Stone Arch Bridges of Washington County, MD

Presentation for the County Engineers Association of Maryland (CEAM)

2009 Spring Conference

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Washington County Division of Public Works

Overview

- Introduction
- Washington County Bridges
- Bridge Inspection Program
- Funding
- Decision Making
- Design
- Rehabilitation
- Costs
- Repairs
- Closing
- Questions

Introduction

- Washington County goes to great efforts to preserve and maintain its infrastructure, including our stone arch bridges.
  - To ensure the maximum useful life of our structures.
  - To provide acceptable service to the public.

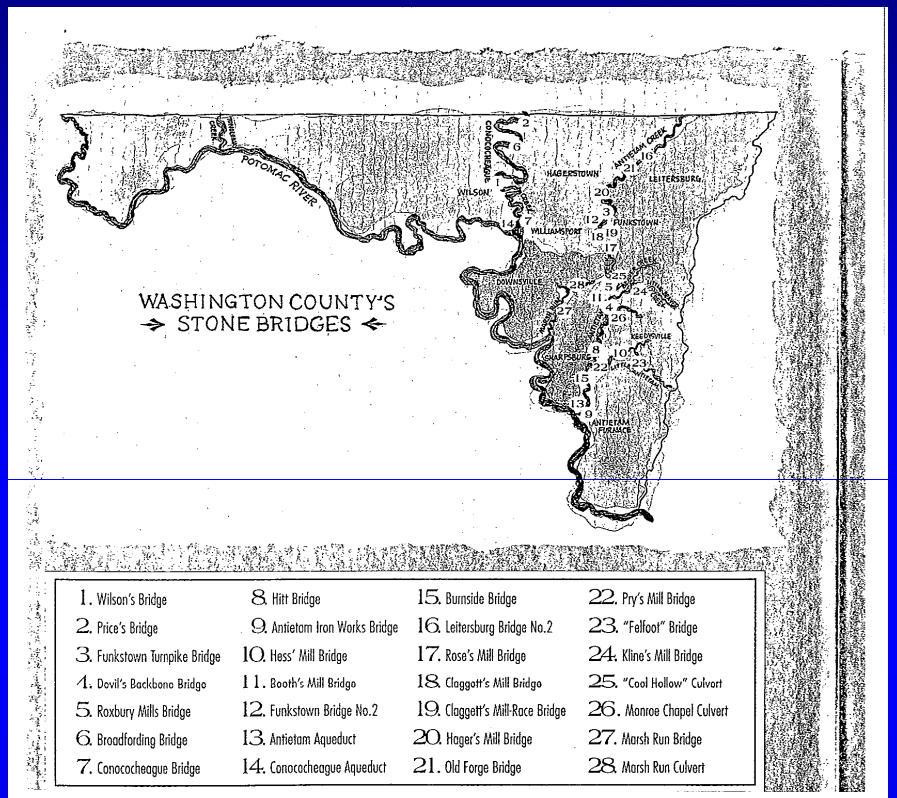
Washington County Bridges

- Major Structures - Culverts or bridges with spans of 20'+
- Minor Structures - Culverts or bridges with spans 6'-20'

- 90 Major Structures owned and maintained by County
  - 14 Stone Arch Bridges
- 185 Minor Structures owned and maintained by County
  - 12 Stone Arch Bridges

- 179 Major Structures owned and maintained by SHA
  - 7 Stone Arch Bridges
- 215 Minor Structures owned and maintained by SHA
  - 7 Stone Arch Bridges

- Approx. 580,000 major bridges in U.S.


WASHINGTON COUNTY'S
STONE BRIDGES
POTOMAC RIVER
CONOCOCHEAGUE
WILSON
HAGERSTOWN
ANTIETAM CREEK
LEITERSBURG
FUNKSTOWN
WILLIAMSPORT
DOWNSVILLE
KEEDYSVILLE
HARPERS FERRY
ANTIETAM FURNACE
1. Wilson's Bridge
2. Price's Bridge
3. Funkstown Turnpike Bridge
4. Devil's Backbone Bridge
5. Roxbury Mills Bridge
6. Broadfording Bridge
7. Conococheague Bridge
8. Hitt Bridge
9. Antietam Iron Works Bridge
10. Hess' Mill Bridge
11. Booth's Mill Bridge
12. Funkstown Bridge No.2
13. Antietam Aqueduct
14. Conococheague Aqueduct
15. Burnside Bridge
16. Leitersburg Bridge No.2
17. Rose's Mill Bridge
18. Claggett's Mill Bridge
19. Claggett's Mill-Race Bridge
20. Hager's Mill Bridge
21. Old Forge Bridge
22. Pry's Mill Bridge
23. "Felfoot" Bridge
24. Kline's Mill Bridge
25. "Cool Hollow" Culvert
26. Monroe Chapel Culvert
27. Marsh Run Bridge
28. Marsh Run Culvert

Bridge Inspection Program

- Federal Aid Highway Act of 1968 and Surface Transportation Assistance Act of 1978.
  - National Bridge Inspection Standards (NBIS)

