR)	0307100	BA-2070	Glyndon Bridge (MD 128 over WMRR)	Glyndon	Baltimore	State	1947	Eligible
MD 140 over North Branch of Patapsco River (Liberty Reservoir)	0308300	BA-2185	MD 140 over North Branch of Pataspsco River	Reisterstown/Finksburg	Baltimore	State	1946	Eligible
MD 147 (Harford Rd) over Little Gunpowder Falls	0309000	BA-2865	MD 147 (Harford Rd) over Little Gunpowder Falls	Reckford	Baltimore	State	1928	Eligible
MD 147 (Harford Rd) over Haystack Branch	0309100	BA-2866	MD 147 (Harford Rd) over Haystack Branch	Mt. Vista	Baltimore	State	1915	Eligible
MD 147 (Harford Rd) over Long Green Creek	0309300	BA-2867	MD 147 (Harford Rd) over Long Green Creek	Mt. Vista	Baltimore	State	1915	Eligible
MD 151 over Patapsco & Back River Railroad and MD 151B	0309900	BA-2714	MD 151 over Patapsco & Back River Railroad and MD 151B	Sparrows Point	Baltimore	State	1954	Eligible
Rolling Road over CSX RR near MD 166	0310100	BA-2722	Rolling Road over CSX RR near MD 166	Arbutus	Baltimore	State	1931	Eligible
Patuxent River Bridge	0400800	CT-1214	MD 231 over	Bowens/Benedict	Calvert/Charl	State	1950-1951	Eligible

Inventory

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
(Benedict Bridge) (MD 231 over Patuxent River)			Patuxent River		es			
MD 261 over Fishing Creek	0401100	CT-1187	MD 261	Chesapeake Beach	Calvert	State	1940	Eligible
Sandy Island Bridge (MD 287 over Choptank River)	0500200	CAR-257	MD 287 (Sandtown Road) over Choptank River	Goldsboro	Caroline	State	1919	Eligible
MD 304 (Ruthsburg Rd) over Long Marsh Ditch	0501800	CAR-303	MD 304 (Ruthsburg Rd) over Long Marsh Ditch	Bridgetown	Caroline	State	(C) 1920	Eligible
Forge Branch Bridge	0501900	CAR-304	MD 480 (Ridgely Road) over Forge Branch	Greensboro	Caroline	State	1932	Eligible
MD 315 (E. Central Ave) over Marshyhope Creek	0503000	CAR-305	MD 315 (E. Central Ave) over Marshyhope Creek	Federalsburg	Caroline	State	1910/1936	Eligible
MD 86 over Branch of Gunpowder Falls	0601800	CARR-1469	MD 86 over Branch of Gunpowder Falls	Lineboro	Carroll	State	1929	Eligible
MD 97 over Big Pipe Creek	0603100	CARR-1462	MD 97 over Big Pipe Creek	Union Mills	Carroll	State	1934	Eligible
MD 32 over Liberty Reservoir	0604900	CARR-1673	MD 32 over Liberty Reservoir	Finksburg	Carroll	State	1952	Eligible
US 1 over Octoraro Creek	0700300	CE-1480	US 1 over Octoraro Creek	Richardsmere	Cecil	State	1934	Eligible
Northeast Creek Bridge (MD 7C over Northeast Creek)	0700900	CE-1495	MD 7 (Old Philadelphia Road) over Northeast Creek	Northeast	Cecil	State	1922	Eligible
US 40 (Pulaski Highway) over Principio Creek	0701400	CE-1496	US 40 (Pulaski Highway) over Principio Creek	Perryville	Cecil	State	1941	Eligible
US 222 over Octoraro Creek	0702600	CE-1482	US 222	Kilby Corner	Cecil	State	(c) 1877/1930	Eligible

