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Best Practices for Historic Masonry Repair and Rehabilitation

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Final Report VTRC 23-R10

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Abstract:

The most recently published update of the Virginia Department of Transportation's (VDOT's) historic bridge management plan, *A Management Plan for Historic Bridges in Virginia: The 2017 Update*, noted a number of special considerations regarding stone masonry on VDOT's historic bridges (i.e., those state-owned bridges that are individually eligible for or listed on the National Register of Historic Places). Key considerations included the types of masonry work identified on management plan bridges; various types of repair and stabilization methods; and references to compatible mortars for use on bridges of older construction. The 2017 update of the historic bridge management plan also contained a fifth recommendation: conduct an in-depth historic masonry study and produce a best practices document identifying procedures for repair and/or rehabilitation of historic masonry structures and masonry components, particularly those on VDOT's historic bridges. This study addressed that fifth recommendation.

This study assembled data related to masonry in historic bridges, including archival documentary evidence, materials, and construction and repair technologies, and yielded a best practices document for facilitating appropriate management of VDOT's historic bridges with stone masonry components.

The study concluded that (1) historic bridges in Virginia with stone masonry construction exhibit a number of different forms, materials, building practices, and technologies that reflect the time periods when the bridges were built; (2) a variety of maintenance, repair, and rehabilitation practices have been used on these bridges; (3) best practices in historic preservation can evolve over time as additional information is acquired; and (4) knowledge of these various forms, materials, practices, and technologies, and the necessary specialized treatments required, must be taken into account when planning and undertaking maintenance, repair, and rehabilitation for the various types of stone masonry construction found in Virginia's historic bridges. Using the most appropriate practices as outlined in this report may help avoid inappropriate repairs and damage to stone masonry elements.

The study recommends that (1) the practices regarding bridge maintenance, repair, and historical documentation described in this report be used by VDOT structure and bridge engineers, environmental cultural resource personnel, and corresponding district staff; and (2) the information, including historical background, condition, and maintenance needs on specific bridges, included in this report be referenced in the forthcoming update of *A Management Plan for Historic Bridges in Virginia* (now in progress).

FINAL REPORT

BEST PRACTICES FOR HISTORIC MASONRY REPAIR AND REHABILITATION

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Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

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ABSTRACT

The most recently published update of the Virginia Department of Transportation's (VDOT's) historic bridge management plan, *A Management Plan for Historic Bridges in Virginia: The 2017 Update*, noted a number of special considerations regarding stone masonry on VDOT's historic bridges (i.e., those state-owned bridges that are individually eligible for or listed on the National Register of Historic Places). Key considerations included the types of masonry work identified on management plan bridges; various types of repair and stabilization methods; and references to compatible mortars for use on bridges of older construction. The 2017 update of the historic bridge management plan also contained a fifth recommendation: conduct an in-depth historic masonry study and produce a best practices document identifying procedures for repair and/or rehabilitation of historic masonry structures and masonry components, particularly those on VDOT's historic bridges. This study addressed that fifth recommendation.

This study assembled data related to masonry in historic bridges, including archival documentary evidence, materials, and construction and repair technologies, and yielded a best practices document for facilitating appropriate management of VDOT's historic bridges with stone masonry components.

The study concluded that (1) historic bridges in Virginia with stone masonry construction exhibit a number of different forms, materials, building practices, and technologies that reflect the time periods when the bridges were built; (2) a variety of maintenance, repair, and rehabilitation practices have been used on these bridges; (3) best practices in historic preservation can evolve over time as additional information is acquired; and (4) knowledge of these various forms, materials, practices, and technologies, and the necessary specialized treatments required, must be taken into account when planning and undertaking maintenance, repair, and rehabilitation for the various types of stone masonry construction found in Virginia's historic bridges. Using the most appropriate practices as outlined in this report may help avoid inappropriate repairs and damage to stone masonry elements.

The study recommends that (1) the practices regarding bridge maintenance, repair, and historical documentation described in this report be used by VDOT structure and bridge engineers, environmental cultural resource personnel, and corresponding district staff; and (2) the information, including historical background, condition, and maintenance needs on specific bridges, included in this report be referenced in the forthcoming update of *A Management Plan for Historic Bridges in Virginia* (now in progress).

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FINAL REPORT

BEST PRACTICES FOR HISTORIC MASONRY REPAIR AND REHABILITATION

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INTRODUCTION

The most recently published update of the Virginia Department of Transportation's (VDOT's) historic bridge management plan, *A Management Plan for Historic Bridges in Virginia: The 2017 Update* (Miller, 2018) [hereinafter "the 2017 Update"], noted a number of special considerations and issues relative to stone masonry on VDOT's historic bridges (i.e., those state-owned bridges that are individually eligible for or listed on the National Register of Historic Places [hereinafter "National Register"]). These considerations and issues included types of masonry work identified on bridges in the management plan (hereinafter "management plan bridges"); various types of repair and stabilization methods; and references to compatible mortars for use on older construction. The 2017 Update also included a fifth recommendation endorsing a more in-depth historic masonry study and the production of a best practices document identifying procedures for repair and/or rehabilitation of historic masonry structures and masonry components, particularly those on VDOT's historic bridges.

Two sets of stakeholders also supported the creation of a more detailed study of specialized methods for rehabilitation of historic masonry structures. One was VDOT's Structure and Bridge Division, which identified this study as an important need. The other was the Historic Structures Task Group (HSTG). (The HSTG is the interdisciplinary advisory body that reviews, consults, and makes recommendations on questions of historic significance and management of state-owned transportation-related cultural resources. In operation since the 1980s, the HSTG has representatives from the Virginia Transportation Research Council [VTRC], VDOT, the Federal Highway Administration, and the Virginia Department of Historic Resources [the state historic preservation office].) Members have expertise in engineering, history, architectural history, and archaeology.

Twenty-two of the 36 historic bridges on VDOT's historic bridge management plan are the subject of this detailed study. They include stone masonry components, either as the primary structure (such as stone arch bridges), as elements such as stone piers and abutments, or as stone veneer. These bridges range in date from the early 19th century to the mid-20th century and are the subject of the recommendation from the 2017 Update. The problem is that key details needed to repair stone masonry components on some of these bridges are not readily available. There are varying amounts of background information surviving on these bridges: substantial information exists for the majority of the bridges, and little or no early construction information is known to survive on 6 of these bridges.

Although not all of Virginia's historic bridges have surviving contracts and specifications, enough information survives to provide a good cross section of the various bridge types and technologies that used stone masonry components. Accordingly, this study identified and examined the various issues related to stone masonry in historic bridges; reviewed original contracts, manuals, and specifications relating to stone masonry in Virginia's historic bridges; investigated and compared various methods of stone masonry construction, stabilization, and repair; and developed guidance on different construction methods and technologies associated with historic masonry (including procedures for determining appropriate mortars, which often differ among structures of various ages and construction). The results of this study are expected to facilitate appropriate management of Virginia's historic bridges with stone masonry components and to support repairs of contributing structures in historic districts that have stone masonry components. (Although bridges in historic districts are not specifically included in the management plan, rehabilitation concerns with these structures are increasingly an issue, and many of these bridges are subject to the same environmental review as bridges eligible for the National Register. The best practices developed in this study should help address these concerns.)

PURPOSE AND SCOPE

The fifth recommendation of the 2017 Update (Miller, 2018) directed VDOT to identify techniques for repair or rehabilitation of historic masonry structures:

> VTRC, VDOT's Structure and Bridge Division, the appropriate district structure and bridge offices, and VDOT's Environmental Division should collaborate to identify potential avenues to establish best practices for repair of historic masonry structures or masonry components.

The purpose of this study was to document these best practices, thereby implementing that recommendation.

METHODS

The study consisted of four tasks:

1. *Identify and examine the unresolved challenges for repair of stone masonry in historic bridges.* The 2017 Update showed that these challenges involve masonry stabilization and identification of compatible mortar specifications for historic masonry repairs. This task thus included three iterative elements:

    - Conduct a literature review of stone masonry technology and construction, maintenance, and repair practices

    - Assemble data regarding Virginia historic bridges under VDOT ownership with stone masonry construction such as original materials, technologies used in construction, and when they were built. These data are located in repositories such as the VTRC history files available to the author, county circuit court clerk offices, and the Library of Virginia.

- Consult with VDOT district structure and bridge engineers to identify historic bridges with urgent needs. Such bridges either were in poor condition or had been scheduled for upcoming repair or rehabilitation.

2. *Locate, review, and compare original contracts, manuals, and specifications relating to stone masonry in Virginia's bridges, ranging in date from the early 19th century to the mid-20th century.* This task built and expanded on data in VTRC history files and involved further research to locate additional early contracts and specifications relating to stone masonry in bridges, with an emphasis on information in county and state archival repositories. This research was undertaken throughout most of the course of the study as leads and information on the location of these materials were identified. To the greatest extent possible, those bridges that were identified in consultation with VDOT district structure and bridge engineers as having urgent needs (as noted under Task 1) were given priority and addressed as early as possible in this task.

3. *Investigate and compare various methods of stone masonry construction, stabilization, maintenance, and repair.* Building on the information identified in Tasks 1 and 2, this task compared original and current practices and knowledge regarding materials, technologies, construction methods, maintenance, and repair. This task also included the identification of types of stone and probable sources of stone for a number of Virginia's historic bridges under VDOT purview, procedures for determination of appropriate mortars (which often differ between structures of various ages and construction), and interviews with restoration practitioners.

4. *Synthesize results.* The information gleaned from the preceding tasks was organized across four areas:

   - Types of Stone Masonry Bridge Construction
   - Categorization of VDOT Bridges in the Management Plan
   - Construction and Workmanship
   - Masonry Considerations and Maintenance Needs.

   These results serve as a set of best practices for repair and rehabilitation that may be applied to bridges with stone masonry components.

RESULTS AND DISCUSSION

Types of Stone Masonry Bridge Construction

Historical Context

Men at first made bridges of wood, as being attentive to their present necessity only; but since they have begun to have a regard for the immortality of their name, and when riches gave them *spirit, and conveniency to do greater things, they began to build with stone, which is more durable, of greater expence, and of more glory to the builders.*

Andrea Palladio, *The Four Books of Architecture* (1570), Third Book, Chapter X, “Of Stone Bridges, and what ought to be observed in the building of them” (English translation, Isaac Ware, 1738) (spellings as in the original)

When the influential Italian Renaissance architect Andrea Palladio wrote these words in his treatise *The Four Books of Architecture*, in the late 16th century, the use of stone masonry construction for buildings, bridges, and other structures was already thousands of years old. Palladio’s book covered structures ranging from mundane agricultural buildings, to decorative and elaborate country villas, to churches, and to roads and bridges. Although the stone bridges described by Palladio (which are nearly all arch structures) are highly decorated with sculptures and other Classical elements, a perusal of his designs and comments indicates that Palladio, trained as a sculptor and a stonemason, understood the material and its usage and potentialities from the standpoint of both a designer and a builder/craftsman. His comments include proportions, designs, and motifs based on ancient Roman precedents and descriptions of different types of stone, directions for their preparation, and how they should be joined and maintained (Palladio, 1570).

In this knowledge he was part of the ancient, medieval / post-medieval, and early modern traditions of what have been called “architect-engineers” and “master builders.” These were individuals who combined knowledge of materials and construction with design ability and practical/empirical knowledge of science. They generally were trained through a hierarchical system such as apprenticeships (under the immediate supervision and training of a master in the trade, and—at least in pre-modern Europe—under the overall direction of a craftsmen’s guild). Some practitioners also received their knowledge—or honed their skills—through service in military bridge building operations.

In addition to historical context and background, this report presents information on a variety of repair and rehabilitation methods. A brief background of the traditions and the varying talents involved in the production of the original Virginia structures described herein can help VDOT staff understand and use the appropriate method for each bridge element. Many of these historic stone masonry bridges, or stone masonry bridge elements, were designed and constructed by individuals who were trained through an apprenticeship or indenture system or were born into and trained in a family tradition. However, as can be seen in Appendix B, a few had formal training. Schools of engineering, and of architecture, were relatively late developments, with formal schools of engineering arising in the 18th century in Europe and the early and mid-19th century in the United States and formal schools of architecture arising in the mid-19th century in Europe and the last half of the 19th century in the United States.

The use of stone masonry in bridges has taken various forms over the centuries. The most common examples of historic bridges with stone masonry elements are (1) those with stone masonry abutments and piers (and the related stone masonry beam bridges), and (2) stone masonry arch bridges. These forms date back into antiquity. In addition, following the increasing use of concrete in bridge construction (post-1900), stone veneer was also used in some specialized 20th century examples. All of these forms have examples among Virginia's historic bridges.

Stone Masonry Bridge Abutments and Piers

Typically, the earliest examples of stone abutments and piers supported wooden bridge elements (such as the floor beams and deck, and in some cases, wooden trusses). By the mid- to later 19th century, wooden trusses were being succeeded by combination (wood and metal) trusses and metal trusses. Stone masonry continued to be used for abutments and piers on truss bridges through the end of the 19th century and into the very early 20th century. In Virginia, examples are not uncommon, particularly on 19th century and early 20th century truss bridges and small beam bridges. Examples of stone masonry piers and abutments on two of Virginia's historic truss bridges (Brunswick County Structure No. 6104 and Alleghany County Structure No. 9007) are shown in Figures 1 and 2.

Some specialized, ornamental, or rustic examples, either of stone masonry or involving the use of stone veneer over concrete construction, were built during the 20th century. Rehabilitation, repair, and enlargement of early masonry work with concrete also were common during the 20th century, and some early masonry abutments were partly or entirely encased in later concrete work.

Figure 1. Stone Masonry Piers and Abutments Supporting an 1884 Truss Bridge (Brunswick County Structure No. 6104)

Figure 2. Stone Masonry Abutments and Stone Masonry Approaches on Humpback Bridge, 1857 (Alleghany County Structure No. 9007)

In addition, some Virginia examples also include remnants of early abutments and piers that have been rehabilitated; repaired; and, often, enlarged or increased in height with later concrete work and are still present in extant bridges. A number of historic bridges under VDOT ownership exhibit this type of construction feature.

It should be noted that an alternative type of pier built in various areas (including in Virginia, and particularly during the 19th century) also used stone in its construction but did not use actual stone masonry (i.e., coursed or rubble, mortared or dry laid) construction. This alternative involved the construction and use of timber "pens" or "cribs" (i.e., heavy timbers or logs that were set on a firm footing; joined at the corners [jointed and often spiked, similar to the construction of a small log cabin, and sometimes with tie rods or timbers]; and then filled with stones for additional stabilization). (In later examples, gravel or concrete was sometimes used to fill the pens.) Such pens would last until the logs or timbers deteriorated or were damaged. This type of construction was used in rural areas, including in Virginia, into the 20th century (see, for example, the specifications for the 1844 Germanna bridge in Appendix C). Examples of this construction for backcountry and trail use in structures built by the U.S. Forest Service still appear in current U.S. Forest Service publications (U.S. Forest Service, 2020). None of Virginia's historic bridges eligible for or listed on the National Register under VDOT ownership include this feature, but ruinous examples may be encountered in rural areas or in archaeological features.