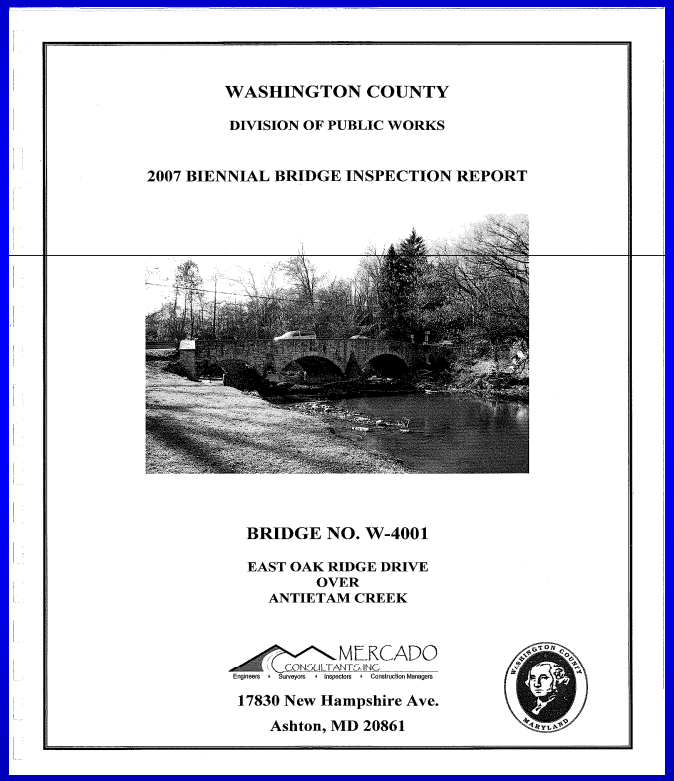
- Primary purpose is to locate and evaluate existing bridge deficiencies to ensure the safety of the traveling public.
  - Stone arch bridges were not built to carry the vehicles of today.
  - Provide a thorough bridge inspection. Document and monitor the deficiencies until appropriate repairs can be made.
    - In turn, we can adequately preserve and maintain our historic structures.

Bridge Inspection Program

- NBIS require major structures to be inspected at least every 2 years.
  - Set national standards for proper safety inspection and evaluation of bridges
  - Bridge inspection reports

- Local jurisdictions determine the inspection cycle for minor structures. Every 4 years in Washington County.

Bridge Inspection Program



WASHINGTON COUNTY

DIVISION OF PUBLIC WORKS

2007 BIENNIAL BRIDGE INSPECTION REPORT

BRIDGE NO. W-4001

EAST OAK RIDGE DRIVE
OVER
ANTIETAM CREEK

MERCADO CONSULTANTS, INC.
Engineers • Surveyors • Inspectors • Construction Managers

17830 New Hampshire Ave.
Ashton, MD 20861

- From the Inspection Reports, the County evaluates:

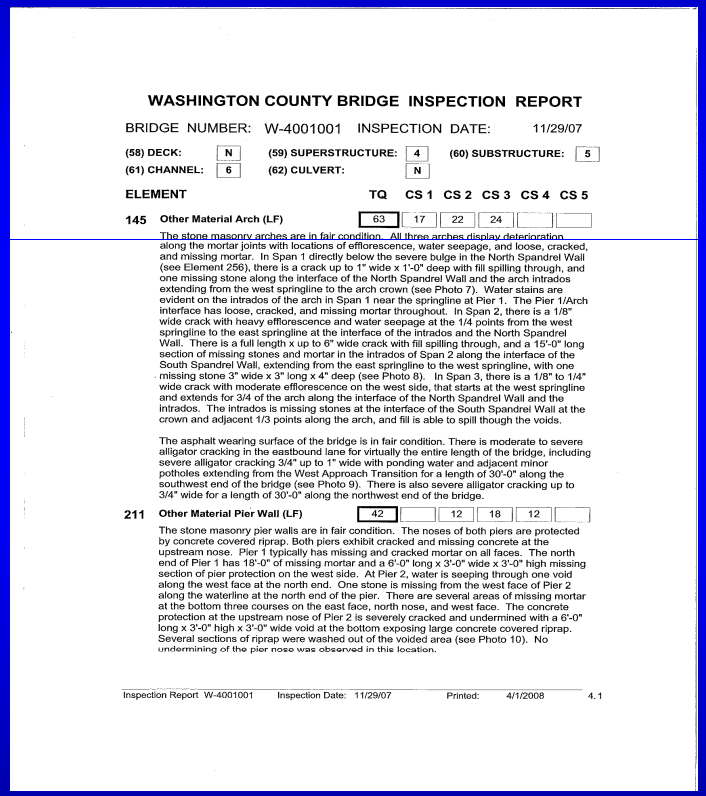
> Structure Inventory & Appraisal (SI&A) Ratings,

> Bridge Sufficiency Ratings (BSR),

> and PONTIS Ratings

- Based on the numbers, our stone arch bridges are at the top of the priority list for repairs.