Inventory								
Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 6 (Port Tobacco Rd) over Wards Run	0801300	CH-495	MD 6 (Port Tobacco Rd) over Wards Run	Welcome	Charles	State	1929	Eligible
Brookview Bridge (MD 14 over Marshyhope Creek)	0900100	D-584	MD 14 over Marshyhope Creek	Brookview	Dorchester	State	1931	Eligible
Cambridge Bridge (MD 795 over Cambridge Creek)	0900800	D-707	MD 795 over Cambridge Creek	Cambridge	Dorchester	State	1938	Eligible
US 15B (Catoctin Mountain Highway) over Flat Run	1000100	F-6-117	US 15B (Catoctin Mountain Highway) over Flat Run	Emmitsburg	Frederick	State	1927	Eligible
Toms Creek Bridge (US 15B over Toms Creek)	1000200	F-6-118	US 15B (Seton Ave South) over Toms Creek	Emmitsburg	Frederick	State	1923	Eligible
US 15 over B&O RR and Potomac River	1001700	F-2-34	US 15 over B&O RR and Potomac River	Point of Rocks	Frederick	State	1939	Eligible
Green Bridge (MD 17 over Catoctin Creek)	1001800	F-2-37	MD 17 over Catoctin Creek	Middletown	Frederick	State	1934	Eligible
MD 28 over Monocacy River	1002900	F-1-132	MD 28 over Monocacy River	Dickerson	Frederick	State	1931	Eligible
US 40 (National Pike) over Catoctin Creek	1003000	F-4-115	US 40 (National Pike) over Catoctin Creek	Myersville	Frederick	State	1936	Eligible
US 40 over Little Catoctin Creek	1003200	F-4-117	US 40 (National Pike) over Little Catoctin Creek	Myersville	Frederick	State	1936	Eligible
MD 144FA over the Monocacy River	1003803	F-3-205	MD 144FA over the Monocacy River	Frederick	Frederick	State	1955	Eligible
MD 144FA over the Monocacy River	1003804	F-3-251	MD 144FA over the Monocacy River	Frederick	Frederick	State	1942	Eligible
Catoctin Creek Bridge, US 40 Alt. over Catoctin Creek	1004000	F-4-26	US 40 Alt. (Old Nat'l Pike) over Catoctin Creek	Middletown	Frederick	State	1923	Eligible
MD 77 over Monocacy River	1005500	F-6-23	MD 77 over Monocacy River	Rocky Ridge	Frederick	State	1932	Eligible

Inventory

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 180 (Jefferson Pike) over Catoctin Creek	1008200	F-2-95	MD 180 (Jefferson Pike) over Catoctin Creek	Petersville	Frederick	State	1928	Eligible
MD 355 over Monocacy River	1008500	F-7-117	MD 355 (Urbana Pike) over Monocacy River	Frederick	Frederick	State	1930	Eligible
Old US 40 over Little Savage River	1100800	G-I-B-034	Old US 40 over Little Savage River (off of US 40 Alt.)	Finzel	Garrett	State	1840	Eligible
MD 42 (Friendsville Hoyes Road) over Buffalo Run	1101000	G-II-A-374	MD 42 (Friendsville Hoyes Road) over Buffalo Run	Friendsville	Garrett	State	1930	Eligible
MD 135 over Savage River	1101800	G-I-E-199	MD 135 over Savage River	Bloomington	Garrett	State	1937	Eligible
US 1 over Susquehanna River/Conowingo Dam	1200100	HA-1971	US 1 over Susquehanna River/Conowingo Dam	Conowingo	Harford	State	1927	Eligible
Winters Run Bridge (US 1 Bel Air Rd)	1200400	HA-1984	US 1 Bus. (Bel Air Rd) over Winters Run	Bel Air	Harford	State	1930	Eligible
MD 24 over Deer Creek	1201600	HA-1576	MD 24 over Deer Creek	Rocks	Harford	State	1934	Eligible
Priest Ford Road Bridge	1203300	HA-1579	MD 136 over Deer Creek	Trappe	Harford	State	1931	Eligible
US 40 over Little Patuxent River	1303200	HO-649	US 40 over Little Patuxent River	Ellicott City	Howard	State	1939	Eligible
US 40 over Forest Road Underpass	1303400	HO-656	US 40 over Forest Road Underpass	Ellicott City	Howard	State	1936	Eligible
MD 299 over Herring Branch of Sassafras River	1401700	K-682	MD 299 (Sassafras Rd. over Herring Branch of Sassafras River	Sassafras	Kent	State	1913	Eligible