A subset of this type of stone masonry construction is stone masonry beam bridges (examples of beam bridges include simple culverts and larger, multi-span examples). Bridges of this type typically featured stacked stone masonry abutments and piers (often dry laid) supporting decks consisting of heavy, even massive, stone slabs. Worldwide, some well-known examples range in type from (1) the ornate multi-span stone beam Luoyang bridge in China (46 spans, approximately 3,900 feet long, 130 feet wide; dating to ca. 1053-1059 A.D., although the present bridge represents the results of various later rebuildings), and (2) the picturesque British "clapper" (or "post") bridges, made of roughly shaped stones and usually only a few spans long (and generally of medieval or later date, although often popularly believed to be much more ancient). A related technology in the United States, including Virginia, is seen in various non-arched stone culverts, generally of the 19th or very early 20th century, which consist of narrow spans with parallel stone walls capped with stone lintels that carry the roadway. The most substantial extant examples were often constructed by turnpike companies, canal companies, or railroads. Smaller examples were constructed to serve as small stream crossings, mill races, or cattle passes. These structures were often dry laid (built without mortar) or built with minimal mortar. None of Virginia's historic bridges eligible for or listed on the National Register under VDOT ownership are of this type, but examples are likely to be encountered in National Register historic districts or other properties. (See Appendix C for examples of specifications for similar culverts on the 1840s Thornton's Gap turnpike.) On small examples dating from or rehabilitated in the early 20th century, concrete slabs were sometimes used to carry (or widen) the roadway of such bridges or culverts.

Stone Masonry Arch Bridges

In bridges of this type, most, and usually all, of the structure consisted of stone masonry, generally with exterior walls of stone blocks, with stone rubble infill. A number of the well-known monumental stone arch viaducts constructed by the Romans, such as the Pont du Gard in France (ca. 50 A.D.), still stand. Other early examples of stone arch bridges are known to have been built in China and Persia: these include the Anji (or Zhaozhou) bridge in China (one span, 167 feet long, 31 feet wide, built 595-605 A.D.), considered to be the world's oldest open-spandrel stone bridge. Later British and European examples of stone masonry arch bridges, of varying sophistication and elaboration, ranged in date from the medieval period, through the Renaissance, and through the 18th and 19th centuries, with some ornamental examples built into the 20th century.

Some early stone masonry arch bridges were constructed without mortar; significant structures of this type usually had iron clamps to connect the stones. The Pont du Gard is a notable ancient example of a bridge using this sort of technology. However, the majority of extant stone masonry bridges were structures that were built with mortar (Proske and van Gelder, 2009).

In Virginia, stone masonry arch bridges range in date from the early 19th to the late 19th century and into the very early 20th century. This was a time and place when most bridges were simple wooden beam structures built on the orders of county courts. Stone masonry arch bridges were more expensive and required greater skill (including more extensive preparation of materials) to build, hence, their comparative rarity compared to other bridge types. Factors in the construction of stone masonry arch bridges in Virginia after the early 19th century may be attributed to (1) the increasing support for internal improvements for transportation, including the establishment of the Board of Public Works (and the employment of a state engineer); (2) the rise of companies such as turnpikes, canals, and—slightly later—railroads that had the resources to build large and more permanent bridge structures and employ skilled builders; (3) improvements in materials (particularly the development and availability of extensive supplies of hydraulic cement, which allowed for more durable mortar; and (4) the increasing presence of semi-skilled and skilled labor and organized contractors and builders who were well trained and experienced in handling large projects. A number of engineers and contractors, and many of their crews, were immigrants from the British Isles or Europe: their presence in the United States was in no small measure due to the wars, political upheavals, and famines in their home areas and the seeking of new opportunities in the United States during portions of the 19th century.

Six historic Virginia bridges in the management plan are of stone masonry arch construction: these variously were constructed by turnpike companies (the Southwest Turnpike Company bridge in Wythe County, the Falling Creek bridge in Chesterfield County, Loudoun County Structure No. 1025, and Loudoun County Structure No. 6088); canal companies (Nelson County Structure No. 6070); and railroads (the Valley Railroad bridge, Augusta County Structure No. 6997). All of the original builders were organizations that could marshal the funds, the engineering talent, the additional skilled craftsmen, and the materials needed to produce stone arch bridges. Three of these stone masonry arch bridges, i.e., Augusta County Structure No. 6997, Nelson County Structure No. 6070, and Loudoun County Structure No. 1025, are shown in Figures 3, 4, and 5, respectively.

Stone masonry arch bridges have a specific terminology and construction process. Historically, arches have been constructed over a supporting framework (centering). The lower surface (inner curve or soffit) of the arch ring is the *intrados*; the upper surface (the exterior of the spandrel wall) is the *extrados*. Between the arch ring and road surface is fill. From evidence in several of Virginia's older arch bridges, the composition of the fill may take various forms: stone rubble, broken stone, soil with some lime-based mortar for binding, or a combination of these seems to have been the norm in 19th century stone masonry arch bridges.

Figure 3. Stone Masonry Arch, Built as a Railroad Bridge, 1874 (Augusta County Structure No. 6997)

Figure 4. Stone Masonry Arch, Originally Built as a Canal Viaduct, 1835 (Nelson County Structure No. 6070). Note the particularly fine finishing of the voussoirs.

Figure 5. Stone Masonry Arch, Built as a Turnpike Bridge in the First Quarter of the 19th Century (Loudoun County Structure No. 1025). A contrasting color of stone was used in the voussoirs for decorative effect. Note the relatively flat arch that is seen in many stone masonry bridges of this era.

At the exterior of the arch ring, and forming the face of the arch at that point, are the wedge-shaped voussoirs that define the curve of the arch and rise to a central keystone. Treatment of the voussoirs can range from utilitarian (such as stone finished in the same manner as the rest of the masonry, as seen on the ca. 1850 Southwest Turnpike bridge in Wythe County) to decorative (such as the voussoirs made from a stone of contrasting color to that of the rest of the bridge on the old turnpike bridge carrying Rt. 50 at Aldie [Loudoun County Structure No. 1025] and the notable smooth, beautifully shaped voussoirs on the former James River and Kanawha Canal viaduct in Nelson County [Nelson County Structure No. 6070]).

Some older stone masonry arch bridges were repaired or enlarged with concrete in the 20th century. The Nelson County structure noted above exhibits one such enlargement: a concrete arched extension.

A useful, concise overview of the technical background for arch bridges is given in the 2000 VTRC report *A Survey of Masonry and Concrete Arch Bridges in Virginia* (Miller et al., 2000). Also of considerable usefulness and interest, from both the historical and an engineering perspective, is Proske and van Gelder's *Safety of Historical Stone Arch Bridges* (Proske and van Gelder, 2009).

As is seen in the following section, specialized, ornamental, or rustic examples of arch bridges, often involving the use of stone veneer, were constructed in Virginia well into the 20th century.

Bridges With Stone Masonry Veneer Over Concrete Construction

Two of the bridges noted in this report (Rockbridge County Structure No. 1012 and Arlington County Structure No. 5020) are of concrete rigid frame construction with stone veneer and date to the 1940s (see Figures 6 and 7). Other structures, often not individually eligible for the National Register, are contributing structures to larger historic districts or to designated route categories such as scenic roads or parkways. Many of these structures, and their associated projects, were designed and built by the federal government in the second and third quarters of the 20th century. The structures were designed to blend aesthetically into and harmonize with the surroundings of historically or scenically significant areas and parks such as national military parks and battlefields. Examples include a sizable number of bridges along the Blue Ridge Parkway, with stone veneer over, variously, both rigid frame and concrete arch bridges. In such contemporary federal projects, Bureau of Public Roads engineers and National Park Service landscape architects worked together to produce structures that harmonized with the surrounding environments.

Outside the scope of this study, but worthy of note due to similar technology, are various bridges in Virginia that feature brick veneer over concrete rigid frame construction. As with the Blue Ridge Parkway bridges noted previously, many of these structures were built by the federal government in the second and third quarters of the 20th century to blend aesthetically into historically significant areas and parks such as national military parks and battlefields.

Figure 6. Stone Masonry Veneer on a Concrete Bridge in a Rustic Setting, 1940 (Rockbridge County Structure No. 1012)

Figure 7. Stone Masonry Veneer on a Concrete Rigid Frame Bridge in an Urban Setting, 1945 (Arlington County Structure No. 5020)

An interesting example (although not owned by VDOT) is the large rigid frame bridge with decorative red brick veneer designed by the U.S. Department of Public Roads for the Petersburg National Military Park in 1936 (later transferred to the City of Petersburg and now City of Petersburg Structure No. 8018). This bridge has brick veneer with some features (such as moldings, applied voussoirs, and brick quoins) that evoke antebellum brickwork features. Similar in feeling are the bridges on the Colonial Parkway in Tidewater Virginia, which feature various concrete rigid frame and arch bridges with colonial-style brick veneer and decorative elements.

Categorization of VDOT Bridges in the Management Plan

To identify the bridges discussed in this report, the following is a listing of the management plan bridges identified by the major types of stone masonry components: stone masonry abutments/piers, stone masonry arch, and stone masonry veneer over concrete rigid frame. (Additional and more specific information on these bridges, listed by district, is provided in Appendix A.) In the following listing, bridges are arranged by VDOT construction district and are then arranged alphabetically by county within the construction district.

Bridges With Stone Masonry Abutments/Piers

District 2. Salem

- Bedford County Structure No. 6087: stone masonry abutments, ca. 1850, supporting a metal truss bridge, 1915
- Botetourt County Structure No. 6100: stone masonry abutment and pier (lower portion of present abutment and pier), possibly late 19^{th} century, with concrete tops and caps and concrete abutment added ca. 1902, supporting a metal truss bridge, 1886, moved to site 1902
- Botetourt County Structure No. 6386: stone masonry abutments and pier, possibly late 19^{th} century, with concrete caps added ca. 1903, supporting a metal truss bridge, 1887, and later approach span, moved to site 1903.

District 4. Richmond

- Brunswick County Structure No. 6104: stone masonry abutments and pier, supporting a metal truss bridge, 1884
- Chesterfield County Structure No. 1900: aluminum triangular multi-girder bridge (Fairchild design), 1960-1961, with remnant stone masonry abutment from an earlier wooden truss or metal truss bridge on the site.

District 7. Culpeper

- Culpeper County Structure No. 6906: stone masonry abutment and piers (some portions are pre-1878, other portions date from 1878, supporting a metal truss bridge, 1878.

District 8. Staunton

- Alleghany County Structure No. 9008 (formerly No. 6064): stone masonry abutments and piers, supporting a metal truss bridge, 1896

- Alleghany County Structure No. 9007 (Humpback bridge): stone masonry abutments, supporting a wooden truss covered bridge, 1857
- Augusta County Structure No. 6027: stone masonry abutments, supporting a metal truss bridge, 1898
- Augusta County Structure No. 6147: stone masonry abutments, supporting a metal truss bridge, ca. 1903-1904
- Highland County Structure No. 6034: stone masonry abutments, supporting a metal truss bridge, 1896
- Rockbridge County Structure No. 6145: stone masonry abutments and pier, supporting a metal truss bridge, 1890
- Rockingham County Structure No. 6166: stone masonry abutments, supporting a semi-integral steel beam bridge, 1937
- Shenandoah County Structure No. 6078 (Meems Bottom bridge): stone masonry abutments, supporting a wooden truss covered bridge, 1894 (auxiliary concrete piers added, 1985).

Stone Masonry Arch Bridges

District 1. Bristol

- Wythe County (Southwest Turnpike Company bridge; no number): stone masonry arch bridge, ca. 1850.

District 3. Lynchburg

- Nelson County Structure No. 6070: stone masonry arch bridge, 1835.

District 4. Richmond

- Chesterfield County (Falling Creek bridge; no number): stone masonry arch bridge, ca. 1823.

District 8. Staunton

- Augusta County (Valley Railroad bridge) Structure No. 6997: stone masonry arch, 1874.

District 9. Northern Virginia

- Loudoun County Structure No. 1025: stone masonry arch bridge, ca. 1810-1824
- Loudoun County Structure No. 6088: stone masonry arch bridge), ca. 1829.

Bridges With Stone Masonry Veneer (Over Concrete Rigid Frame Construction: Specialized 20th Century Examples)

District 8. Staunton

- Rockbridge County Structure No. 1012: concrete rigid frame bridge with stone veneer, 1940.

District 9. Northern Virginia

- Arlington County Structure No. 5020: concrete rigid frame bridge, with stone veneer, 1945.

Construction and Workmanship

Different Types of Stone Masonry Construction: Rubble and Ashlar

Stone masonry construction generally comes under the heading of either “rubble” or “ashlar.” Rubble masonry uses blocks of stones that are not dressed (i.e., worked or squared) or are minimally dressed. Ashlar masonry uses blocks of stones that are squared. Ashlar masonry stones often are given additional finishes to produce a decorative or consistent appearance. This can range from a simple “rough tooling” or “rock face” (roughly dressed to produce a consistent dimension but a rough face to the stone) through several types of increasingly labor-intensive dressing to “fine tooling” (in which the stones are dressed with a chisel to produce a smooth finish). Both types of construction can be seen in stone masonry elements, including stone veneer, on Virginia’s historic bridges.

Stone masonry can be dry laid (without mortar) or with mortar; uncoursed (without long continuous horizontal joints); or coursed (with continuous horizontal joints). In some older bridge elements, particularly those built more for strength rather than beauty, the horizontal joints may fall somewhere in between (random coursed).

Variations in Quality of Stonework and Workmanship

Depending on need and the skill of the builder, stone masonry, including that in bridges, can range from crude and extremely utilitarian to finely finished, elegant work. Some examples were meant as showpieces of the stonemason’s art and some merely as fairly inexpensive and relatively sturdy creations that did not require more expensive and skilled finishing. It should be noted that although stonework is often thought “charming” or “attractive” by the layperson, not all examples of stonework are well done or are potentially historic. The examples of stonework on the bridges included in the management plan include some notable examples of the stonemason’s and designer’s work—such as the ashlar stone masonry and the graceful arch proportions in the four-arch Valley Railroad bridge (Augusta County Structure No. 6997); the broad, substantial ashlar abutments and pier of the Goshen bridge (Rockbridge County Structure No. 6145); the attractive rubble stone masonry that contrasts with the finely finished decorative voussoirs on the James River and Kanawha Canal viaduct (Nelson County Structure No. 6070); and the rustic rubble and ashlar veneer of the Laurel Run bridge in Goshen Pass (Rockbridge County Structure No. 1012), which was designed as part of a complete landscape plan for Rt. 39 through the pass.

Remnant Stonework Examples

There is also the issue of remnant stonework on historic bridges that do not otherwise have historically significant stonework. An example is the remnant stone abutment at the base of the north abutment of Chesterfield County Structure No. 1900 (Aluminum multi-girder bridge, built 1960-1961). Nearly all of the substructure of this bridge is of concrete and dates to the same period as the bridge (1960-1961), and the structure’s primary historic significance stems from its aluminum components. However, the stone masonry footing under the north abutment is a remnant of the stone abutments from one of the earlier bridges on the site. This structure provides a useful example of an historic bridge for which stone masonry is not a significant or character-defining feature but for which a stone masonry element nevertheless must be considered in its maintenance.

Masonry Considerations and Maintenance Needs

Several issues and considerations related to stone masonry in bridges were identified in the course of this study:

- Source of Stone and Compatible Stonework for Repair
- Vegetation and Tree Issues
- Drainage Issues
- Masonry Stabilization and Repair (Various Practices)
- Compatible Mortar.

Source of Stone and Compatible Stonework for Repair

Given the difficulties involved in hauling heavy stone components prior to the advent of modern paved roads and heavy equipment, most stone used in older stone masonry bridges probably came from near the bridge site. There are a few references to exact locations for stone sources in contemporary specifications and older historical articles. A few 19th century bridge contracts note that stone from previous bridges on the site will be reused. Railroads, of course, could haul material from considerable distances, although more frequently, local or relatively local stone sources were used. Information on the few documented stone sources, as well as probable sources of stone for the management plan bridges, is noted in Appendix A.