Bridge Inspection Program



WASHINGTON COUNTY BRIDGE INSPECTION REPORT

BRIDGE NUMBER: W-4001001 INSPECTION DATE: 11/29/07

(58) DECK:	N	**(59) SUPERSTRUCTURE:**	4	**(60) SUBSTRUCTURE:**	5
(61) CHANNEL:	6	**(62) CULVERT:**	N		

ELEMENT		TQ	CS 1	CS 2	CS 3	CS 4	CS 5
145	Other Material Arch (LF)	63	17	22	24		

The stone masonry arches are in fair condition. All three arches display deterioration along the mortar joints with locations of efflorescence, water seepage, and loose, cracked, and missing mortar. In Span 1 directly below the severe bulge in the North Spandrel Wall (see Element 256), there is a crack up to 1" wide x 1'-0" deep with fill spilling through, and one missing stone along the interface of the North Spandrel Wall and the arch intrados extending from the west springline to the arch crown (see Photo 7). Water stains are evident on the intrados of the arch in Span 1 near the springline at Pier 1. The Pier 1/Arch interface has loose, cracked, and missing mortar throughout. In Span 2, there is a 1/8" wide crack with heavy efflorescence and water seepage at the 1/4 points from the west springline to the east springline at the interface of the intrados and the North Spandrel Wall. There is a full length x up to 6" wide crack with fill spilling through, and a 15'-0" long section of missing stones and mortar in the intrados of Span 2 along the interface of the South Spandrel Wall, extending from the east springline to the west springline, with one missing stone 3" wide x 3" long x 4" deep (see Photo 8). In Span 3, there is a 1/8" to 1/4" wide crack with moderate efflorescence on the west side, that starts at the west springline and extends for 3/4 of the arch along the interface of the North Spandrel Wall and the intrados. The intrados is missing stones at the interface of the South Spandrel Wall at the crown and adjacent 1/3 points along the arch, and fill is able to spill though the voids.

The asphalt wearing surface of the bridge is in fair condition. There is moderate to severe alligator cracking in the eastbound lane for virtually the entire length of the bridge, including severe alligator cracking 3/4" up to 1" wide with ponding water and adjacent minor potholes extending from the West Approach Transition for a length of 30'-0" along the southwest end of the bridge (see Photo 9). There is also severe alligator cracking up to 3/4" wide for a length of 30'-0" along the northwest end of the bridge.

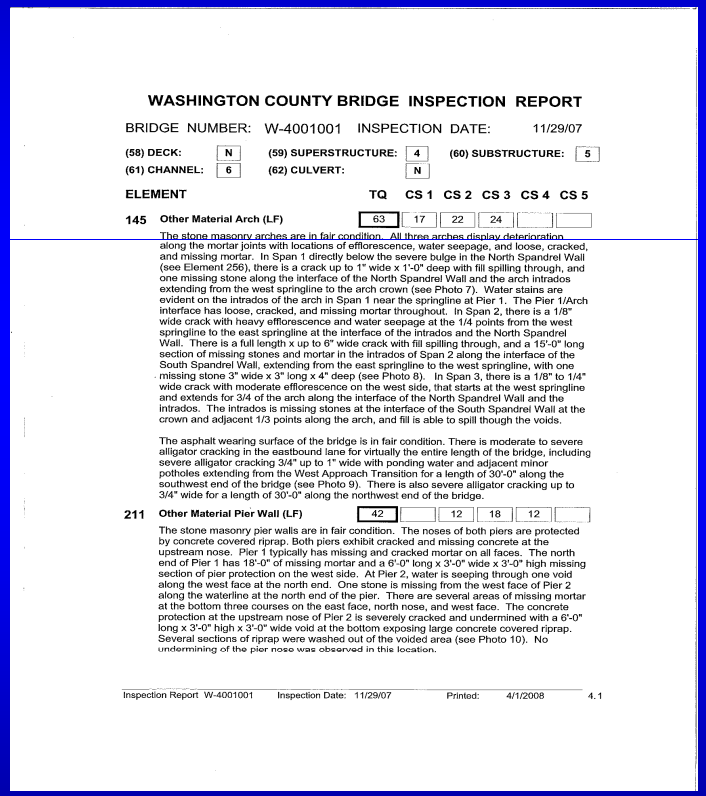
211	Other Material Pier Wall (LF)	42		12	18	12	

The stone masonry pier walls are in fair condition. The noses of both piers are protected by concrete covered riprap. Both piers exhibit cracked and missing concrete at the upstream nose. Pier 1 typically has missing and cracked mortar on all faces. The north end of Pier 1 has 18'-0" of missing mortar and a 6'-0" long x 3'-0" wide x 3'-0" high missing section of pier protection on the west side. At Pier 2, water is seeping through one void along the west face at the north end. One stone is missing from the west face of Pier 2 along the waterline at the north end of the pier. There are several areas of missing mortar at the bottom three courses on the east face, north nose, and west face. The concrete protection at the upstream nose of Pier 2 is severely cracked and undermined with a 6'-0" long x 3'-0" high x 3'-0" wide void at the bottom exposing large concrete covered riprap. Several sections of riprap were washed out of the voided area (see Photo 10). No undermining of the pier nose was observed in this location.

Inspection Report W-4001001 Inspection Date: 11/29/07 Printed: 4/1/2008 4.1

- Structural Inventory and Appraisal (SI&A) Ratings
  - Each component of a bridge gets a rating value from 0 to 9.