Inventory								
Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 299 over Jacobs Creek	1401800	K-681	MD 299 (Massey Road) over Jacobs Creek	Sassafras	Kent	State	1938	Eligible
Hopewell Bridge (MD 291 over Morgan Creek)	1402200	K-453	MD 291 over Morgan Creek	Hopewell	Kent	State	1934	Eligible
Snell Bridge (MD 108 over Patuxent River)	1500800	M: 15-95	MD 108 (Ashton Rd. over Patuxent River)	Ashton	Montgomery	State	1928	Eligible
Sligo Creek Bridge (MD 195 over Sligo Creek)	1503300	M: 37-7	MD 195 (Carroll Avenue) over Sligo Creek	Takoma Park	Montgomery	State	1932	Eligible
MD 212 over Indian Creek	1603800	PG: 61-27	MD 212 over Indian Creek	Greenbelt	Prince George's	State	1937	Eligible
Northwest Branch Bridge (MD 212) over Northwest Br	1604200	PG:65-22	MD 212 (Riggs Rd) over Northwest Branch	Takoma Park	Prince George's	State	1932	Eligible
MD 412A (Riverdale Rd) over NE Branch of Anacostia	1606900	PG:68-84	MD 412A (Riverdale Rd) over NE Branch of Anacostia River	Riverdale	Prince George's	State	1931	Eligible
MD 201 (Edmonston Rd) over Beaverdam Creek	1611100	PG:67-6	MD 201 (Edmonston Rd) over Beaverdam Creek	Greenbelt	Prince George's	State	1940	Eligible
MD 18B over Kent Narrows	1700600	QA-542	MD 18B over Kent Narrows	Grasonville	Queen Anne's	State	1951	Eligible
MD 238 (Maddox Rd) over Burroughs Run	1801800	SM-617	MD 238 (Maddox Rd) over Burroughs Run	Maddox	St. Mary's	State	1929	Eligible
US 40 over Branch of Antietam Creek	2101300	WA-I-730	US 40 over Branch of Antietam Creek	Hagerstown	Washington	State	1941	Eligible
US 40 WB (National Pike) over Antietam Creek	2101400	WA-I-842	US 40 WB (National Pike) over Antietam Creek	Hagerstown	Washington	State	1936	Eligible
US 40 over Landis Spring Branch	2101500	WA-II-1113	US 40 over Landis Spring Branch	Hagerstown	Washington	State	1936	Eligible

Inventory

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
US 40 over Beaver Creek	2101600	WA-II-0476	US 40 over Beaver Creek	Wagners Crossroads	Washington	State	1936	Eligible
Funkstown Turnpike Bridge (First Funkstown Bridge)	2101800	WA-I-029	US 40 Alt. over Antietam Creek	Funkstown	Washington	State	1823/1931	Eligible
Kline's Mill Bridge (Newcomer's Mill/US40Alt. Br.)	2102000	WA-II-042	US 40 Alt. over Beaver Creek	Benevola	Washington	State	1840/1948	Eligible
MD 56 (Big Pool Rd) over Little Conococheague Cr.	2102300	WA-V-063	MD 56 (Big Pool Rd) over Little Conococheague Cr.	Clear Spring	Washington	State	1907	Eligible
Antietam Creek Bridge (MD 64)	2102800	WA-I-843	MD 64 (Jefferson Blvd) over Antietam Creek	Hagerstown	Washington	State	1934	Eligible
MD 68 over Conococheague Creek	2103600	WA-I-020	MD 68 over Conococheague Creek	Williamsport	Washington	State	1829/1984	Eligible
Devil's Backbone Bridge	2103900	WA-II-0017	MD 68 over Beaver Creek	Boonsboro	Washington	State	1824/1979	Eligible
Sandy Hook Bridge	2104100	WA-III-168	US 340 over Potomac River, CSX RR, C&O Canal, Sandy Hook Road	Sandy Hook	Washington	State	1947	Eligible
Conococheague Creek Bridge	2104200	WA-I-462	MD 494 over Conococheague Creek	Fairview	Washington	State	1932	Eligible
US 522 over Potomac River, CSX Railroad, and C&O	2104300	WA-VI-053	US 522 over Potomac River, CSX Railroad, and C&O Canal	Hancock	Washington	State	1939	Eligible
US 522 over MD 144 and Tonoloway Creek	2112400	WA-HAN-349	US 522 over MD 144 and Tonoloway Creek	Hancock	Washington	State	1937	Eligible
US 13 Business over	2200400	WI 224	US 13 Business	Salisbury	Wicomico	State	1937	Eligible