For repair or rebuilding of stone masonry on historic bridges, stonework should be compatible. Original stones that are loose but sound and intact should be put back in place. If original stones must be replaced (due to, for example, spalling or impact damage), any new stone should be as close as possible in composition, color, texture, and general appearance to the stone on the bridge. Finishing/tooling of the stone blocks should also match that of the original stonework. Where the original source of the stone is known, this resource may still be available for replacement repair material if needed. The same considerations and criteria should be applied to bridges with stone veneer elements. (In addition, as noted below, the new mortar and mortar joint profile should match the original.)

Vegetation and Tree Issues

A simple but extremely effective method of preventing damage to stone masonry is to prevent encroachment of vegetation upon the bridge elements. The root systems of shrubs, vines, and especially trees can seriously compromise the integrity of stone masonry if they are allowed to grow into the stonework of a bridge: roots, as well as the weight of trees, can literally pry stone masonry apart. Physical removal or use of herbicides that will not harm stonework or mortar is a recommended measure. Ideally, vegetation should be removed before it grows large enough to cause disruption to the structure. Cutting the smaller plants off at the root (possibly in concert with applying herbicide to the stump) and then subsequently removing the root after it has deteriorated is preferable (and potentially less damaging) than pulling out a well-established and extensive live root system that may dislodge stone and mortar. If mortar or stones are damaged or dislodged in the removal of vegetation, they should be replaced and repaired as soon as feasible.

A notable example of issues caused by vegetation was seen in the late 1990s on the former James River and Kanawha Canal viaduct in Nelson County (Nelson County Structure No. 6070). Several large trees growing near and on the structure were impacting the stonework; these trees had to be removed before further damage was done. The large size of the trees necessitated greater effort for removal of the trees and repair of the structure than would have been necessary if the trees had been removed when small.

Drainage Issues

Stone masonry structures will be affected, and ultimately damaged, by water infiltration, which can erode mortar, damage and loosen stonework, and increase the potential for damage from cycles of freezing and thawing. Ideally, water infiltration into historic stone masonry bridges should be avoided or minimized, and provision should be made to carry off water that does make its way into the bridges.

A particular problem with fill on older stone arch bridges is that water infiltration can saturate the base material, eventually causing loss of fill and damage to the stone masonry from cycles of freezing and thawing. Over time, portions of the soil and mortar fill can leach out, leaving voids between the arch ring and the roadway. Another potential issue is horizontal thrust as the result of pressure from soil / compacted masonry fill in the bridge, which in some cases causes movement, bulging, and separation of the spandrel wall from the deck. This separation has been observed on several historic stone arch bridges in Virginia. Such separations are more often seen on the flatter arches that were developed in the 18th and early 19th centuries and were used by some turnpike companies in 19th century Virginia. (For several methods of addressing early 19th century turnpike bridges with saturated fill and spandrel wall deformation, see the sections on “Grouted Anchors,” “Tie Rods / Tie Bars,” and “Partial Disassembly, Repair, and Replacement of Fill” below.)

Water infiltration under stone or concrete coping or stone veneer can also cause damage, including damage from cycles of freezing and thawing, to the underlying material of the bridge and deterioration of the adjoining coping, stonework, and mortar. Similar damage can ensue on bridge walls, abutments, and piers from water infiltration through damaged or displaced stone masonry blocks or missing mortar. Repairs (such as repointing and/or repair or replacement of damaged stonework) are needed at the first signs of damage. This early identification of deterioration will greatly reduce the scope and cost of the subsequent repairs should further damage occur. For this reason, coping, as well as mortar and stonework, should be closely monitored and maintained.

There are indications in some early references that it was not uncommon for stonemasons to leave some mortar joints open on the underside of arch bridges (essentially as weepholes) to facilitate drainage and prevent water being trapped inside the bridge. The potential for encountering such early drainage provisions should be kept in mind when repointing, maintenance, or rehabilitation of stone arch bridges is planned. In addition, the underside of the arch should not be parged, shotcreted, or sealed completely, as this sealing will have the effect of trapping any water that enters the fill.

As noted below, underdrains, which have been inserted in some rehabilitation projects, including at least one in Virginia involving a stone masonry arch bridge (Loudoun County Structure No. 6088), are also a potentially useful method for addressing drainage issues. Application of a waterproof membrane over replacement fill (applied in concert with removal and replacement of saturated or deteriorated fill) to prevent water infiltration has potential for use in stone masonry arch bridges. However, this method has not yet been used to address drainage issues on stone masonry arch bridges in Virginia.

Masonry Stabilization and Repair

A number of methods have proved effective to stabilize stone masonry on bridges. These include the following:

- Concrete Aprons
- Concrete Backwalls
- Grouted Anchors
- Tie Rods and Tie Bars
- Partial Disassembly, Repair, and Replacement of Fill
- Determination and Use of Compatible Mortar.

Concrete Aprons

The following management plan bridges with stone masonry components have had concrete aprons added, particularly to address scour and undermining of structures. As one example, this method was used successfully in 2002 by the Lynchburg District Structure and Bridge Office on Nelson County Structure No. 6070 to stabilize the arches, repair undermining, and prevent movement of the 1835 stone viaduct: the condition ratings of the substructure and deck were raised by several points because there was no more movement after the aprons were placed.

Aprons may not be appropriate for all applications: successful application of aprons is predicated on a number of factors, including location of the scour and undermining, direction of the water flow, stability of the channel, type of underlying material, and other situationally related factors. The potential application will have to be assessed on a case-by-case basis. However, in the following cases, the aprons appear to be performing well. For specific information on these bridges, see Appendix A.

- *In the Lynchburg District (3):* Nelson County Structure No. 6070 (stone masonry arch, built 1835; with 20th century concrete extension).

- *In the Richmond District (4):* Chesterfield County [no number] (Falling Creek bridge) (stone masonry arch, built ca. 1823, it should be particularly noted that the substantial concrete apron, which was placed at the pier, is an extremely early example, dating to the 1910s).

- *In the Staunton District (8):* Alleghany County Structure No. 9007 (Humpback bridge) (covered wooden through truss, built 1857); Augusta County Structure No. 6997 (Valley Railroad bridge) (stone masonry arch, built 1874); Rockbridge County Structure No. 1012 (concrete [rigid frame] arch with stone veneer, built 1940); Rockbridge County Structure No. 6145 (Goshen bridge) (metal through truss, built 1890).

- *In the Northern Virginia District (9):* Loudoun County Structure No. 1025 (stone masonry arch, built 1820s); Loudoun County Structure No. 6088 (stone masonry arch, built ca. 1829).

Concrete Backwalls

Concrete backwalls placed at each end of a bridge can help stabilize the structure, acting as soil retention features and serving to avoid the abutment fill material being washed away. In one notable recent example, such backwalls made a significant difference in preserving one of Virginia's most historic bridges. Backwalls, placed at the interface of the bridge portals and the stone-walled approaches of Humpback bridge (Alleghany County Structure No. 9007) during the 2013 rehabilitation of that structure, were instrumental in minimizing damage to Virginia's only National Historic Landmark bridge in the record flooding on Dunlap Creek in June 2016. The backwalls were a major factor in the bridge resisting the pressure of debris and water against it.

Grouted Anchors

Also effective is a proprietary process (grouted anchors), which consists of mesh bags inserted into a deteriorating stone masonry bridge by drilling, followed by the pumping of grout into the bags. The grout expands these mesh bags to stabilize the bridge and restore it to functionality. The small stone cylinders removed in the drilling are then replaced in the drill holes.

This process has had substantial success over a number of decades in addressing a number of masonry stabilization issues, as well as strengthening various types of masonry structures. This process can aid in stabilizing and strengthening structures with deterioration issues and in preventive strengthening against seismic and severe weather threats.

A grouted anchor process was used in 2001 on Loudoun County Structure No. 1025 (the Little River Turnpike bridge). An inspection had revealed that a portion of the bridge's wing wall and buttress required reconstruction due to severe deterioration of the mortar between the stones. Accordingly, portions of the wing wall and buttress were reconstructed, and the proprietary (Cintec) grouted anchor system was used to repair and strengthen the bridge. The system has worked well.

Tie Rods and Tie Bars

Tie rods, inserted horizontally through a structure and secured with exterior tie rod ends (either decorative or utilitarian), have been used to control horizontal thrust on stone masonry buildings since the 15th century. Although not in widespread use on Virginia bridges, a VDOT professional engineer with extensive experience in this area pointed out that this technology has been used on at least two stone arch bridges in Virginia and is a valid method for retrofit or stabilization of older stone masonry arch bridges (Rex L. Pearce, personal communication, November 15, 2022). In both of the Virginia examples, noted below, tie bars (covering a more extensive area of the bridge than a traditional tie rod end) were used in concert with the tie rods to stabilize the bridge.

Tie rods with tie bars were inserted below the deck level on the Falling Creek stone arch bridge in Chesterfield County. There have been several episodes of severe flood damage to this bridge; the tie rods and bars were apparently inserted during the ca. 1922 repairs to the bridge. General, rather than detailed, records of those repairs survive, but it was theorized that the tie rods and bars were inserted to counteract the horizontal thrust as the result of pressure from the soil / compacted masonry fill in the bridge. The rods were placed to run between the arches below the deck and through the center pier. (Concrete was poured above the arch barrels to encase the tie rods and form a base for the roadbed.) The bar was placed horizontally just above the arch rings (Miller and Wells, 2011). The tie bars were lost, along with much of the upper portions of the bridge, in the massive flooding and debris impacts resulting from Tropical Storm Gaston in 2004; a tie rod is still in place in the remaining bridge structure.

Tie rods and a tie bar also were inserted at some point on the Goose Creek stone arch bridge at Atoka in Loudoun County (bypassed and taken off-system when Rt. 50 was realigned in the 1950s). A former turnpike bridge built before 1820, this structure was subsequently transferred to Loudoun County and was overseen by the local garden club as a wayside; the wayside, with associated historical exhibits, is now the Goose Creek Bridge Historic Park, part of the regional park system as one of the county's significant Civil War–related sites. The tie rods, located on the west arch, are anchored with what appears to be salvaged I-bars set at a 45-degree angle. The date of the tie bars is uncertain, but they have been in place at least from the mid-20th century.

Depending on their associated time periods, early tie bars were of either wrought or cast iron. For modern versions of this technology, tie rods made of newer types of metals (such as stainless steel) would be appropriate as long as the metal has the needed strength and does not react with the stone in a negative manner.

Partial Disassembly, Repair, and Replacement of Fill

For stone arch bridges with substantial deterioration or damage, more major interventions and rehabilitation may be required. These can include removal of the fill, partial disassembly (particularly of the parapets and part of the spandrel walls), repair of the stone elements, and replacement of the older stone elements with new lightweight fill (such as lightweight concrete). Insertion of a concrete saddle may also be part of such a project.

In Virginia, the stone arch Hibbs bridge (also known as the Snickersville Turnpike bridge, Loudoun County Structure No. 6088) was rehabilitated in 2007 by disassembling the spandrel walls and removing the fill and then inserting a reinforced concrete slab floating on a gravel base (to distribute load more evenly to the arch); adding a reinforced concrete saddle; and then rebuilding the stonework. Underdrains were installed to collect drainage material. As noted in Appendix A, the project was intended to increase the longevity of the bridge, not to increase its weight-carrying capacity.

Various other states recently have also undertaken projects of this type. Particularly useful for this study was the information received from the Washington County [Maryland] Division of Public Works, which has responsibility for a large number of early stone masonry arch bridges, most dating from the 1820s to the 1850s (Andrew Eshleman, personal communication, June 8, 2020). The county owns and maintains 26 historic stone arch bridges: 14 major structures and 12 minor structures; in addition, the Maryland State Highway Administration has responsibility for 14 other early stone masonry arch bridges, owning and maintaining 7 major and 7 minor structures in the county. The county makes considerable effort to preserve and maintain its historic stone arch bridges (but it is acknowledged that these bridges were not built to carry modern vehicles).

Recent projects undertaken by the Washington County Division of Public Works have used rehabilitation techniques that strengthen the bridge but do not visually alter its appearance to any great extent. Previous repairs undertaken in the late 1970s and early 1980s involved placing a concrete cap over the arches and inserting drainage pipes (underdrains) in the existing soil-gravel fill. Over decades, these concrete caps have proven to be effective in protecting the arch and keeping it intact during construction. However, it was noted that not replacing the soil-gravel fill has led to the development of bulging spandrel walls and severe deterioration of mortar joints. The county has undertaken rehabilitation projects every 1 to 2 years, on average. Current (post-2000) rehabilitation projects have involved the following:

- Excavating and replacing the soil-gravel fill with lightweight reinforced concrete and repointing/reconstructing the stone masonry spandrel and parapet walls as needed.

- Following standard historic preservation practices (i.e., the *Secretary of the Interior's Standards*): the new features will match the old in design; color; texture; and, where possible, materials. Reconstruction of stone spandrel walls and/or parapets uses existing salvaged stone or new stone that matches the existing stone as closely as possible. The concrete parapet cap is replaced.

- Placing concrete "collars" (aprons) around piers and abutments to address undermining and scour issues and stabilize these elements. As part of repairing/reconstructing damaged pier noses, stones are numbered and photographed to ensure they are returned to their original placement.

The concrete caps placed over the arches in the Washington County bridges during the 1970s through 1980s reflect a practice similar to the concrete placed over the arches of the Falling Creek bridge in Chesterfield County in the ca. 1922 repairs, suggesting a relatively early tradition of such work (see Appendix C). The possibility of encountering additional evidence of this practice in Virginia should be considered by those planning rehabilitation of stone masonry arch bridges

Both the practices used in the Virginia masonry stabilization projects (especially regarding installation of grouted anchors and partial disassembly / replacement of fill) and the practices of partial disassembly / replacement of fill cited here for Washington County, Maryland, have good potential for further use to rehabilitate and strengthen stone masonry arch bridges while having very few impacts on their appearance, thus preserving their historic integrity and appearance.

Determination and Use of Compatible Mortar

Ensuring compatible mortars and practices for repointing, stonework repair, and construction pointing is important for structures with stone masonry components, and a major initial purpose of this "best practices" study was to identify procedures for repair of historic masonry structures.

As noted in one of the recommendations from the 2017 Update, it was anticipated that the present study would identify historically compatible "soft" mortar specifications in order to facilitate appropriate maintenance, repair, and/or rehabilitation of historic masonry bridges, which often require specialized materials and methods. In particular, for older (pre–early 20th century) structures, the use of a "soft," relatively flexible mortar with a substantial lime content (such as was typically used on brick and stone masonry buildings before the advent of portland cement in the early 20th century) was seen as necessary to ensure compatibility with the original mortar and avoid damage to historic stone masonry from cycles of freezing and thawing and other issues that can be factors with the use of harder modern portland cement mortars, which may be harder than the adjoining stone.

It was planned to identify such specifications by (1) identifying original contracts and specifications for mortar and stonework on management plan bridges (when such specifications survived and could be located); (2) conducting a literature search to identify period treatises on masonry construction; (3) consulting the Virginia Department of Historic Resources for rcommended mortar formulas; and (4) consulting modern stone masonry / mortar practitioners, including those at the National Park Service's Historic Preservation Training Center.

As the research for this study progressed, it was noted that the issue of identifying appropriate mortars for use in repairing stone masonry construction, including historic bridges, has become increasingly complex in the last decade. Until the early 2010s, accepted historic preservation practices often involved the common use of "soft" mortars (containing both portland cement and lime) such as Type N, plus guidance from a few standard publications, notably the National Park Service's 1976 (revised 1980) bulletin *Preservation Brief No. 2: Repointing Mortar Joints in Historic Brick Buildings* (National Park Service, 1976) and Harley J.