Bridge Inspection Program



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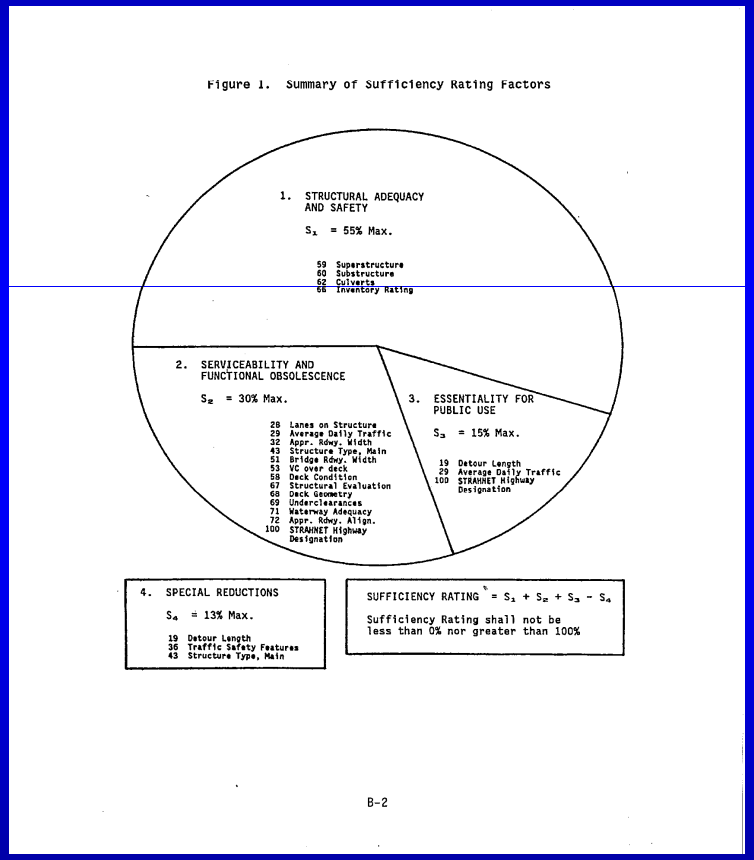
Inspection Report W-4001001 Inspection Date: 11/29/07 Printed: 4/1/2008 4.1

- A bridge is considered structurally deficient if:
- Deck, Superstructure, Substructure, or Culvert are rated a 4 or less (poor or worse condition).
  - Some of our stone arch bridges needing repairs are considered structurally deficient.

Bridge Inspection Program



- Each bridge has a bridge sufficiency rating (BSR).
  - 0-100 (100 is new bridge)
- FHWA tracks each major bridge in the U.S. by this number.

Bridge Inspection Program

- If a bridge has a BSR of less than 50 and has a bridge component rated 4 or less, the bridge qualifies for replacement funding.
- If the bridge has a BSR from 50 to 80 and has a bridge component rated 4 or less, the bridge qualifies for rehabilitation funding.
  - 9 stone arch bridges qualify for rehabilitation funding.

Bridge Inspection Program

- Washington County spends $300,000 on major bridge inspections and $90,000 on minor bridge inspections.
  - Visual (hands-on) inspection and underwater inspection.
  - Written inspection report with documented conditions and photographs.
  - Approx. $40,000 major arches
  - Approx. $5,000 minor arches

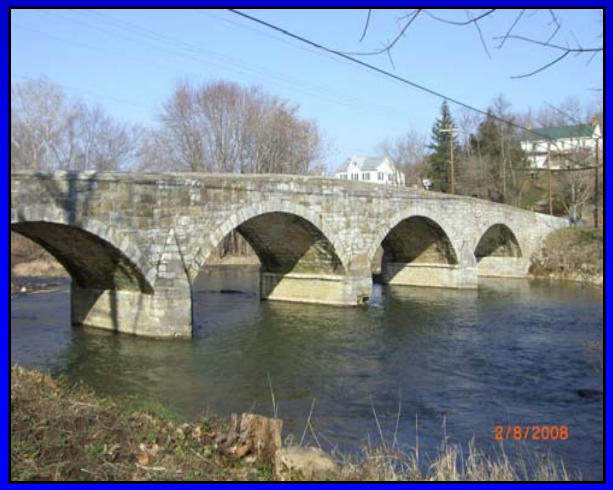
Funding

- Funding is limited.
- Washington County spends app. $2.5 million per year on maintaining, repairing, rehabilitating, replacing bridges.
- Average rehabilitation cost for a three span stone arch bridge is app. $1,000,000 dollars.

Funding

- Prioritize funding.
- Capital Improvement Plan (CIP).
  - 6 major stone arch bridges are scheduled for rehabilitation in the next 10 years.
  - 4 stone arch bridges were rehabilitated since 2000.

Decision Making



- Due to the aging infrastructure and the lack of funding available, Washington County typically follows a “Worst-First” evaluation.
- “Worst-First” - Structures with the lowest ratings are grouped together for review.
  - If a structure is eligible for federal aid funding, it goes to the top of the list for rehabilitation or replacement.
  - Most of our stone arches fall under worst-first criteria.