Inventory								
Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
East Branch of Wicomico River			over East Branch of Wicomico River					
MD 347 over Quantico Creek	2201400	WI-340	MD 347 over Quantico Creek	Quantico	Wicomico	State	1926	Eligible
US 50 WB over Herring Creek	2300604	WO-482	US 50 WB over Herring Creek	Ocean City	Worcester	State	1942	Eligible
Ocean City Bridge (US 50 over Sinepuxent Bay)	2300700	WO-461	US 50 over Sinepuxent River	Ocean City	Worcester	State	1942	Eligible
US 113 over Purnell Branch	2300800	WO-483	US 113 over Purnell Branch	Snow Hill	Worcester	State	1952	Eligible

Attachment C: Non-priority Historic Level Bridges

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 36 over Jennings Run	0100700	AL-V-B-312	MD 36 over Jennings Run	Mount Savage	Allegany	State	1929	Non-priority Eligible
MD 935 over Georges Creek	0101900	AL-VI-C-327	MD 935 over Georges Creek	Barton	Allegany	State	1932	Non-priority Eligible
MD 51 over Sawpit Run	0104600	AL-II-B-146	MD 51 over Sawpit Run	Town Creek	Allegany	State	1932	Non-priority Eligible
MD 170 over Severn Run	0204400	AA-2119	MD 170 over Severn Run	Odenton	Anne Arundel	State	1936	Non-priority Eligible
MD 25 over George's Run	0301900	BA-2783	MD 25 over George's Run	Hampstead	Baltimore	State	1932	Non-priority Eligible
MD 25 over Jones Falls	0302700	BA-2663	MD 25 over Jones Falls	Timonium	Baltimore	State	1932	Non-priority Eligible
US 40 over Gunpowder Falls	0303500	BA-2720	US 40 over Gunpowder Falls	Kingsville	Baltimore	State	1935	Non-priority Eligible
US 40 over Whitemarsh Run	0303700	BA-2666	US 40 over Whitemarsh Run	White Marsh	Baltimore	State	1935	Non-priority Eligible
MD 150 over MD 700	0309500	BA-2724	MD 150 over MD 700	Middle River	Baltimore	State	1942	Non-priority Eligible
MD 404 Alternate over Tuckahoe	0501700	CAR-297	MD 404 Alternate over	Hillsboro	Caroline	State	1915	Non-priority Eligible