McKee's *Introduction to Early American Masonry: Stone, Brick, Mortar and Plaster* (McKee, 1973). In addition, many state historic preservation offices (in Virginia, the Department of Historic Resources) had standard approved "soft" mortar formulas for use on historic brick and stone masonry structures. Precise analysis of mortar components was generally confined to use in museum-quality restorations or work on extremely high-profile historic structures.

Over the last decade, however, the thinking among historic preservationists has altered considerably. The information in the National Park Service's *Preservation Brief No. 2* is now considered outdated; the percentages of portland cement in earlier accepted standard formulas are now considered to be too high. State historic preservation offices (such as the Virginia Department of Historic Resources) no longer maintain and recommend approved mortar formulas. (McKee's book still contains much useful information, particularly on historical craftsmanship, technology, and materials.) In general, though, the issue and practice of identifying compatible mortar formulas currently are unsettled and in a state of flux. The question of identifying compatible mortar formulas is now treated as a somewhat more complex issue than had been previously thought. It became apparent in the course of the present study that this question cannot always be answered by having a group of pre-approved formulas but rather that some custom analysis and mixtures may be necessary to provide mortar formulas that will be appropriate for the physical demands of a particular project and will pass the required cultural resource review (by both VDOT and the Virginia Department of Historic Resources) for repairs to historic structures.

On advice of a number of historic masonry practitioners, in both the National Park Service's Historic Preservation Training Center and University of Virginia Facilities Management (both groups have particular experience in historic masonry preservation and rehabilitation), for any historic bridge in Virginia that has stone masonry elements needing rehabilitation or repair, the following points should be addressed during initial planning to identify compatible mortars:

- Identify the time frame and background/historical information on the stonework of the historic bridge (for historic context and to identify likely technologies that could have been used).

- As an adjunct to the identification of mortar, identify the type of stone used in the bridge prior to a final decision on the mortar type (e.g., softer stone such as sandstone requires a softer mortar formula than a harder stone such as granite).

- Identify the original mortar formula through both information from original specifications (if these survive) and physical analysis of the components of original mortar specimens from the bridge**.** The physical identification should include sand and fines. The physical identification generally can be done by a competent practitioner familiar with 19th and 20th century masonry practices and materials.

Replacement mortar and repointed mortar joints should match the original/old mortar joints, not only in materials but also in color and profile. (Care must be taken to identify the early mortar joint profiles so as not to duplicate substandard much later repointing that differed considerably from the original material and workmanship.)

In addition, for 19th century bridges that have no existing/known original or early specification or plan information, it is likely that identification of contemporary mortars used on similar bridge projects can provide clues to the type of mortar and practices originally used for the bridge. This may be especially useful where much of the original mortar has deteriorated or did not survive.

Accordingly, an important part of this best practices study was the identification of original mortar contracts and specification documents for those historic bridges in Virginia with stone masonry components (where such original contracts and specifications survive and can be located) and the identification of the same documents for other, similar contemporary structures (see Appendix A and Appendix C). In the process of this study, it was noted that some bridges have several types of mortar specified in their original construction depending on whether the location was above or below the water line.

A particular issue that became apparent in the course of this study is that high-lime-content "soft" mortars, although generally compatible with pre-20th century mortars used on historic buildings, are not conducive to the long-term longevity of bridge elements that are located under water or are frequently immersed. In bridge contracts dating from the mid- to late 19th century, hydraulic cement that will set under water was originally specified for use in bridge elements below the water line, although lime mortar was still specified for some applications above the water line. Only one application among the materials located for this study, the 1840s specifications for the substructure of the Hazel River wooden truss bridge on the Thornton's Gap turnpike, indicated the use of lime mortar in an underwater location (see Appendix C). This specification probably dates to the early 1840s, prior to the widespread availability of hydraulic cement for bridges. It is worth remembering that at that time, the average life of a bridge was usually estimated at 7 to 10 years.

Virginia's extant historic bridges that have stonework components range in date from the early 19th century to the mid-20th century. Surviving specifications for mortared bridge stonework in Virginia bridges in the last half of the 19th century indicate that, commonly, several mortars were to be used in the same bridge (in different locations). The use of different mortars generally relates to whether the mortar would be above or below the water line. Typically, hydraulic cement mortar was to be used at and below the water line. Lime-sand mortars of various strengths, sometimes with hydraulic cement, might be specified for use above the water line. Transcriptions of a number of contracts and related period specifications for bridge elements (primarily abutments and piers) dating from the 1840s to the 1890s are included in Appendix C.

Virginia bridge contract specifications for hydraulic cement during the middle and last half of the 19th century may refer to a Virginia product. Beginning in 1848, natural cement deposits at Balcony Falls in Rockbridge County were developed by Charles H. Locher at the James River Cement Works to produce hydraulic cement. Initially developed for use in the construction of the James River and Kanawha Canal, the production of hydraulic cement from these works reportedly expanded to supply most, if not nearly all, of the hydraulic cements used in Virginia for decades. The works continued under C. H. Locher, and later two of his sons, until 1907. By then, portland cement had become the new standard for mortar and cement, driving older natural cement works such as the Lochers' out of business.

The commercial manufacture of portland cement in the United States began in 1871, and portland cement became increasingly available over the next decades. By the early 20th century, the harder portland cement mortar, and reinforced concrete, had essentially superseded older lime-sand and hydraulic cements.

In any bridges that use stone masonry elements built after the beginning of the 20th century, it should be assumed that portland cement mortar likely was used in the construction of the stonework unless there is evidence to the contrary. Two bridges dating from the second quarter of the 20th century (Arlington County Structure No. 5020, completed 1945, and Rockbridge County Structure No. 1012, built in 1940) have extant plans with material specifications, including portland cement mortar. The mortar in a third bridge of this vintage (Rockingham County Structure No. 6166, built in 1937 by the U.S. Forest Service) was identified as portland cement mortar in both a visual field inspection and specifications in then contemporary National Park Service and U.S. Forest Service documents (National Park Service, 1941; U.S. Forest Service, 1936). Although no plans were located for this bridge, its rubble stone masonry abutments appear identical to the plans for this type of abutment noted in the U.S. Forest Service's *Acceptable Bridge Plans* (U.S. Forest Service, 1936).

Bridges with concrete components, and later reinforced concrete bridges, began to appear in Virginia ca. 1901. The first State Highway Commission standards for Virginia bridges were issued in 1909 (State Highway Commissioner, 1909). For early 20th century bridges with concrete components, or older bridges with post–ca. 1901 concrete repairs, rehabilitation, partial rebuilding, or enlargements, the use of portland cement concrete should be assumed unless there is evidence to the contrary.

Specifications for the stone masonry repair and rehabilitation work as part of the recent rehabilitation of one of the management plan bridges (Culpeper County Structure No. 6906, the Waterloo bridge, built in 1878) are included as Appendix D. The text of the original specifications is included in Appendix C.

CONCLUSIONS

- *Historic bridges in Virginia with stone masonry construction exhibit a number of different forms, materials, building practices, and technologies that reflect the time periods when the bridges were built.*

- *General categories of stone masonry on historic bridges in Virginia are stone masonry bridge abutments and piers, stone masonry arch bridges, and bridges with stone masonry veneer over concrete construction.*

- *A variety of maintenance, repair, and rehabilitation practices have been used on these bridges.* These include removing vegetation, preventing and addressing drainage problems, using various practices for masonry stabilization and repair, and identifying compatible mortar.

- *Practices for masonry stabilization and repair include identifying the types of stonework used (i.e., rubble and ashlar); determining compatible stonework for use in repair; using applications such as concrete aprons, concrete backwalls, grouted anchors, and tie rods / tie bars; and conducting partial disassembly, repair, and replacement of fill.*

- *Determination and use of appropriate/compatible mortar (in both composition and the mortar joint profile) are particularly important in order to avoid damage to the stonework from an incompatible mortar (especially mortars that are harder than the stone) and/or alteration of the appearance of the stonework as the result of an inappropriate mortar joint profile.*

- *Best practices in historic preservation can evolve over time as additional information is acquired.* A good example of this is the change in thinking regarding appropriate mortars. Two decades ago, standard formulas using a "soft" (high lime content) mortar were being recommended for use in older masonry work. It is now known that analysis of mortar samples from a structure will produce the most accurate identification of the original formulas. In addition, research into early bridge contracts indicates that several types of mortar, including hydraulic cement, were used for specific locations on bridges, particularly during the mid- and later 19th century.

- *Knowledge of these various forms, materials, practices, and technologies, in addition to the necessary specialized treatments required for their use, must be taken into account when planning and undertaking maintenance, repair, and rehabilitation for the various types of stone masonry construction found in Virginia's historic bridges.* Attention to this knowledge and planning will ensure use of the most appropriate practices and will prevent inappropriate repairs and damage to the stone masonry elements.

RECOMMENDATIONS

1. *VDOT structure and bridge engineers, environmental cultural resource personnel, and corresponding district staff should use the practices regarding bridge maintenance, repair, and historical documentation described in this report.*

2. *VTRC history personnel should reference the information, including historical background, condition, and maintenance needs on specific bridges, included in this report in the forthcoming update of the Management Plan for Historic Bridges in Virginia (now in progress; the updated management plan will be implemented by the Assistant State Structure and Bridge Engineer for Bridge Maintenance, who is the project champion).*

IMPLEMENTATION AND BENEFITS

The researcher and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and to determine the benefits of doing so. This is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

Implementation

Recommendation 1 will be implemented within 12 months of the publication of this report. The resulting best practices will be presented by the researcher to interested staff in VDOT's Structure and Bridge Division, VDOT's Environmental Division, and VDOT districts and to the VTRC Senior Project Manager. After this presentation, it is expected that the State Structure and Bridge Engineer will work with VTRC to ensure that this information is available for use as guidance for historic bridge maintenance and rehabilitation.

Recommendation 2, regarding referencing the information in this report in the next update of the management plan, will be implemented by VTRC. The next update, which is in progress, is scheduled for completion in November 2024.

Benefits

The benefit of implementing Recommendation 1 is the facilitation of managing and planning for certain Virginia historic bridges eligible for or listed on the National Register under VDOT purview. These bridges are those in which stone masonry is present and those with contributing structures with stone masonry elements in historic districts.

The benefit of implementing Recommendation 2 is ease of use of the updated management plan by VDOT staff: having this historical background and best practices information collected in a single report will ensure that the most complete and consistent information possible on this aspect of historic bridge management is readily available to VDOT personnel.

For both recommendations, the benefit to VDOT is the avoidance of costly delays, errors, and even damage that can result from the application of inappropriate materials and methods on historic masonry structures and components, since these require appropriate and specialized methods.

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APPENDIX A

VIRGINIA HISTORIC BRIDGE MANAGEMENT PLAN BRIDGES: BRIDGES WITH STONE MASONRY LISTED BY VDOT DISTRICT AND COUNTY, INCLUDING BACKGROUND INFORMATION AND REFERENCES TO KNOWN PLANS / SPECIFICATIONS / MORTAR / BUILDERS, AND RELATED DATA

This appendix includes brief descriptions and background information for each historic bridge on the current management plan in which stone masonry is present. Surviving 19th and early 20th century plans, contracts, and specifications; early mortar formulas; later (1930s-1940s) state and federal specifications for stone masonry construction and mortars; sources of the stone; and original masonry contractors have been identified where possible.

Research for information on the history and records for these bridges was undertaken using a variety of repositories and resources. In addition to VTRC history files, searches primarily were done at the relevant county clerk offices, in published sources, in records of the Virginia Department of Historic Resources, and in records at the Library of Virginia (in county records on deposit at the library and in records of the Board of Public Works).

As noted in the body of this report, bridges with concrete components began to appear in Virginia ca. 1901, and the first State Highway Commission standards for Virginia bridges were issued in 1909 (State Highway Commissioner, 1909). For early to mid-20th century bridges with concrete in addition to stone masonry components, or for older bridges with post–ca. 1901 mortar or concrete repairs, rehabilitation, or enlargements, the use of portland cement mortar and portland cement concrete should be assumed unless there is evidence to the contrary.

[NOTE: Numbers in parentheses after the name of a district signify the VDOT district number; numbers after the name of a county signify the VDOT county number.]

Bristol District (1)

Wythe County (98)
Wythe County [No Number] (Southwest Turnpike Company bridge) (Stone masonry arch, 1 barrel, built ca. 1850, off Rt. 11, crossing Reed Creek): The entire structure is stone masonry; the bridge dates from ca. 1850 and was constructed for the Southwest Turnpike. The builder/contractor for this bridge is not known. No original plans have been located. (NOT UNDER PUBLIC TRAFFIC: a neighboring landowner's right of way prevents complete closure, but the bridge is gated to restrict access to the property entrance.) The source of the stone is not documented, but the stone appears consistent with local stone.

Salem District (2)

Bedford County (9)
Bedford County Structure No. 6087 (Metal deck truss, built 1915; on earlier stone masonry abutments, built ca. 1850, Rt. 666 crossing Elk Creek): The large stone masonry abutments of this bridge date to the original ca. 1850 Virginia & Tennessee Railroad bridge; the original

bridge had a wooden trestle; the present metal deck truss dates to 1915. The builder/contractor for the original bridge (ca. 1850) is not known. No original (ca. 1850) plans have been located; no plans for the 1915 bridge and any attendant rehabilitation, if any, of the ca. 1850 stone masonry structure have been located. The source of the stone is not documented, but the stone appears consistent with local stone.

Botetourt County (11)
Botetourt County Structure No. 6100 (Metal deck truss, built 1886, Rt. 817 crossing Craig Creek): Stone masonry is present on the lower portions of the abutments and pier; the upper portions of these are poured concrete; the present metal truss bridge (originally built in 1886) was moved to the present site in 1902 by the C&O Railway for its Craig Valley branch. It is possible that the stone masonry dates to an earlier structure on the line, which was originally built in 1890-1891. The builder/contractor for this bridge is not known. No original plans have been located. The source of the stone is not documented, but the stone was likely local stone.

Botetourt County (11)
Botetourt County Structure No. 6386 (Metal through truss, built 1887, Rt. 685 crossing Craig Creek): The abutments and the pier are stone masonry with concrete caps; the wings are concrete; the bridge (originally built in 1887) was moved to the present site in 1903 by the C&O Railway for its Craig Valley branch. It is possible that the stone masonry dates to an earlier structure on the line, which was originally built in 1890-1891. The builder/contractor is not known. Original 1887 plans for this bridge or an extremely similar bridge exist (copies in the district structure and bridge office; copies in the VTRC history file for Botetourt County Structure No. 6386) but do not include mortar or masonry specifications. The source of the stone is not documented, but the stone was likely local stone.

Lynchburg District (3)

Nelson County (62)
Nelson County Structure No. 6070 (Stone masonry arch, 2 barrels, built 1835, Rt. 606 crossing Owens Creek): VDOT has an easement on the 1835 portion of the bridge; this portion of the bridge is of stone masonry and was originally a viaduct carrying the James River and Kanawha Canal over Owens Creek. The general structure of the bridge is of well-laid but utilitarian rubble stone masonry, but it has beautifully finished voussoirs at the arches. The original structure has been enlarged, via a concrete arched extension, to carry Owens Creek to the James River. The CSX Corporation owns the structure; VDOT has only an easement on the old viaduct and so has limited control over the concrete portion of the structure. The builder/contractor for the canal viaduct is not known. No original plans have been located. The source of the stone is not documented, but the stone appears consistent with local stone. In 2002, concrete aprons were poured in both arches to repair undermining and arrest movement of the arches. There was no further movement after the aprons were poured, and as a result, the condition ratings of the deck and superstructure were raised.