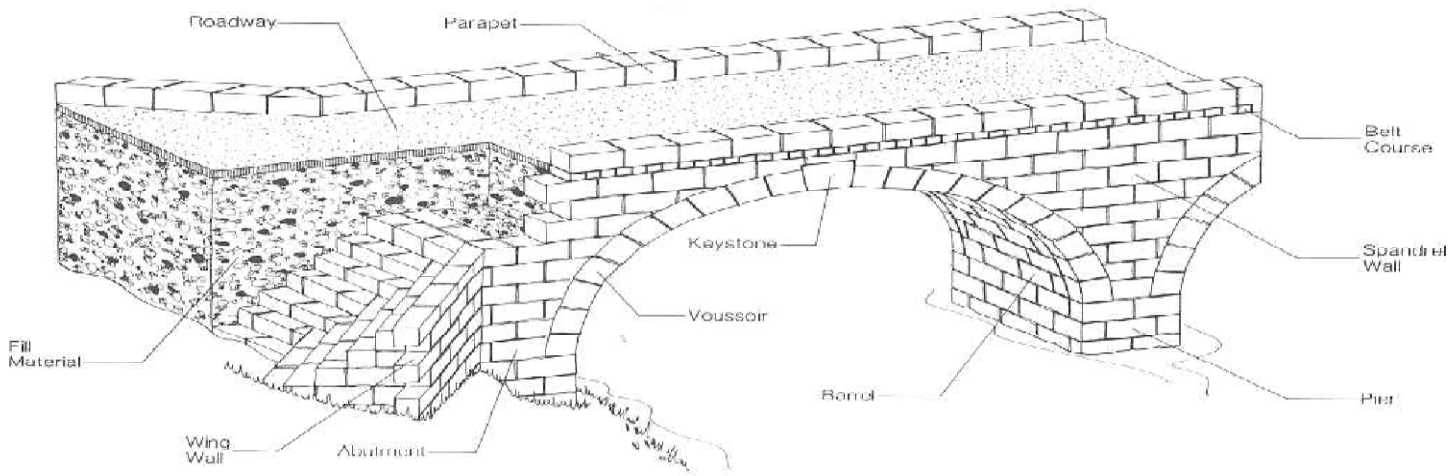
Decision Making

- Capital Projects Engineering
  - Maintains inventory, develops priority list and cost estimates for review
- Director of Public Works and CIP Budget Committee Review
  - Evaluates list and prioritizes against other project needs (Buildings, Roads, Parks, etc.)
- Washington County Commissioners
  - Continue to invest in repairing and rehabilitating our stone arch bridges.

Design

- Our stone arch bridges are identified as historic.
  - Eligible for listing in the National Register of Historic Places.
- Must comply with Section 106
  - Afforded a degree of protection under historic preservation laws.
- Must adhere to Secretary of the Interior's Standards for the Treatment of Historic Properties
  - To provide an acceptable rehabilitation or repair.

Design



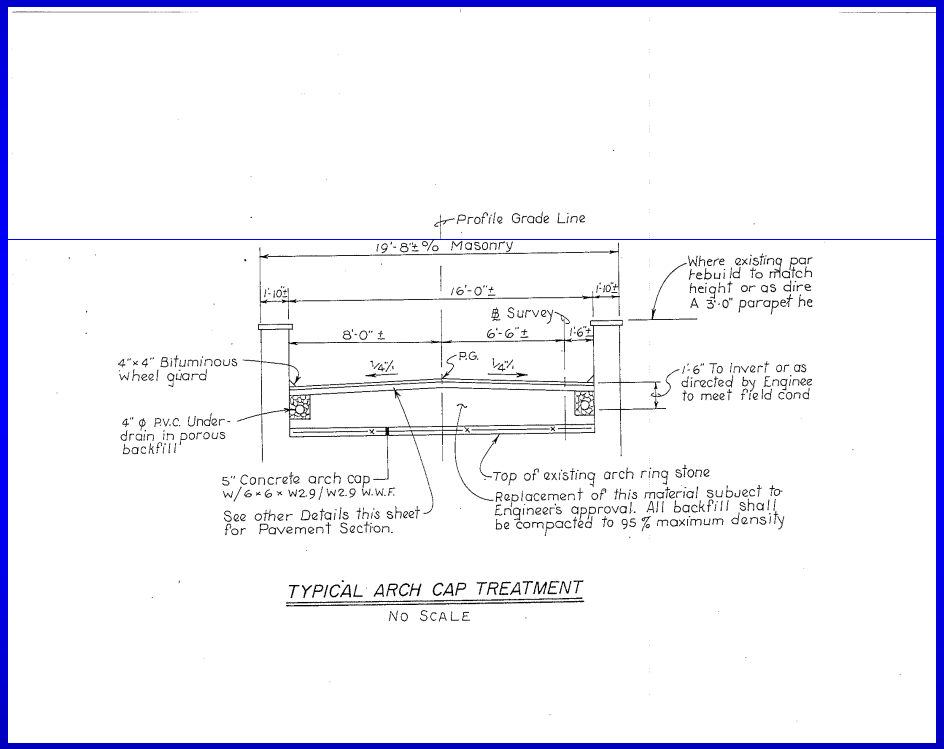
Typical Stone Arch Bridge

28

Design

- Major rehabilitation projects are designed by a consultant hired by the County through SHA's open-ended consultant process.
  - $150,000 design cost per bridge
    - Using Federal Aid Funding and SHA Review Process
  - Design and load rating based on finite element analysis modeling of reinforced lightweight fill concrete and stresses on the stone masonry arch.
- Repair plans are prepared in-house.

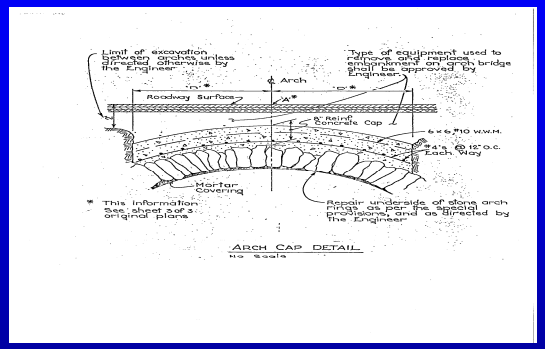
Design



- Repairs to the bridges in the late 1970's and early 1980's provided a concrete cap over the arches and drainage pipes within the existing soil-gravel fill.
  - Not replacing the soil-gravel infill with lightweight concrete has been proven to be an issue with the development of bulging spandrel walls and severe deterioration of mortar joints.