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
Creek			Tuckahoe Creek					
MD 31 over Dickerson Run	0600700	CARR-1557	MD 31 over Dickerson Run	New Windsor	Carroll	State	1924	Non-priority Eligible
MD 31 over Sams Creek	0600800	CARR-1468	MD 31 over Sams Creek	New Windsor	Carroll	State	1929	Non-priority Eligible
MD 850 over Talbot Branch	0604200	CARR-1473	MD 850 over Talbot Branch	Franklinville	Carroll	State	1930	Non-priority Eligible
MD 7 over Stoney Run	0700800	CE-1489	MD 7 over Stoney Run	North East	Cecil	State	1931	Non-priority Eligible
MD 272 SB over North East Creek	0703700	CE -1469	MD 272 SB over North East Creek	North East	Cecil	State	1944	Non-priority Eligible
MD 5 SB over Zekiah Swamp	0800200	CH-487	MD 5 SB over Zekiah Swamp	Bryantown	Charles	State	1931	Non-priority Eligible
MD 5 SB over Zekiah Swamp	0800300	CH-488	MD 5 SB over Zekiah Swamp	Bryantown	Charles	State	1931	Non-priority Eligible
MD 6 over Nanjemoy Creek	0801500	CH-387	MD 6 over Nanjemoy Creek	Grayton	Charles	State	1922	Non-priority Eligible
MD 224 over Reeders Run	0801800	CH-381	MD 224 over Reeders Run	Chicamuxen	Charles	State	1928	Non-priority Eligible
MD 806A over Little Hunting Creek	1000700	F-6-107	MD 806A over Little Hunting Creek	Thurmont	Frederick	State	1927	Non-priority Eligible

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 85 over Branch of Monocacy River	1001300	F-1-81	MD 85 over Branch of Monocacy River	Buckeystown	Frederick	State	1929	Non-priority Eligible
MD 28 over Branch of Potomac River (Rocky Fountain Branch)	1001500	F-1-82	MD 28 over Branch of Potomac River (Rocky Fountain Branch)	Point of Rocks	Frederick	State	1937	Non-priority Eligible
US 40 over Branch of Little Catoctin Creek	1003300	F-4-102	US 40 over Branch of Little Catoctin Creek	Myersville	Frederick	State	1936	Non-priority Eligible
US 40 WB over Rock Creek	1003400	F-3-49	US 40 WB over Rock Creek	Frederick	Frederick	State	1936	Non-priority Eligible
MD 75 over Branch of Bennett Creek	1004600	F-7-125	MD 75 over Branch of Bennett Creek	Urbana	Frederick	State	1930	Non-priority Eligible
MD 77 over Owens Creek	1005300	F-6-115	MD 77 over Owens Creek	Rocky Ridge	Frederick	State	1932	Non-priority Eligible
MD 140 over Flat Run	1006200	F-6-111	MD 140 over Flat Run	Emmitsburg	Frederick	State	1910/1932	Non-priority Eligible
MD 140 over Middle Creek	1006300	F-6-112	MD 140 over Middle Creek	Emmitsburg	Frederick	State	1932	Non-priority Eligible
MD 478 over unnamed	1008800	F-2-92	MD 478 over unnamed	Knoxville	Frederick	State	1926	Non-priority Eligible

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
tributary of Potomac River			tributary of Potomac River					
MD 478 over Branch of the Potomac River	1008900	F-2-92	MD 478 over Branch of the Potomac River	Brunswick	Frederick	State	1925	Non-priority Eligible
MD 17 over Catoctin Creek	1017600	F-4-41	MD 17 over Catoctin Creek	Myersville	Frederick	State	1928	Non-priority Eligible
MD 17 over Catoctin Creek	1017700	F-4-112	MD 17 over Catoctin Creek	Myersville	Frederick	State	1919	Non-priority Eligible
MD 828 over Youghiogheny River	1101100	G-II-A-366	MD 828 over Youghiogheny River	Friendsville	Garrett	State	1932	Non-priority Eligible
MD 135 over CSX RR	1101600	G-IV-B-271	MD 135 over CSX RR	Altamont	Garrett	State	1930	Non-priority Eligible
MD 136 over Big Branch	1203000	HA-1977	MD 136 over Big Branch	Harkins	Harford	State	1934	Non-priority Eligible
MD 136 over Falling Branch	1203100	HA-1866	MD 136 over Falling Branch	Pylesville	Harford	State	1930	Non-priority Eligible
MD 176 over Deep Run (aka MD 103?)	1304100	HO-650	MD 176 over Deep Run (aka MD 103?)	Dorsey	Howard	State	1937	Non-priority Eligible
MD 291 over Cypress Creek	1401500	K-675	MD 291 over Cypress Creek	Millington	Kent	State	1928	Non-priority Eligible
MD 28 over the Little Monocacy	1500100	M:12-47	MD 28 over the Little	Dickerson	Montgomer y	State	1925	Non-priority Eligible