Richmond District (4)

Brunswick County (12)
Brunswick County Structure No. 6104 (Metal through truss, built 1884, Rt. 715 crossing Meherrin River): This bridge has its original 1884 stone masonry abutments and pier. Original bridge contracts and specifications, including mortar specifications and pier and abutment information, exist (copies in the district structure and bridge office and Central Office Structure and Bridge Office; copies in the VTRC history file for Brunswick County Structure No. 6104). One abutment is specified to be supported on a wooden "grillage" (i.e., a wooden framework or platform set in cement, a type of structure sometimes known as a wooden raft). The contract for the masonry work was awarded to Stewart & Shirreffs, of Richmond, Virginia; they were agents for the Wrought Iron Bridge Company of Canton, Ohio, the company that had the contract for the metal truss bridge. The 1884 specifications contained a number of separate mortar mixtures (for below the water line and for above the water line). Plans for a full rehabilitation project on this early wrought iron through truss bridge are in process. The Richmond District Structure and Bridge Office currently is planning to use sheet piling to stabilize the banks near the south span. The historic stonework will not be impacted by this work. The sheet piling, although not a period treatment, will be relatively unobtrusive and will protect the original structure while being completely reversible. The source of the stone is not documented, but the stone appears consistent with local stone. (For the text of the original mortar specifications and information on the contractors, see Appendices B and C.)

Chesterfield County (20)
Chesterfield County [No Number] (Falling Creek bridge) (Stone masonry arch, 2 barrels, built ca. 1823, at Falling Creek Wayside, off Rt. 1, crossing Falling Creek): This bridge, originally built ca. 1823 as part of the Manchester-Petersburg Turnpike, has been off system in the Falling Creek Wayside since the early 1930s. From the 1930s until August 2004, this bridge served as a pedestrian bridge at the Falling Creek Wayside. Due to flooding and debris damage during Tropical Storm Gaston on August 30-31, 2004, the bridge has remained closed to all traffic / public access since that time. The structure has been stabilized as a ruin and landscape feature within the wayside with a concrete cap over the damaged stonework. The bridge consisted of two arch barrels. It is important to note that this bridge has apparently undergone several major episodes of flood damage and repair since at least the early 20th century. A concrete apron was in place on the pier by the 1910s, and a major rehabilitation was undertaken (probably related to previous flood damage) ca. 1922 (Miller, 2011; Miller and Wells, 2011). Probably from repairs made in the ca. 1922 work, a tie rod and tie bar were in place over the pier, and concrete had been added over the arches for additional reinforcing, beneath the roadway paving. The structure currently consists of the stabilized ruins of the original ca. 1823 stone masonry arch and remnants of later repairs. There is some local advocacy for restoration/repair of the bridge—however, an inadequate original hydraulic opening makes complete restoration inadvisable. The builder/contractor for the turnpike company is not known. No original plans for this bridge have been located. The source of the stone is not documented, but the stone appears consistent with local stone. (NOT UNDER TRAFFIC.)

Chesterfield County (20)
Chesterfield County Structure No. 1900 (Aluminum triangular multi-girder [Fairchild design], built 1960-1961, Rt. 36 crossing Appomattox River): This bridge is significant as the first aluminum multi-girder bridge built in the United States. Original plans exist. Nearly all of the substructure is of concrete. However, the bottom portion of the north abutment has a stone masonry footing, a remnant of the stone abutments from one of the earlier bridges on the site. The source of the stone is not documented, but the stone appears consistent with local stone. This structure provides a useful example of an historic bridge for which stone masonry is not a significant or character-defining feature but for which a stone masonry element nevertheless must be considered in its maintenance.

Culpeper District (7)

Culpeper County (23)
Culpeper County Structure No. 6906 (Waterloo bridge) (Metal through truss, built 1878, Rt. 613 crossing Rappahannock River): This bridge has its original ca. 1878 stone masonry abutment and piers; portions of one abutment and pier apparently survived from an earlier bridge and were repaired/rebuilt and altered for the 1878 work. The steel beam approach spans on the south end of the bridge are supported on concrete bents; this portion of the bridge dates from 1919 repairs after flood damage. The 1878 construction work required repairing the wing wall of the abutment and raising the height of the pier on the Fauquier County side of the river (these were the elements that survived, at least partially, from the earlier bridge). Original (1878) bridge contracts and specifications, including mortar specifications and pier and abutment information, exist (copies in the district structure and bridge office; copies in the VTRC history file for Culpeper County Structure No. 6906). As part of the 1878 work, a new stone masonry pier was built on the Culpeper side of the river. The contract for the masonry work was awarded to a local man, Bushrod Thompson. (A man named Bushrod Thompson, born ca. 1824, is listed on the 1850 Fauquier County Census as a stonemason living in Fauquier County and appears to be the same individual.) Written material included with the bridge contract indicates that Thompson lived very close to the bridge site and did stonework and that he was not overly familiar with the requirements of truss abutments, since the finished work had to be altered and corrected before the metal truss elements of the bridge could be constructed. To date, research into local and regional records has not succeeded in documenting other structures built by him, or the extent of his business operations. Original (1878) bridge contracts and specifications, including mortar specifications and pier and abutment information, exist (see Appendices B and C). The stone is consistent with local stone. Comparable stone was available at various quarries in the region, and in the contract papers for the bridge, Bushrod Thompson stated that materials were available on his land, which was close to the bridge. In 2020-2021, the bridge underwent an extensive rehabilitation that involved rehabilitation of both the truss and the stonework and concrete of the substructure. Special provisions were required to match the appearance of the historic mortar joints on the stone abutment and piers (see Appendix D).

Staunton District (8)

Alleghany County (3)
Alleghany County Structure No. 9008 (formerly No. 6064) (Metal through truss, built 1896, Rt. 633 crossing Cowpasture River): This three-span bridge has its original 1896 abutments and its two stone masonry piers in place. *[Note: This bridge is off system and bypassed, and it currently serves as a landscape feature near its replacement structure.]* The contract for the masonry work for the bridge was awarded to the firm of Rinehart & Valz; Rinehart & Valz and its successor firms undertook substantial commissions in the upper South and mid-Atlantic in the later 19th and early 20th centuries. Original (1896) bridge contracts and specifications for this Alleghany County bridge exist; these include at least some mortar specifications and pier and abutment information (partial copies in the district structure and bridge office; partial copies in the VTRC history file for Alleghany County Structure No. 9008) (see Appendices B and C). The source of the stone is not documented, but the stone appears consistent with local stone. (NOT UNDER TRAFFIC.)

Alleghany County (3)
Alleghany County Structure No. 9007 (Humpback bridge) (Covered wooden through truss, built 1857, now a pedestrian bridge, in the wayside off Rt. 60 west of Covington, crossing Dunlap Creek): This bridge is one of only two state-owned covered bridges remaining in Virginia; it has been closed to vehicular traffic since 1929. The bridge was built for the James River and Kanawha Turnpike. The 19th century stone masonry abutments and approaches are still in place and functioning. The stone masonry has been repaired at various times after flooding; it is uncertain if some of the stone masonry dates to one of the previous bridges at the site or whether the stone masonry elements were built new for the construction of the present bridge in 1857. The bridge underwent an extensive rehabilitation in 2013. In addition to repair and replacement of deteriorated wooden elements and the roof covering, concrete backwalls were placed at each end of the bridge and the stone masonry was repaired as needed. Further repairs were made after the massive 2016 flooding of the area. (It should be noted that the backwalls inserted in the 2013 work likely saved the bridge from being badly damaged or washed away during the 2016 flooding and attendant debris impact to the bridge.) Modern "soft" mortar (Type N) was used in both the 2013 and 2016 repair episodes. The builder/contractor for the 1857 work has not been documented beyond doubt. No original (1857) plans have been located. The bridge has been performing well since the emergency repairs following the record 2016 flooding on Dunlap Creek, as noted in the 2017 Update. In addition to its National Register status, this is Virginia's only National Historic Landmark bridge (the highest level of historic significance). The source of the stone is not documented, but the stone appears consistent with local stone. (NOT UNDER TRAFFIC.)

Augusta County (7)
Augusta County Structure No. 6027 (Metal pony truss, built 1898, Rt. 907 crossing Christian's Creek): This bridge has its original stone masonry abutments in place. The construction of the bridge was ordered by the Augusta County government in 1893, but financial problems delayed the project until 1898. No information on the builder/contractor or the construction of the abutments has been identified in the county records. No original plans have been located despite an examination of the county road and bridge records. The source of the stone is not

documented, but the stone was likely local stone. (CURRENTLY CLOSED DUE TO CONDITION ISSUES.)

Augusta County (7)
Augusta County Structure No. 6147 (Metal through truss, often dated as 1909 but probably built 1903-1904 [from HAER research in county records], Rt. 775 crossing Middle River): This bridge has one stone masonry abutment and one concrete abutment that is at least partly faced with concrete. The concrete abutment appears to overlay a stone masonry abutment. The Augusta County Board of Supervisors Order Book records (Order Book 4, p. 264) indicate that J. T. Muddiman was awarded the contract to build the stone masonry abutments. No original plans have been located despite an examination of the county road and bridge records. The source of the stone is not documented, but the stone was likely local stone. (CURRENTLY CLOSED DUE TO CONDITION ISSUES.)

Augusta County (7)
Augusta County Structure No. 6997 (Valley Railroad bridge) (Stone masonry arch, 4 barrels, built 1874, crossing Folly Mills Creek just west of I-81, south of Staunton): The entire structure is stone masonry; this four-arch former railroad bridge, originally built for the Valley Railroad, dates from 1874 (the date is documented on a carved stone set into the bridge). The railroad ceased operations in 1942. The bridge is now a landscape feature within the I-81 right of way; it has never carried road traffic and is closed to all traffic / public access. The construction of this bridge was by the Mason Syndicate (Hildebrand, 2001). Antonio M. [A. M.] Valz, an Italian immigrant trained as a civil engineer at the University of Turin, was reportedly involved in the construction of this bridge as a "contractor." A. M. Valz was later a principal in the firm of Rinehart & Valz, which constructed the stonework for the 1896 McKinney's Hollow bridge, noted above (Alleghany County Structure No. 9008; formerly No. 6064). No original plans for Augusta County Structure No. 6997 have been located. The source of the stone is not documented, but the stone appears consistent with local stone. The quarrying and use of local stone for bridge masonry were consistent with the practices of the Mason Syndicate on the Valley Railroad construction (Hildebrand, 2001). In additional support of this is a strong local tradition that the stone was quarried at a site near the bridge. Concrete aprons were placed on the piers of the bridge nearest Folly Mills Creek, probably in the late 1970s or the early 1980s (Park W. Thompson, personal communication, February 8, 2021). 3-D scanning has been completed for this bridge. (NOT UNDER TRAFFIC.)

Highland County (45)
Highland County Structure No. 6034 (Metal pony truss, built 1896, Rt. 645 crossing Crab Run): Stone masonry abutments are in place but have been faced with concrete; the abutments are undermined and the overlying concrete is deteriorated. Due to the concrete overlay, the stonework could not be examined for further description. The truss bridge was constructed in 1896 on the Lane Patent by the West Virginia Bridge Works (as was noted on a now-vanished bridge plaque). The builder/contractor for the stonework of this bridge is not known. No original plans for the bridge or the stone masonry work have been located. This structure is closed to vehicular traffic (since 1994) and is a pedestrian and bicycle bridge. (NOT UNDER TRAFFIC.)

Rockbridge County (81)
Rockbridge County Structure No. 1012 (Concrete arch, 1 barrel, built 1940, Rt. 39 crossing Laurel Run): This bridge was built in 1940 as part of the design of the scenic highway (then Rt. 501, now Rt. 39) through Goshen Pass. The bridge is a concrete rigid frame structure with stone masonry rubble veneer and stone rubble wing walls to match the other stonework on the Goshen Pass project. This project was the Virginia Department of Highways' first large-scale integration of highway design and landscaping to avoid or minimize highway impact to an historic/scenic area. H. J. Neale, the Department of Highway's "Landscape Engineer" (a then-common term for Landscape Architect), was closely involved with the planning and design of the Goshen Pass project. He conceived an overall design including roadway design, plantings, stone retaining walls, and the bridge over Laurel Run (Miller, 2019). His involvement as a landscape architect was not dissimilar to the case with contemporary federal projects, such as the stone veneer bridges along the Blue Ridge Parkway, in which Bureau of Public Roads engineers and National Park Service landscape architects worked together to produce structures that harmonized with the surrounding environment. As was typical in bridges built after the beginning of the 20th century, the Rt. 39 bridge over Laurel Run has portland cement mortar. The probable source of the stone for the Goshen Pass project was a now-closed quarry near Lexington (James W. White, Jr., personal communication, May 1, 2020). Original Virginia Department of Highways plans exist for the bridge (as do the plans for the rest of the Goshen Pass project). The "General Notes" on the bridge plans reference the Virginia Department of Highways Bridge Specifications, 1932, and contain instructions to incorporate the appearance of the bridge with that of the overall aesthetics of the project:

> Rail and Wing Wall Copings to be of Laminated Stone of a thickness of 3 to 4 inches, and to conform to the requirements of Mortar Rubble in all other respects, and to be paid for as such. Masonry Facing on Arch Barrel to be Rough Finished Ashlar: omit chisel draft on exposed face. Masonry in Rails, Curbs, Spandrel and on Frame (except Arch Barrel) to be of Mortar Rubble. Wing Walls outside of constr. Joint J-J and below copings to be dry rubble masonry. . . . All Stone shall be taken from the same Quarry.

Rockbridge County (81)
Rockbridge County Structure No. 6145 (Goshen bridge) (Metal through truss, built 1890, Rt. 746 crossing Calfpasture River): The bridge has its original stone masonry piers and abutments. The bridge was rehabilitated in 2002, and the stonework was cleaned and repaired by James Moran (Moran Construction, Abingdon, Virginia), a stonemason with experience in repairing National Park Service monuments (Park W. Thompson, personal communication, January 14, 2019). It is probable that a modern "soft" mortar was used for this work. Archival photographs in the VTRC history files show some partial concrete aprons in place in the 1970s; these subsequently were expanded to full concrete aprons. The 1890 bridge was constructed by the Groton Bridge & Manufacturing Co. for the Goshen Land & Improvement Co., a private company planning the development of the town of Goshen. The builder/contractor for the stone masonry work is not known. No original plans have been located. The source of the stone is not documented, but the stone was likely local stone.