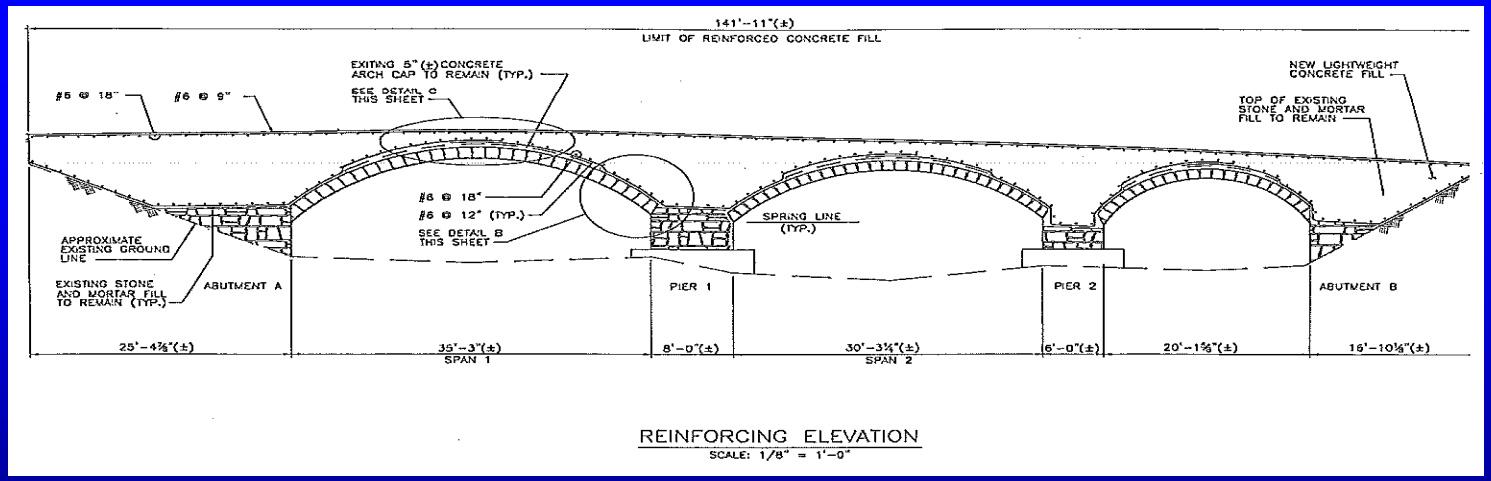
Design

- The concrete cap over the arch has proven to be effective in protecting the arch and has assisted in ensuring the arches remain in tact during construction.

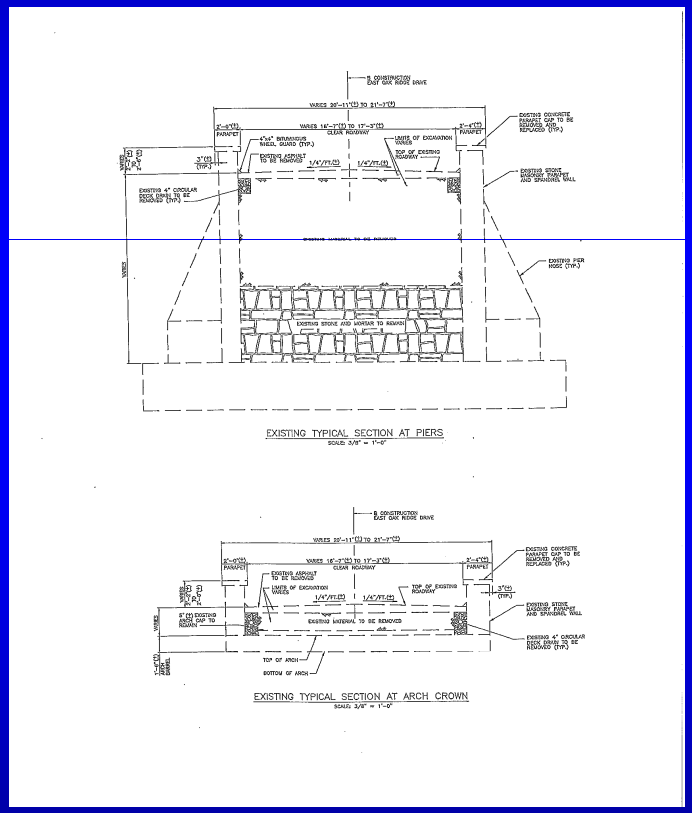


Design

- We use an effective technique for rehabilitation that strengthens the bridge and does not alter its visual appearance.
  - Replacing the soil-gravel fill with reinforced lightweight concrete and reconstructing the stone masonry spandrel and parapet walls.
    - The fill of the bridge is not considered a character defining element.