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
River			Monocacy River					
MD 97 over Hawlings River	1501100	M:23-125	MD 97 over Hawlings River	Suncshine	Montgomery	State	1930	Non-priority Eligible
MD 650 over Hawlings River	1501700	M:23-127	MD 650 over Hawlings River	Ashton	Montgomery	State	1929	Non-priority Eligible
MD 117 over Bucklodge Branch	1501800	M:18-46	MD 117 over Bucklodge Branch	Bucklodge	Montgomery	State	1932	Non-priority Eligible
MD 547 over Rock Creek	1506200	M:31-16	MD 547 over Rock Creek	Kensington	Montgomery	State	1932	Non-priority Eligible
MD 978 over Collington Branch	1604800	PG:74B-21	MD 978 over Collington Branch	Bowie	Prince George's	State	1929	Non-priority Eligible
MD 382 over Mataponi Creek	1606200	PG:86A-28	MD 382 over Mataponi Creek	Croom	Prince George's	State	1930	Non-priority Eligible
MD 410 over Sligo Creek	1606700	PG:65-20	MD 410 over Sligo Creek	Takoma Park	Prince George's	State	1934	Non-priority Eligible
MD 213 over Gravel Run	1702000	QA-480	MD 213 over Gravel Run	Centreville	Queen Anne's	State	1934	Non-priority Eligible
MD 405 over Southeast Creek	1703300	QA-479	MD 405 over Southeast Creek	Church Hill	Queen Anne's	State	1933	Non-priority Eligible

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
MD 456 over Branch of Wye River	1703500	QA-482	MD 456 over Branch of Wye River	Queenstown	Queen Anne's	State	1924	Non-priority Eligible
MD 6 over Lockes Swamp Creek	1801200	SM-515	MD 6 over Lockes Swamp Creek	Huntersville	St. Mary's	State	1930	Non-priority Eligible
MD 6 over Persimmon Creek	1801300	SM-516	MD 6 over Persimmon Creek	Cremona	St. Mary's	State	1932	Non-priority Eligible
MD 244 over Poplar Hill Creek	1802400	SM-506	MD 244 over Poplar Hill Creek	Chingville	St. Mary's	State	1938	Non-priority Eligible
MD 471 over St. Mary's River	1802900	SM-514	MD 471 over St. Mary's River	Great Mills	St. Mary's	State	1932	Non-priority Eligible
MD 303 over Norwich Creek	2001000	T-947	MD 303 over Norwich Creek	Queen Anne	Talbot	State	1928	Non-priority Eligible
MD 662C over Potts Mill Creek	2002200	T-942	MD 662C over Potts Mill Creek	Easton	Talbot	State	1911	Non-priority Eligible
MD 62 over Little Antietam Creek	2102600	WA-I-735	MD 62 over Little Antietam Creek	Leitersburg	Washington	State	1931	Non-priority Eligible
MD 858 over Little Antietam Creek	2104700	WA-III-121	MD 858 over Little Antietam Creek	Rohrersville	Washington	State	1922/1930s	Non-priority Eligible
MD 353 over	2201800	WI-220	MD 353 over Burnt Mill	Pittsville	Wicomico	State	1934	Non-priority Eligible

Name	SHA Bridge Number	MIHP Number	Location	City/Town	County	Ownership	Date	Preservation Level
Burnt Mill Branch			Branch					
MD 354 over Tilghman Race	2301100	WO-489	MD 354 over Tilghman Race	Whiton	Worcester	State	1932	Non-priority Eligible
US 113 SB over Corkers Creek	2302300	WO-486	US 113 SB over Corkers Creek	Snow Hill	Worcester	State	1912/1930	Non-priority Eligible

Attachment D

Maryland Inventory of Historic Properties Addendum

MIHP Number:

Property Name:

Property Address:

This bridge is considered a "Non-Priority Historic Bridge" under the Programmatic Agreement executed among the Federal Highway Administration, State Highway Administration and the Maryland State Historic Preservation Office for the management of historic highway bridges in Maryland. The State Highway Administration (SHA) has prepared the following documentation to serve as mitigation for future adverse effects to this bridge.