Rockingham County (82)
Rockingham County Structure No. 6166 (Semi-integral steel beam, built 1937, Rt. 924 crossing Mines Run): The bridge has stone masonry abutments and wing walls; the bridge was built by

the U.S. Forest Service in 1937 as part of the improvements in the George Washington National Forest and remained under Rockingham County control until 1951. In the absence of known plans for this structure, it is uncertain if all of the bridge elements are of solid stone masonry. However, given the U.S. Forest Service practices of the time, solid stone masonry seems extremely likely. Near-contemporary U.S. Forest Service plans for stone masonry (collected in the U.S. Forest Service's 1936 volume *Acceptable Bridge Plans,* compiled by their Division of Engineering) show all of their stone masonry abutments and piers as being constructed from solid rubble masonry rather than stone masonry veneer over concrete, although concrete footings were permitted if necessary. In contrast, the 1941 federal S*pecifications for Construction of Roads and Bridges in National Parks and Forests* contains specifications for the use of stone veneer over concrete (U.S. Park Service, 1941). From field examination, all mortar on Rockingham County Structure No. 6166 appears to be contemporary with the 1937 construction date and to contain portland cement. Contemporary mortar specifications appear in the 1936 *Acceptable Bridge Plans* (U.S. Forest Service, 1936) and in the 1941 *Specifications for Construction of Roads and Bridges in National Parks and Forests* (National Park Service, 1941). However, no original plans for Rockingham County Structure No. 6166 have been located despite a detailed examination of U.S. Forest Service records and Rockingham County road and bridge records. The bridge has battered (2 inches : 1 foot) rubble masonry abutments and wing walls and is built on a 31% skew. Portland cement mortar appears to be used throughout for the stone masonry. The stone portion of each abutment has a concrete cap, and above the stone masonry and concrete cap of each abutment is the concrete backwall. The rubble stone masonry wing walls are capped with rubble stone coping. All of the stone masonry work on this bridge appears to be original and is consistent with the types of rubble stone masonry for bridge abutments and wing walls shown in the 1936 *Acceptable Bridge Plans* (U.S. Forest Service, 1936). The source of the stone is not documented, but the stone appears consistent with local stone.

Shenandoah County (85)
Shenandoah County Structure No. 6078 (Meems Bottom Covered bridge) (Covered wooden through truss, built 1894, Rt. 720 crossing North Fork of Shenandoah River): The original 1894 stone masonry abutments are in place; the wooden portions of the bridge were heavily damaged and underwent extensive repairs after a 1976 arson attempt. The bridge was reopened in 1979; steel beams on modern concrete piers were added in 1985 to support the wooden bridge. This bridge is one of only two state-owned covered bridges remaining in Virginia, and it is the last covered bridge in Virginia open to public vehicular traffic. No original (1894) plans have been located. This bridge originally was privately constructed, built by local bridge builder John W. B. Woods for landowner F. H. Wisler. In 1895, Woods built another private covered bridge, at D. U. Biedler's farm in Rockingham County. In the case of the Biedler farm bridge, the August 8, 1895, edition of the local newspaper, *The Shenandoah Valley*, reported that John J. Estep and J. Michael Zirkle, two expert stonemasons from Forestville, had completed the two large stone abutments for the bridge. The paper's edition of December 12, 1895, reported that Woods had completed the bridge ("Mr. W. is a veteran at the business, and surpassed himself in this structure."). This suggests that Woods was primarily a contractor specializing in the construction of wooden bridges, with the construction of the stone masonry abutments at the Meems Bottom bridge and the Biedler farm bridge and other bridge projects being undertaken by stonemasons specializing in this work. However, no stonemasons have specifically been

documented for the work on the Meems Bottom bridge (Newlon, 2011). An article on Virginia's covered bridges in the March 1939 *Virginia Highway Bulletin* noted of the Meems Bottom bridge abutments: "Stone for the abutments, which extend 10 feet below the bed of the stream, was quarried at the river bluff near Rudes Hill" (Lawrence, 1939). Rudes Hill is a short distance from the bridge site.

Northern Virginia District (9)

Arlington County (0)

Arlington County Structure No. 5020 (Concrete rigid frame with stone veneer, 2 spans, completed 1945, Memorial Avenue, crossing Rt. 110, adjoining Arlington National Cemetery): This structure was completed in 1945 from plans dated 1941. The bridge is a concrete rigid frame structure faced with decorative stone veneer that is compatible with other stonework on structures in the vicinity, particularly on the George Washington Memorial Parkway, with which this structure is associated. The original plans for this bridge exist: it was designed as "Bridge No. 1 / Heavy Duty Road Underpass at Memorial Avenue" by the Federal Works Agency, Public Roads Administration, as part of the War Department Building Road Network. (The War Department Building now is more commonly known as the Pentagon.) On the plans, the General Specifications were the 1941 *Specifications for Construction of Roads and Bridges in National Parks and Forests* (National Park Service, 1941) and the design specifications were referenced as the *Standard Specifications for Highway Bridges, A.A.S.H.O., 1941* (American Association of State Highway Officials, 1941). To produce an appearance consistent with that of other federal bridge projects associated with the George Washington Memorial Parkway, the source of the stone would have been one of the several regional Maryland quarries (all located within 50 miles or less of the bridge) that provided the stone for other bridges on this parkway (see the HAER VA-69 documentation for the George Washington Memorial Parkway, copy in the VTRC history file for Arlington County Structure No. 5020). This bridge was a late project of the noted architect and industrial designer Paul Philippe Cret, whose work included a number of bridges and monuments. (See Appendix B.)

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Loudoun County (53)

Loudoun County Structure No. 1025 (Stone masonry arch, 2 barrels, built ca. 1810-1824 [probably 1820s], Rt. 50 crossing Little River): The entire structure is stone masonry; the structure dates from the 1820s. An inspection in 2001 revealed that a portion of the bridge's wing wall and buttress required reconstruction because of severe deterioration of the mortar between the stones. To achieve the needed repair and strengthening, portions of the wing wall and buttress were reconstructed. In addition, grouted anchors (the proprietary Cintec system) were inserted to stabilize the structure as part of the 2001 repairs. The anchor system is performing well. The original (1820s) builder/contractor is not known. No original (1820s) plans have been located. Copies of the 2001 rehabilitation plans exist (copies in the district structure and bridge office). The source of the stone is not documented, but the stone appears consistent with local stone.

Loudoun County (53)

Loudoun County Structure No. 6088 (Stone masonry arch, 2 barrels, built ca. 1829, Rt. 734 crossing Beaverdam Creek): The entire structure originally was of stone masonry; the structure dates from ca. 1829. In 2007, after prolonged discussion between VDOT and Loudoun County, the bridge underwent a major rehabilitation. The spandrel walls were dismantled and rebuilt, the fill was removed, and a reinforced concrete slab floating on gravel base material was added to distribute load more evenly to the arch. An integral reinforced concrete saddle was added. Underdrains were installed to collect drainage material and prevent it from saturating the base material, leaking, and causing damage to the stone masonry from cycles of freezing and thawing. The objective of the project was to increase the durability and longevity of the bridge rather than to increase its weight capacity, which remained posted at 6 tons. The original (ca. 1829) builder/contractor is not known. No original (ca. 1829) plans have been located. Copies of the 2007 rehabilitation plans exist (copies in the district structure and bridge office). The source of the stone is not documented, but the stone appears consistent with local stone.

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APPENDIX B

NINETEENTH CENTURY AND EARLY 20TH CENTURY CONTRACTORS AND RELATED DESIGN PROFESSIONALS ASSOCIATED WITH STONEWORK ON EXTANT MANAGEMENT PLAN HISTORIC BRIDGES IN VIRGINIA AND CONTRACTORS FOR BRIDGES THAT ARE NOT EXTANT BUT FOR WHICH SOME REPRESENTATIVE CONTRACTS/SPECIFICATIONS FOR STONEWORK ON BRIDGES HAVE BEEN IDENTIFIED

Although the contractors and designers for some of the bridges included in this study have not been identified, a number of 19th century and early 20th century contractors were positively identified as being associated with stone masonry work on Virginia's extant historic bridges. In addition, a number of the builders involved with some other representative contracts for bridges that are no longer extant but are similar to surviving historic bridges were also identified. Of the identified contractors, Bushrod Thompson (who built the 1878 stonework on Culpeper County Structure No. 6906) apparently was a local stonemason without extensive experience in building bridge substructures. The other identified contractors were well organized and often involved with companies that had considerable—even widespread—and fairly sophisticated bridge/engineering experience. These contractors had a variety of national origins and backgrounds.

The most recent bridge on the list (Arlington County Structure No. 5020, built in 1945), although built from federal plans, also had design input from noted architect and industrial designer Paul Philippe Cret.

- **Paul Philippe Cret.** Arlington County Structure No. 5020 (Concrete rigid frame with stone veneer, built 1941-1945): This bridge included some involvement, as a late project, of the noted architect and industrial designer Paul Cret, whose work included a number of bridges and monuments. Born in Lyon, France, Cret was a classically trained architect—with both a distinguished career as an architect / industrial designer / design consultant and an over 30-year teaching career at the University of Pennsylvania. His design work encompassed public buildings, university structures, war memorials, bridges, and train designs. Cret was a member of the U.S. Commission on Fine Arts from 1940 through 1945 (White, 1973). Semi-retired at the time of his design work on the Arlington County bridge, Cret is noted on the plans as a "Consulting Architect" for the project. Since his name appears only on the plan pages showing the decorative stonework, it is possible that he was responsible for this portion of the design.

- **The Mason Syndicate (Claibourne Rice Mason and various, often situational, partners).** Augusta County Structure No. 6997 (Valley Railroad bridge) (Stone masonry arch, built 1874): The construction of this bridge was by the Mason Syndicate (Claibourne Rice Mason and others); Antonio M. Valz (see below) is cited as a "contractor" for the project in his 1916 obituary. Although C. R. Mason was known for extensive partnerships with other contractors and firms, these partnerships were also fluid—predicated on a specific project or even a specific structure. No comprehensive list of his partnerships and employees for this era survives. The Mason firm became known as Mason & Hoge in the 1870s. Still in existence, the firm is now Mason & Hanger (Hildebrand, 2001; Merritt, 1928).

- **J. T. Muddiman.** Augusta County Structure No. 6147 (Metal through truss, probably built 1903-1904): Although no specifications or plans for this bridge are known to survive, the Augusta County Board of Supervisors Order Book records (Order Book 4, p. 264) indicate that J. T. Muddiman was awarded the contract to build the stone masonry abutments. J. T. Muddiman may have been John T. Muddiman, who was a son of the Jacob Muddaman (also spelled Mudaman and Muddiman) who built the stonework of the now-defunct Raccoon Ford bridge across the Rapidan River between Orange and Culpeper counties in 1883 (see below). (Variant spellings of names were not uncommon prior to the first part of the 20th century.) The Muddimans were English immigrants who lived in northern Virginia, near Manassas, for at least part of the last half of the 19th century, and various family members are buried in the Manassas Cemetery.

- **Rinehart & Valz.** Alleghany County Structure No. 9008 (formerly No. 6064) (Metal through truss, built 1896): The contract for the masonry work for the bridge was awarded to the partnership of W. A. Rinehart and A. M. Valz, trading as the firm of Rinehart & Valz (see Appendix C). This firm, and related firms in which the principals were involved, undertook substantial commissions in the upper South and mid-Atlantic in the later 19th and early 20th centuries (Valz obituary, 1916). A. M. Valz had previously done work for the Mason Syndicate (see these entries).

- **Stewart & Shirreffs.** Brunswick County Structure No. 6104 (Gholsons bridge) (Metal through truss, built 1884): The contract for the masonry work was awarded to Stewart & Shirreffs, of Richmond, Virginia, who were the regional agents for the Wrought Iron Bridge Company of Canton, Ohio. (The Wrought Iron Bridge Company also had the contract for the metal truss bridge.) One of the principals, Reuben Shirreffs, was a native of Nova Scotia and had both civil engineering and architectural training. He came to Richmond around 1882 and by 1883 was engineer for water power for the Richmond & Alleghany Railroad. In addition to his mid-1880s work with the Wrought Iron Bridge Company, he subsequently undertook significant architectural and engineering design work in Richmond, Washington, D.C., and elsewhere, designing public buildings, schools, and industrial structures, including hydroelectric power plants (Wells and Dalton, 1997).

- **Bushrod Thompson.** Culpeper County Structure No. 6906 (Waterloo bridge) (Metal through truss, built 1878): The work required repairs to some existing elements and the construction of a new pier. The contract for the masonry work was awarded to Bushrod Thompson, apparently the stonemason (born ca. 1824) who is listed on the 1850 Fauquier County Census. Papers associated with the bridge contract suggest that Thompson was a local man who did stonework and that he was not very familiar with the requirements of truss bridge abutments: his finished work, although sturdily built, had to be altered and corrected before the truss elements could be put in place.

Thompson likely was a local stonemason whose work had been primarily on chimneys, buildings, etc. Additional information on him, notably the extent of his business and construction operations, has not been located to date, despite an examination of the Culpeper and Fauquier county records and the polling of a number of regional restoration masons and historical researchers.

- **Antonio M. [A. M.] Valz.** Augusta County Structure No. 6997 (Valley Railroad bridge) (Stone masonry arch, built 1874): According to his 1916 obituary notices, Antonio M. [A. M.] Valz, an Italian immigrant trained as a civil engineer at the University of Turin, was involved in the construction of this bridge as a "contractor" (i.e., working with the Mason Syndicate in some capacity). A. M. Valz was later a principal in the firm of Rinehart & Valz (see above), which constructed the stonework for the 1896 McKinney's Hollow bridge (Alleghany County Structure No. 9008). In the early 20th century, A. M. Valz operated both as a principal in his own construction firm and as a partner with one of his sons, Arthur A. Valz, in A. M. Valz & Son, with work that included railroad construction and paving projects.

Other contractors for whom names and specifications for various bridges survive (see Appendix C) although their bridges are no longer extant:

- **Ambrose Powell Hill.** Culpeper County resident Hill, uncle of the Civil War general of the same name, served as a county commissioner and superintendent for the 1844 bridge across the Rapidan River at Germanna. As superintendent of the bridge, Hill oversaw T. J. Richards, who was awarded the contract to construct the wooden truss (although it is uncertain if Richards was involved in the construction of the stone abutments and pens). A. P. Hill also was involved in contracting, and specifications for a number of structures on the Thornton's Gap Turnpike during the 1840s and 1850s appear in his family papers; he also served as President of the turnpike during the early 1850s (Hill Family Papers, 1787-1945).

- **Jacob Muddaman (also spelled Mudaman, Muddiman).** Jacob Muddaman built the stonework of the now-defunct Raccoon Ford bridge across the Rapidan River between Orange and Culpeper counties in 1883. The family lived in Manassas for at least part of the later 19th century, although Jacob Muddaman is described in bidding documents as living in Culpeper County at the time the bridge contract was let (Hurst, 2017). He was probably the father of the J. T. Muddiman noted above.

- **John R. Tillett.** Tillett, noted as living in Manassas, got the contract to build the stonework for a bridge across the Rapidan River at Germanna, between Orange and Culpeper counties, in 1881. (This is the present Rt. 3 corridor.) He also was an unsuccessful bidder for the contract to build the nearby Raccoon Ford bridge (losing to Jacob Muddaman) in 1883 and submitted a bid for repairs on the flood-damaged Germanna bridge in 1889 (Hurst, 2017). He was described a "stone contractor" in Manassas after the war and in 1911 was termed "one of Manassas' leading men and bridge contractor" in a local newspaper article. He was a Civil War veteran, serving in the 15th Virginia Cavalry (Capt. Brawner's Company, Partisan Rangers) and later the 43rd Battalion, Virginia Cavalry (Partisan Rangers), under Col. John S. Mosby. After the war, he was active in veterans' organizations (Keen and Mewborn, 1993).

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APPENDIX C

TRANSCRIPTIONS OF EARLY VIRGINIA BRIDGE CONTRACTS/SPECIFICATIONS RELATING TO MORTAR AND/OR STONE MASONRY

Overview

Early contracts/specifications relating to mortar and/or stone masonry were located for the following extant Virginia bridges (all on the Historic Bridge Management Plan):

- Waterloo bridge (Culpeper County Structure No. 6906), built 1878
- Gholsons bridge (Brunswick County Structure No. 6104), built 1884
- McKinneys Hollow bridge (Alleghany County Structure No. 9004 [formerly No. 6064]), built 1896.

Transcriptions of the relevant materials are provided in the following pages.