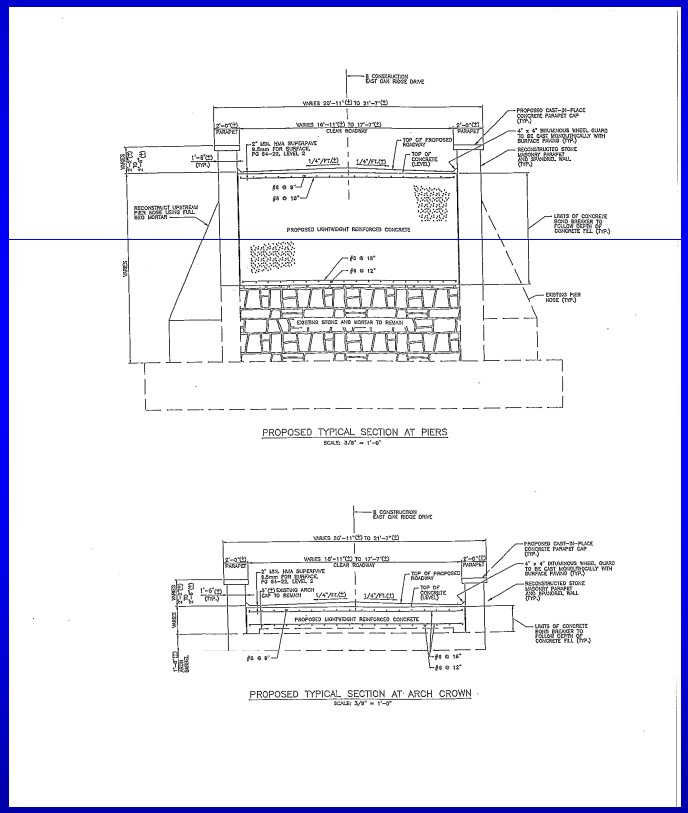


Design



- This type of design follows the Secretary of Interior Standards
  - Deteriorated historic features will be repaired rather than replaced.
  - Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and where possible materials.
  - Replacement of missing features will be substantiated by documentary and physical evidence.

Design



and

- is considered “no adverse effect” by the Maryland Historical Trust.
  - Reconstruction of stone spandrel and parapet walls utilize existing salvaged stone or new stone that matches the existing stone as closely as possible.
  - The mortar used for repointing and reconstruction matches MHT’s recommendations.

Rehabilitation

- Most major stone arches need to be fully rehabilitated by a Contractor with sufficient resources.
  - $300,000 - $1,500,000 per project
    - $300,000 - $700,000 for two span arch
    - $700,000 - $1,100,000 for three span arch
    - $1,100,000 - $1,500,000 for four span arch
  - 4 - 8 months per project

Rehabilitation

General Work Items associated with most bridge rehabilitation projects:

- Excavate soil-gravel fill and replace with lightweight concrete.
  - Temporary shoring
- Reconstruct and/or re-point stone spandrel walls and parapet walls.
  - Scaffolding and stream diversion.
- Construct concrete collars around the pier/abutment.
- Replace concrete parapet cap.

Rehabilitation

- Excavate soil and gravel fill

Rehabilitation

Rehabilitation

- Place epoxy-coated reinforcing

Rehabilitation

- Replace with lightweight fill

Rehabilitation

Rehabilitation

- Reconstruct and/or re-point spandrel walls

Rehabilitation

- Reconstruct and/or re-point parapet walls

Rehabilitation

- Reconstruct pier noses

Rehabilitation

- Types of Mortar Used in Current Construction
  - Lime Mortar (Lime, sand, and water)
    - Used on stone arches in the early 1800's.
    - No longer used because of durability and strength issues.
  - Mason's Hydrated Lime (Cement mortar, lime, sand, and water)
    - Used on stone arches today.
    - Better durability and strength.
  - Masonry Cement Mortar (Portland cement, hydrated lime, plasticizers, air entraining agents, sand, water)
    - Types: M, S, N, O, K
    - Durability, strength, and workability are much better.
    - Type S (1,800 psi).

Rehabilitation

- Mortars
  - White masonry cement
  - Flamingo brand of masonry cement using the color C224 (formerly C280).
  - Mason's hydrated lime
    - 1 part white masonry mortar mix.
    - 3 to 3 ½ parts of washed, sharp bank sand.
    - ¼ part of mason's hydrated lime.
  - Masonry cement mortar - Type S
- Joint Styles
  - Shallow inverted tooled smooth "V" joint or flat joint.

Rehabilitation

- Repointing stone masonry mortar joints

Rehabilitation

- Access and scaffolding
  - Different methods are used depending on size of bridge.
  - Stream bed make-up effects anchoring of scaffolding.
  - Forklifts with aluminum picks for one and two span arches.
  - Scaffolding for three and four span arches.

    - System (engineered)

    - Buck (traditional)

    - Swing-stage

Rehabilitation

Rehabilitation

- Stone reconstruction
  - Stones are removed in an orderly fashion and placed back in an area similar to their original position.
  - Weight considerations of staged material.

Rehabilitation

- Pier nose stones are numbered and photographed to ensure original placement.

Rehabilitation

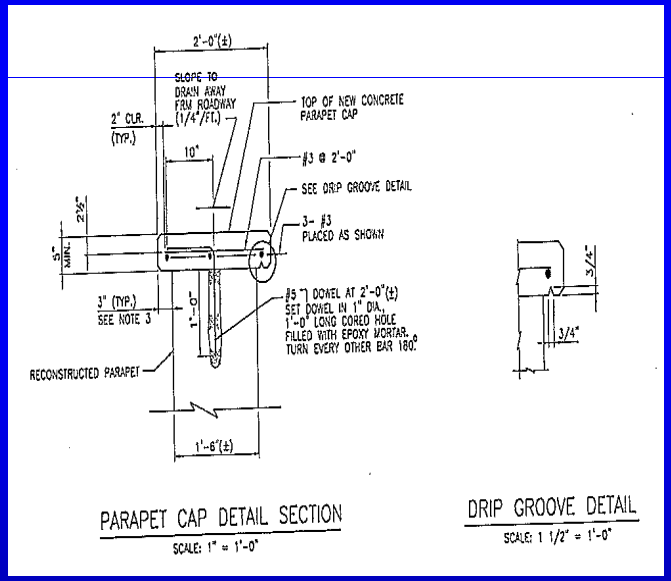
- Install stream diversion around pier and abutments.