INSERT BRIDGE DESCRIPTION AND STATEMENT OF HISTORIC SIGNIFICANCE FROM DOE FORM PREPARED BY SHA IN 2009 (Do Not Include National Register Evaluation)

ATTACHMENT E
SHA HISTORIC BRIDGE REVIEW FORM

Historic Bridge Review Form

March 22, 2012

Mr. J. Rodney Little
State Historic Preservation Officer
Maryland Historical Trust
100 Community Place
Crownsville MD 21032-2023

Documentation of No Effect Determination
(under the Programmatic Agreement for SHA's Historic Highway Bridges in Maryland)

Project: MD 173 over Stony Creek

Funding Source: Federal Project Number: AX673B22

Description of work

The Maryland State Highway Administration (SHA) is proposing remedial repairs to Bridge No. 0204500 on MD 173 (Ft. Smallwood Road) over Stony Creek in Anne Arundel County. The proposed work includes cleaning and painting as well superstructure and substructure concrete repairs, steel retrofit repairs, in-kind replacement of steel channel diaphragms, fence rehabilitation, replacing compression seals with strip seals, and cast-in-place concrete repairs, where necessary. All work will occur within existing SHA right-of-way.

County: Anne Arundel 7.5' Topographic Map Name: Curtis Bay

Project Type: **NO EFFECT NO ADVERSE EFFECT [WOULD NEED TO CHOOSE]**

Actions Taken:

SHA Architectural Historian Anne E. Bruder consulted the SHA0GIS Cultural Resources Database, as built plans for SHA Bridge No. 0204500 from 1947, and the Maryland Inventory of Historic Properties (MIHP) form for the historic bridge, MIHP No. AA-2196. SHA Bridge No. 0204500 was determined to be eligible for the National Register of Historic Places (NRHP) in February 1999 by SHA and MHT. This project meets the requirements of the FHWA-MDSHPO-SHA Historic Bridge Programmatic Agreement for eligible bridges. Based on the project description and discussions with the Project Engineer, SHA has determined that the proposed repairs will have no adverse impact on historic properties, including SHA Bridge NO. 0204500, since the work will meet the requirements of the Secretary of the Interior's Standards for Rehabilitation (36 CFR Part 68) because the cast-in-place concrete will match the original in color and texture and because the remaining work will also be an in-kind replacement of damaged portions of the bridge.

SHA Archeologist Lisa Kraus assessed the archeological potential of the APE based on review of the SHA-GIS Cultural Resources Database, soil survey data, aerial photography, and historic maps.

The survey area was included in Curry's (1979) archeological reconnaissance of MD 173, but no sites were recorded within the APE as a result of that study. Historic maps (Griffith 1795; Martenet 1860) show no structures within the survey area. The SCS Soil Survey describes soils in the vicinity of the bridge (on either side of Stony Creek) as Udorthents, human-transported highway materials. Soils of this type are unlikely to contain intact archeological remains.

Given the low likelihood for archeological remains and the negative survey coverage, the proposed work is unlikely to impact any intact or potentially significant archeological resources. No further work is recommended.

Very truly yours,

Julie M. Schablitsky
Assistant Division Chief
Environmental Planning Division

by:

Attachments
cc: Ms. Jennifer Martin
Ms. Anne Bruder (w/Attachments)
Ms Lisa Kraus (w/Attachments)
Local Government Agency/Historic Preservation Group