Contracts/specifications were also identified for the following bridges that are no longer extant:

- Raccoon Ford bridge, built 1883-1884
- Germanna bridge, built 1844
- Germanna bridge, built 1881-1882
- Hazel River bridge (and related specifications for Thornton's Gap Turnpike), 1840s
- Springwood bridge, 1883-1884.

These specifications relate to mortar and/or stone masonry work on abutments and piers supporting wooden truss, combination truss, or metal truss bridges. The specifications related to the Thornton's Gap Turnpike also reference small stone masonry culverts. Transcriptions of this information are included in the following pages as examples of period mortar and practices.

[NOTE: Spelling and punctuation in the transcriptions are per the original documents.]

Contracts/Specifications for Three Extant Bridges

Mortar/Masonry Specifications/Contracts for:

Waterloo bridge (Culpeper County Structure No. 6906), metal through truss bridge, built 1878, crossing the Rappahannock River between Culpeper and Fauquier counties)

[NOTE: Commissioners' documents were located in the bridge records of the Fauquier County Circuit Court Clerk's Office by regional historical researcher John Gott during the 1980s; the text below is from John Gott's transcription; copy in the VTRC history file for Waterloo bridge/Culpeper County Structure No. 6909.]

[Masonry specification document for the Waterloo bridge]

"A"

Bridge at Waterloo, over Rappahannock River

Specifications for Masonry of Piers and Abuts.

Masonry shall consist of stones cut in bed and built to a uniform thickness throughout, before being laid, but not hammered. they shall be laid on a level bed and have vertical joints continued back at right angles at least eight inches from the face of the wall. The work need not be carried up in regular courses, but shall be well bonded, having one header for every three stretchers, and not more than one third of the stones shall contain less than two cubic feet, or be less than nine inches thick; and none of that third shall contain less than one and one half cubic or be less than six *[Note: this word is interpreted as "nine" in the Gott transcription but looks like "six" in the photocopy of the original document]* inches thick.

No more small stones shall be used than necessary to make even beds, the whole to be laid in cement mortar and pointed.

Cement

Cement shall be of the best quality, hydraulic, newly manufactured, well housed and packed, and so preserved until required for use. And none shall be used in the work until tested and approved by the Engineer

Cement Mortar

The proportion of sand and cement for construction shall be one of cement to two of clean, sharp sand, unless in special cases the Engineer directs otherwise, for which due allowance shall be made. It shall be used directly after mixing, and none remaining overnight shall be remixed.

=

The work to be done consists of repairing the wing wall of Abutment, and raising one Pier, on the Fauquier side, and building one Pier on the Culpeper side of River, the whole containing from 110 to 125 cubic yards; also the filling, pointing and grouting of the old work.

Contractors will be allowed the use of such of the old stone of bridge, as may be suitable, but will furnish all other material required, and in the price per Cu. Yd. paid for new work, will be included cost of filling, pointing and grouting the present work

"A"

[end of mortar specification document]

[NOTE: The contract for the stone masonry work was awarded to Bushrod Thompson, apparently a local stonemason. Other papers included with the contract for the bridge that cite masonry issues follow:]

[Letter from Bushrod Thompson regarding specifications for stonework on Waterloo bridge]:

1877
April the 10
I examined the specification of stonework at waterloo Bridge & think I understand all about what Mr. Norris Indionier *[i.e., engineer]* wants & means. I will Build the work for 3 $ a cubit yard & furnish all or I will do the work & furnish all excerpt sement that is to be delivered at Warrenton free of charge for the sum of three hundred dollars masonry & filing Pointting & grouting this. I coldnot do only the work is at mi dore *[i.e., my door]* & Meterl *[i.e., material]* on mi farm close By if this work is let to me I expect to give sadifaction. Respectfully yours tr.
Bushrod Thompson

[Letter from George Devin, Manager & Engineer, Pittsburg Bridge Company, to T. N. Fletcher, Commissioner]:

The Pittsburg Bridge Company
Bridges, Roofs and General Iron Construction,
Established January 1878

Pittsburg
July 15, 1878

T.N. Fletcher, Comr.
Warrenton, Fauquier County, Virginia, July 15, 1878
Dear Sir:

We have this day received first payment on Waterloo Bridge, County Treasurer, Fauquier County, Ck. No. 450 for $498.00 (four hundred and ninety-eight dollars), made payable to our order by yourself.

Many thanks—our Mr. King writes that by some means there was an error of something like four feet made in setting out the abutment. Mr. K. measured it 93'-9". Should be 98'-)" (see your letter May 9th to us.) This is unfortunate but can be remidied by some additions to the stonework. Please see to it that the stonework is thorough and secure. It will not pay you to allow of any questions as to the stability of the foundations. Mr. K. will lend you every assistance [&] can no doubt be of service to you in the matter.

[Excerpt from the report of the "Comrs. [i.e., Commissioners] on the part of Fauquier County for the construction of the Waterloo Bridge," filed July 25, 1878)]:

. . . There was some extra masonry necessary to be done on the piers in order to give a rest for the bridge which [illegible] finally was done by November 13.

[end of Waterloo bridge documents]

Mortar/Masonry Specifications/Contracts for:

Gholsons bridge (Brunswick County Structure No. 6104), metal through truss bridge, built 1884, over Meherrin River, Brunswick County

[NOTE: Commissioners' documents were located in the Brunswick County bridge records (Box 4 of the collection "Brunswick County Road and Bridge Records / Bridges"), on deposit at the Library of Virginia. The text below is from Ann Miller's transcription; copy in the VTRC history file for Gholsons bridge/Brunswick County Structure No. 6104. The contract for the masonry work was awarded to Stewart & Shirreffs, of Richmond, Virginia; they were agents for the Wrought Iron Bridge Company of Canton, Ohio, which had the contract for the metal truss bridge.]

Specification for Masonry at Gholson's Bridge

--- \\ ---

To be two abutments with wings and one pier.

Front walls of abutments to be 3' x 16' at top and 8 feet wide at bottom, to batter 1 in 12 on face and sides. Pier to be 4' x 16' at top, to batter 1 in 12 on sides & ends. South abutment wings to be 12' long on top and to step up on the solid ground. North abutment wings to be long enough to retain the filling, 12 feet of the length to be mortared masonry on same foundation as front wall, remainder dry work.

Foundations of piers and front walls to be two feet below bed of river on white oak platform or on rock at this or a less depth.

To be laid in cement mortar, three sand to one cement to water line or surface of ground & above this of mortar with equal parts of lime & cement. To be pointed on faces with cement mortar one sand to one cement.

Work to be first class rubble masonry of good size, & shape, straight split stone, with good beds and builds. Particular care to be taken with exposed corners and bridge seats.

[end of Gholsons bridge documents]

[Notes on] Mortar/Masonry Specifications/Contracts for:

McKinney's Hollow bridge (Alleghany County Structure No. 9004 [formerly No. 6064]), metal through truss bridge, built 1896-1897, over Cowpasture River, Alleghany County

[NOTE: Commissioners' documents were located in Alleghany County bridge records at the Alleghany County Courthouse, Covington, Virginia; the notes below are taken from metal truss bridge survey information (in VTRC history files) and the 1994 HAER documentation for this bridge. A copy of the HAER VA-104 documentation is in the VTRC history file for Alleghany County Structure No. 9004 (formerly No. 6064).

The following excerpts are from the contract for the stone masonry substructure of the bridge, dated November 14, 1896, between the Alleghany County Board of Supervisors and W. A. Rinehart and A. M. Valz, trading as Rinehart & Valz. (The superstructure of the bridge was built by the firm of Nelson and Buchanan, cited in their drawings and on the bridge plaque as "Engineers & Contractors / Chambersburgh Pa.").]

The contractors will be responsible for building masonry cofferdams and for all of the excavation and grading for the approaches to the bridge

The county will furnish the cement

All mortar used in the face walls to be mixed of half cement and half sand

All mortar used in the backing to be mixed of two parts of sand and one part of cement

The sand should be clean and sharp, free from loam, screened if necessary, and equally as good as the sand found at the junction of the Cowpasture and Jackson rivers (two miles to the south of the bridge to be constructed)

[end of McKinney's Hollow bridge document]

Contracts/Specifications for Five Non-Extant Bridges

Mortar/Masonry Specifications/Contracts for:

Raccoon Ford bridge, built 1883-1884 (no longer extant), metal through truss bridge, crossing the Rapidan River between Orange and Culpeper counties)

[NOTE: Document, not dated but from the events noted dating from spring of 1883, entitled "In The Matter of the Iron Bridge at Raccoon Ford to the Hon. John W. Bell Judge County Court of Culpeper, Va." (Culpeper County Circuit Court bridge records and Morton-Halsey papers, University of Virginia; see Patricia J. Hurst, Bridges Over the Rapidan River in Virginia *(pvt. prt., Charlottesville, Va., 2017).]*

Bridge Letting Handbill

[NOTE: The bridge letting handbills were dated March 21, 1883, and were distributed to bridge contractors with a proposal deadline of April 16, 1884. The bridge would be a 167-foot span across the river. There were to be two abutments of "first class rubble work of 20 feet face, with wings 20 feet long and 8 feet thick." The abutments were to be on "solid hard pan, or rock, below" and 15 feet above the water level when the water was running over the mill dam. The abutments were to be laid "of Syenite or solid hard stone" in cement to the water level and lime mortar above the stone in cement. The bridge was to be "of Entire Wrought Iron" with the exception of a white oak floor of two and one-half inch planks. The planks were to be laid diagonally across. The roadway was to be 12 feet wide. The bridge was not to cost more than $5000.00; the price limited by court orders. The handbill noted that bids would be received "for [the] entire work, or separately, for masonry and bridge." The bidding ended by May as a contract was signed by Jacob Muddaman for the abutments on May 18, 1883, and with the Wrought Iron Bridge Company of Canton, Ohio, on May 23, 1883, for the bridge superstructure.]

Transcribed Handbill

NOTICE TO BRIDGE CONTRACTORS!

Proposals will be received until the 16th day of April next, by the undersigned commissioners on the part of the undersigned commissioners on the part of the counties of Orange and Culpeper, in the state of Virginia, for the Masonry and Construction of a Wrought Iron Bridge, about 167 feet span, across the Rapidan River, at Raccoon Ford.

The masonry required consists of two abutments, first-class rubble work of 20 feet face, with wings 20 feet long and 8 feet thick, and to be founded on solid hard pan, or rock, below, and raised 15 feet above level of water when running over the entire length of the mill dam, to be laid of Syenite or solid hard stone in cement to water level, and with lime mortar above, and the bridge to be of ENTIRE WROUGHT IRON, floor excepted, which is to be of White Oak Plank, two and a-half inches thick, laid diagonally across, and with roadway twelve feet wide, the whole not to cost over FIVE THOUSAND DOLLARS, as limited by orders of the court.

Transcribed Jacob Muddaman Contract

Muddaman Contract

These articles of Agreement and Covenant, made and entered into this eighteenth day of May 1883, between the Counties of Orange and Culpeper in the State of Virginia of the first part and Jacob Muddaman of the County of Culpeper, in the state aforesaid, of the second part, Witness, that the said Jacob Muddaman on his part, for and in consideration on the sums of money herein below stipulated to be paid to him by the said Counties of Orange and Culpeper, doth hereby covenant, agree, and bind himself, to build and construct for the use of the said counties, at Raccoon Ford on the Rapidan River, at the points selected by the commissioners of the two counties; said stone abutments to be founded on solid hard pan on rock, below, - to be each 20 feet front, 8 feet thick, and raised 15 feet above the level of the Rapidan river when running over the entire length of the mill dam; all that part of the Walls below water level to be cemented with hydraulic cement, and above water level to be cemented with hydraulic cement, and above water level with strong lime mortar: the abutments to be located directly and squarely opposite each other, the front walls no to be better over one inch to lineal foot, and when done to measure exactly 163 feet in the clear, so as to receive a wrought iron bridge of 167 feet span 163 feet in the clear, and further to furnish all material, and do all necessary work of excavating for solid foundation, and making cofferdams to reach the proper depth for solid foundation for abutments, and to fill in said wings behind the stone work of the said abutments, so that they bridge may be passable for wagons lightly loaded, and to secure the abutments from action of highwater; the whole work to be completed according to the plans and specifications heretofore exhibited by the commissioners of the two counties, and contained in the advertisement of March 21st 1883, for proposals and repeated herein, to be inspected as work progresses by the special commissions appointed by the Court of said counties for the purpose, and not to be fully paid for until received by them by them. And the said Jacob Muddaman further covenant to and with the counties aforesaid, to have all said work done and ready for the iron bridge by or before the first day of September 1883, unless prevented by floods.

And the said counties of Orange and Culpeper hereby covenant and agree and bind themselves to pay to the said Jacob Muddaman, for the solid stone masonry to be done by him in the said two abutments, four dollars per cubic yard

Transcribed Bids for the Raccoon Ford bridge

The undersigned, Commissioners appointed on the part of the Counties of Culpeper and Orange, to receive proposals for building the abutments. And a wrought iron bridge across the Rapidan River at Raccoon Ford, respectfully report that in pursuance of the order entered into the Culpeper County Court at its February term 1883, they advertised in the “Culpeper Times” and “The Exponent,” and by handbills one of which is filed herewith, for proposals to be received at the Clerk’s Office in Culpeper on or before the 16th day of April 1883, and on said day, they proceeded to open and canvass the various proposals for the bridge and for the masonry, made the following companies towit:

King Bridge Co. (Cleveland, Ohio) bid $27.82 per foot = $4729.40 and for masonry abutments $7.23 per cubic yard.

Smith Iron Bridge Co (Toledo Ohio) bid $27.50 per foot = $4592.50 & for masonry $7.75 per cubic yard

Columbia Bridge Co. (Dayton Ohio) bid $28.65 per foot = $4784.55 & (14 ft roadway) No. 2 @ $29.40 per foot $4909.80

Nelson & Buchanan Bridge Co. (Chambersburg, Pa.) @ $27.89 per foot = $4654.29 14 ft roadway

Massillon Bridge Co. (Massillon Ohio) @ $28.50 per foot = $4757.50 masonry @ $7.50 per cubic yard

Accepted Canton Ohio Bridge Co. bid @ $26.94 per foot @ $4498.98 Masonry @ $7.50 per cubic yard.

Accepted by Jacob Muddaman for masonry $4.00 per cubic yard Excavating for foundation 12 ft deck and dam &c $250.00 & filling to reach bridge $50.00

Your commissioners further report, that the lowest bids for the entire work, as shown above, are the bids made by the Canton Ohio Bridge Co. @ $26.94 per foot = $4498.99 for the iron bridge and the bid of Jacob Muddaman of Culpeper for the work of building the abutments, and approaches to the bridge, and your commissioners would respectfully recommend to the Court of both Culpeper and Orange, the adoption of the said bids of Jacob Muddaman for masonry, and of the Canton Ohio Bridge Co. for the iron superstructure, and that commissioners on part of each of said Counties be appointed to contract with the said parties upon the specifications contained in the advertisement and the proposals tendered for said work, and on the basis that each county shall contribute one half the expense of the said bridge, the contracts as soon as executed to be filed in the Clerk's office with the papers of this case. Respectfully submitted.