Rehabilitation

- Construct concrete collars around the piers and/or abutments.

Rehabilitation

- Concrete pier caps.

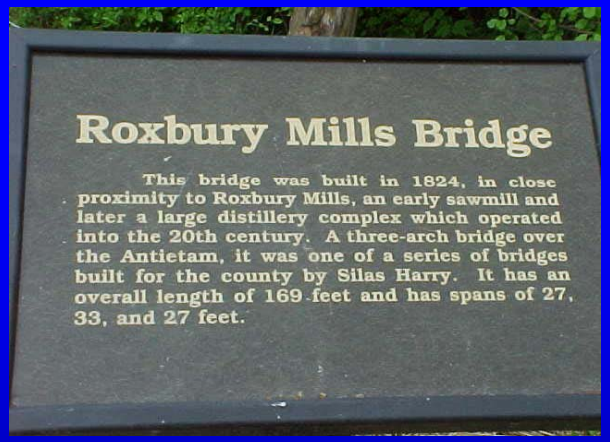


Rehabilitation

- Completed Bridge Rehabilitation Projects

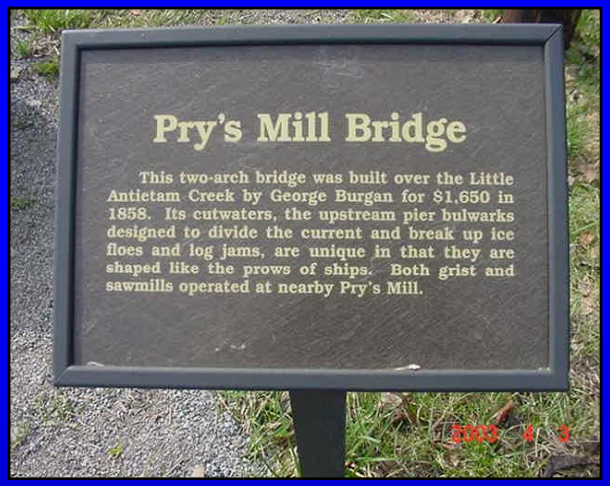
•Roxbury Mills Bridge W-5371

•Rehabilitated in 2002



Rehabilitation

- Prys Mill Bridge W-5652
  - Rehabilitated in 2003

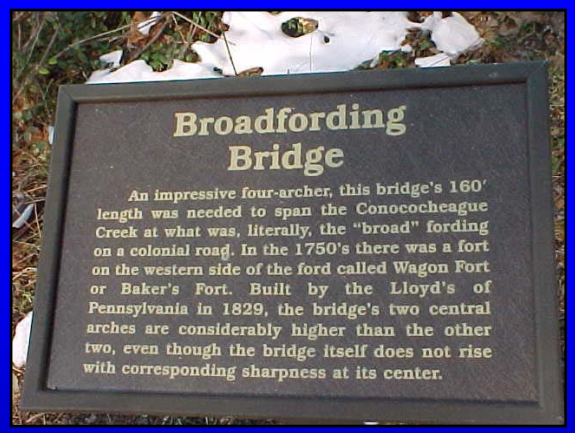


Rehabilitation

- Completed Bridge Rehabilitation Projects

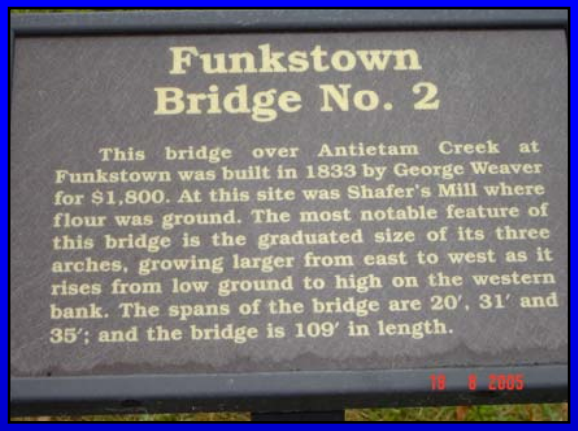
•Broadfording Road Bridge W-0821

•Rehabilitated in 2005



Rehabilitation

- Funkstown Bridge (No. 2) W-4001
  - Rehabilitated in 2008



Costs

- Excavation
  - $100 per CY
- Lightweight Concrete
  - $300 per CY
- Stone Masonry Reconstruction
  - $1,200 per CY
- Repointing Masonry Joints
  - $30 per SF
- Replace Concrete Parapet Cap
  - $2500 per CY
- Concrete Collar
  - $1000 per CY

Repairs

- Flooding damaged pier nose.
  - Stones recovered from the stream were taken to our Highway Department for storage until bridge can be rehabilitated. A temporary concrete pier nose was constructed in its place.

Repairs

- Underwater inspection discovered undermined pier.
  - New concrete collar was constructed to stabilize the foundation.

Repairs

- Vehicle Damage to parapet wall.
  - Stones from the damaged wall were taken to our Highway Department for storage until the bridge can be rehabilitated. A temporary concrete wall was constructed in its place.

Repairs

- Vehicle Damage to parapet and spandrel wall.
  - Stones were recovered from the stream bank by our Highway Department and reconstructed to closely match their original position.

Closing

- To effectively maintain and preserve our stone arch bridges, we need to continually:
  - Assess our inventory
  - Identify and address our needs
  - Invest in one of our county's greatest treasures.
- An effective method of rehabilitation, continued federal funding availability, and strong commitment to preservation is key.

Questions

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