J. J. Halsey H. T. Holladay   Commissioners for Orange County.

M. S. Stringfellow Jno. J. Holladay G. W. W. Nalle Commissioners for Culpeper County

[end of Raccoon Ford bridge documents]

Specifications/Contracts (Including Mortar/Masonry) for:

Germanna bridge, built 1844 (no longer extant), wooden truss bridge, crossing the Rapidan River between Orange and Culpeper counties)

[NOTE: The following is from Hill Family Papers, Virginia Historical Society, Richmond, Va. The Ambrose Powell Hill noted in these documents was the uncle of the Civil War general of the same name; see Patricia J. Hurst, Bridges Over the Rapidan River in Virginia *(pvt. prt., Charlottesville, Va., 2017).]*

Culpeper County Court February 19th 1844

The Commissioners appointed at the last court made their report concerning the erection of a bridge at Germanna, and the court approving said report and being of opinion that a bridge should be built at Germanna accordingly, doth appoint Ambrose P. Hill and Coleman C. Beckham of the county and Sandford Chancellor of Spottsylvania commissioners to let the building of the said bridge on such terms and on such payments as may be agreed on between them or a majority of them and the undertaker, the court undertaking to levy towards the building thereof $2000: one thousand at the next levy and one thousand dollars at the levy to be made in the next year – And the court leave it discretionary with the commissioners to select either of the sites mentioned in the said report – the undertaker agreeing on his part to take the sums subscribed or to be subscribed by individuals for the payment of any further sum than that of $2000: above mentioned which the said bridge may cost, the building to be let to the lowest responsible bidder who will give bond & two good securities for the execution of the contract – the time & place of letting to be advertised at the discretion of the said commissioners: the abutments of said bridge to be secured in a proper legal manner either by deed from the proprietors of the land, or by order of Court of the county in which said abutments may be. And the Court do hereby authorize said commissioners to appoint some person or persons to collect the money subscribed by individuals as aforesaid, to be paid over when collected to Ambrose P. Hill (who is hereby appointed to superintend the building of said bridge) for the undertaker, and the said person or persons are to be allowed ten per cent for their trouble in collecting the same: the said bridge to be examined & received by the said commissioners before the last payment: the commissioners and superintendent aforesaid will be allowed $3.00 a day for the time they serve under said appointments, and when the bridge is finished & received as aforesaid the said commissioners are directed to make report thereof to the court.

A Copy teste

F. Mauzy c.c.

The following are the proposials agreed upon by the undersigned commissioners for letting the building of a bridge a cross the river at Germanna under an order of the County Court of Culpeper bearing date on the 19th day of Fby 1844. and here unto annexed

The bridge to be sixteen feet wide, and a bout three hundred and thirty feet floored, with good sound heart pine plank two Inches thick and from eight to twelve inches wide. A hand rail dressed[?], about 3 ½ feet high, with an upright every 8 feet, and a plank a bout 8 Inches wide, one Inch thick, to be well nailed on the uprights, about half way between the floor and hand rail; the upright, to be mortised through a projected plank of the floor, which projection is to be 3 feet on each side, with a brace in the same plank, the uprights and braces to be keyed underneath, The plank to be three Inches thick and dubed[?] on the lower side to make it even on top, and to be spicked down to the sleepers with not less than five suitable spikes, The balance of the floor to be laid loose, with two pins one at each end of the plank inside of the sleeper. The plank to be sawed off by line, after they are laid down. The scantling for the uprights, hand rails, and braces to be 4 by 5 Inches. The bridge is to be built up[on?] seven pens and two abutments. The four middle pens to be two feet high[er?] than a level with the window sill in the north eas[t?] corner of the millhouse, and pointed out by the commissioners on the day of letting; with a gradual slope from the four middle pens to each abutment of two feet. The timbers for building the pens to be of good sound heart pine, 8 Inches square or 8 by 10 or 12 Inches, as may suit the undertaker, to be ten feet wide, 16 feet long with a 5 feet point up the river, to be dovetailed, every log to be pined at each corner as it is put up, and two ties to each round of logs, to be placed as the superintendant may direct, the cr[illegible]ties to be white oak squared at each end 4 by 6 and barked, to be dovetailed in, and spiked down. The spaces between the logs, in the pens to be from two to 3 Inches, the three upp[er?] corners of the pens to be faced with two Inch whi[te?] oak plank, to be well spiked on, as the superintendant may direct, the foundation for the pens and abutments to be commenced from a sollid foundation of rock, and to be leveled before the pens or stone work is commenced. The pens to be carred *[i.e., carried]* up strait and so filled in with rock as for the larger and feak[?] stone to be on the out edge. The abutment on the Orange side, to be rock without wood, sixteen feet long, six feet thick at the base, and three at the top, of solid masonry, battered on the river side; with two wing walls runing to the road as laid off by stakes, the wing walls to be of the same thickness as the abutment and tyed in with it. The abutment on the Culpeper side to be built in like manner and as laid off by stake. Each abutment to be filled up between the walls as the superintendant may direct. The sleepers for the bridge to be 40 feet long (except one span which will be thirty feet long), six inches thick 15 Inches deep in the center and thirteen Inches at each end, eight sleepers to the span, a sill laid on the center of each pen and on each abutment, 16 feet long, 13 Inches square of good sound heart pine. The sleepers to be let into the sill by mortise, or otherwise as the superintendant may direct, all the mortises and tenants about the bridge to be well pitched as they are put together; all the pins used about the bridge to be of good seasoned locust. A piece of timber 4 by 6 In. 14 feet long to be laid on the wall of the pens and abutments about three feet below the top with 3 Iron boalts 1 ¼ Inches thick to come up through the sill and made fast with a screw and tap on the top. After the sills and sleepers are laid down, the rock to be worked up to the top of the sleepers. The timbers, plank, stone, and workmanship, to be under the entire inspection of the superintendant, who retains and clai[ms?] the power of rejecting any of the work, timber or stone, that he may think not agreeable to contract. When the bridge is finished [illegible] it is to be received or rejected by the same commissioners tha[t?] let out the building or others appointed by the county court of Culpeper to fill up any vacancy or vacancies that may occur. Should the brid[ge?] be received, the county court of Culpeper will pay out of its next levy $1000 and such further sums will be paid as may be raised from the subscriptions, and out of the next county levy thereafter the court will pay $1000 more, and such further sum or sums as may be raised by private subscription will also be paid. The commissioners will in no event bind themselves individually for the payment of any portion of the money. They have no hesitation in beleiving that the due[?] sums necessary will be raised and paid by the time the court makes its last payment. The bridge is to be finished by the first day of November next. The court may for any cause appoint other commissioners or superintendant as necessity may require all the work to be executed in a workmanlike manner. The undertaker will be required to give bond with two good securities in a penalty of double the price of building the bridge for the faith *[i.e., faithful]* performance of his contract. Given under our hands this 8th day of March 1844.

A. P. Hill

C. C. Beckham

Sanford Chancellor

[end of 1844 Germanna bridge documents]

Mortar/Masonry Specifications/Contracts for:

Germanna bridge, built 1881-1882 (no longer extant), combination wood and wrought iron truss bridge, crossing the Rapidan River between Orange and Culpeper counties)

[Note: The following is the masonry contract with contractor John R. Tillett, for construction of two masonry piers and an abutment; see Patricia J. Hurst, Bridges Over the Rapidan River in Virginia *(pvt. prt., Charlottesville, Va., 2017).]*

This contract made and entered into between the undersigned comrs. appointed by the county court of Culpeper County and the undersigned commrs. appointed by the county court of Orange of the first part and John R. Tillett of the second part—Witnesseth that the parties of the first part as comrs. as aforesaid have contracted and do by these presents contract with the said Tillett, to put up the Mason work of a Bridge to be built at the Germanna ford on the Rapidan River—and the said Tillett hereby agrees and binds himself to put up an abutment on the south side of the said River, and repair that on the North side of the said River and to build two piers according to the dimensions and specifications and diagrams on file in the clerk's office of Orange County court. The work to be of second class ruble masonry to be laid in lime-mortar and pointed with cement-mortar and the stone used in the said work to be of the same quality and character as that in the north abutment and all of the said work to be done in a substantial and workmanlike manner—and sufficient in all respects to support the superstructure contracted to be built thereon. And the said parties of the first part agree that the said Tillett shall have, free of charge, all the stone which was used in the old Bridge and that lying nearby belonging to the bridge and any other stone necessary in the completion of the said work, the said comrs.—parties of the first part, guaranty shall be furnished at cost to the said Tillett, not exceeding 10 cents per cubic yard, to be quarried and hauled at the expense of the said Tillett and the parties of the first part agree to furnish all the sand necessary to be hauled at the expense of the said Tillett—and they further agree that in the condemnation of stone, it shall be selected by the said Tillett And the said parties of the first part on behalf of their respective counties agree that Culpeper County shall, upon the completion and acceptance of the work, issue warrants to said John R. Tillett, for the sum of Fifteen Hundred and Ninety & 41/100 dollars and half payment on the 1st day of December 1882 and the other half payable on the first day of July, 1883 And the said Tillett binds himself to complete the said work by the first day of January 1882, provided he shall not be hindered or delayed by providential interposition.

Witness the following signatures this 18th day of July 1881

John R. Tillett
William D. Field Commissioners on the part of Culpeper
A.G. Willis
J. B. Borst
John A. Gordon Commissioners on the part of Orange
Jno C. Willis
C. Sisson

[end of 1881-1882 Germanna bridge documents]

Specifications/Contracts (Including Mortar/Masonry) for:

Hazel River bridge, built ca. 1840s (no longer extant), on Thornton's Gap Turnpike, crossing the Hazel River, probably in Culpeper County), plus related specifications for the turnpike

[NOTE: The following excerpts are from Hill Family Papers, Virginia Historical Society, Richmond, Va.]

Excerpts from Specifications for the Hazel River bridge on Thornton's Gap Turnpike

1st Abutments.

The foundations to be first obtained by sinking sufficient depth to be beyond the influence of the current, not less than 4 feet below the present natural surface unless solid rock is obtained, and then to be sunk in the rock say 6 inches.

Upon a sandy foundation strong cross-timbers must be first laid, and upon the foundation, when obtained, commence a a[?] wall 19 ½ feet long, and 9 feet wide and raise with heavy & large stone, well laid, to the height of low water, and upon the same level upon each side.

The foundation of the abutments being thus prepared the walls must be started 18 ½ feet long and 8 ½ feet wide, leaving thereby a recess of 6 inches o the front sides and at the ends. The front and sides of the abutment to be battaed, to each foot in height a half inch. At the height of 5 feet the abutment to be dropped 15 inches and recede from thence at an angle of about 25 ^{o} as represented in the drawing, for footing for the Braces. From the top of this skew-back the front to resume its usual battae, or slope. The walls opposite, and forming the recess, must be made of large stones, and closely connected so as to combine great strength.

The abutments to be [blank] feet high above the foundation walls and the exterior courses to be laid in Lime mortar 1/3 lime V 2/3 sand, the backing connected with the surrounding walls and well grouted with lime mortar made into a consistency to run into the interstices.

The abutments may be rubble, not range, work, neatly hammer dressed. The largest courses laid out next the foundation, and recede consecutively towards the top. The wings, to be 12 feet long at top. At the foundation and connection with the abutments, they are to be made 4 ½ feet wide or thick and recede to 3 feet at the extreme ends and have the same battae or slope as the abutments, on the front, and such slope on the inside as will reduce them to 3 feet in thickness next the abutments, and 2 ½ feet at the extreme ends when completed. Length and bottom 15 feet.

The Wings made of a circular form, upon which parapet walls are to be built 30 inches above the Bridge floor, and sloped with the grade of the road, and finished with good coping.

Excerpts From Road Specifications for the Thornton's Gap Turnpike

General Specifications for the construction of the T. G. Turnpike

Excerpts from: Part 1. Grading, sections 5, 8 and 9

5. Besides the side-ditches, there must be culverts in every depression, whether named in the note-book or not, where there is a cross-slope, or an insufficient descent in the side-ditches or either of them, unless the water-ways are especially directed. The length of these culverts, must always be equal to the width of the embankments & roadway and enstained[?] by wing walls where necessary.

Small culverts may be formed by two parallel walls flagged on top and bottom by flat stones, those on the top of 10 or 12 inches in thickness, projecting on the walls at each end at least 8 inches. Culverts of more than 18 inches square, if of stone, much be arched and covered with earth, at least 2 feet; the bottoms of heavy embedded stones.

Planked culverts, are to be made similar to the small stone culverts at bottom, and covered as small Bridges, except that railing is dispensed with.

8. Sustaining walls, where necessary, must have a base of two-fifths of their height, and a battae or slope in the outside of one in six; of dry masonry substantially founded and built.

9. Bridges of 30 feet span and under, will be part of the road section in which they are located. When over 12 feet span they must be 18 ft. wide in the clear, and all under 12 ft. span must be 22 feet wide in the clear, unless requiring wings, and then 20 feet wide. The abutments of these bridges to be of good rubble masonry, laid in full mortar, (if directed) with stone of good quality, with headers and stretchers to preserve a bond, the foundation with large stones, the courses diminishing towards the top. The thickness of the blocks used in the face not less than 6 inches, twice that in width, and three times in length. Mean thickness of abutments and wing-walls one third their height, and never less than 2 ft., battae 1 in 12.

[end of Hazel River bridge and Thornton's Gap Turnpike documents]

Mortar/Masonry Specifications for:

Bridge at Jackson, Botetourt County (later called the Springwood bridge), built 1883-1884 by the Richmond and Alleghany Railroad Company, crossing the James River (this bridge is no longer extant)

[NOTE: The bridge became part of the state secondary system in 1932; by the 1970s, it was the only remaining example of a wooden and wrought iron truss in use across the James River. The superstructure was timber with the exception of the bottom chord, hip verticals, and diagonals, which were of wrought iron. The bridge was destroyed by flooding in 1985.

The following excerpt is from the May 21, 1883, contract for the bridge between the Board of Supervisors of Botetourt County, Virginia, and the Richmond and Alleghany Railroad Company, Botetourt County; *mortar/masonry specifications only. (The contract covered two bridges: the bridge at Jackson and a second bridge at Eagle Rock in Botetourt County.) A copy of the contract is attached to the Springwood bridge National Register nomination, 1977; copy in the VTRC history file for the Springwood bridge/Botetourt County Structure No. 60774.]*

At Jackson, Just below the Shafer [i.e., an adjoining landowner] property, at a point where a good foundation can be gotten for abutments, say about 250 feet below the Shafer property . . . Piers and Abutments to be substantial, of Stone Masonry, (in Hydraulic Cement Mortar) to be high enough to put the Bridge above the high water mark of 1877.

[end of Springwood bridge document]

References

Hill Family Papers, 1787-1945. Mss1 H5565 a FA2, Series 2. Virginia Historical Society, Richmond, VA.

Hurst, P. J. *Bridges Over the Rapidan River in Virginia.* Charlottesville, VA, Pvt. Prt., 2017.

APPENDIX D

SPECIFICATIONS FOR STONE MASONRY REPAIR AND REHABILITATION, CULPEPER COUNTY STRUCTURE NO. 6906 (WATERLOO BRIDGE)

ORDER NO.: XXX
CONTRACT ID NO.: XXX

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR
REPOINT MORTAR JOINTS

Date: October 8, 2018
Project: EN18-030-R32, B660

I. DESCRIPTION

This work shall consist of raking and repointing exposed mortar stone masonry joints above existing ground and water level elevations along Pier 8, Pier 9 and Abutment B. Repairs shall be performed by qualified masons and when the water level is near normal water elevation or during the dry season. Underwater repairs will not be permitted unless approved in advance by the Engineer.

Masonry firms and masons shall conform to the qualification standards of or be listed as approved masons by the Department of Historic Resources prior to being allowed to perform masonry repointing mortar joints and other scheduled masonry work in accordance with the special provisions, specifications and plans.

Masonry contractors, firms, and masons not shown on the approved list may seek qualification information and approval by making application to the Virginia Department of Historic Resources 30 days prior to commencing work. Requests should be made on business letterhead, should include the Contractor's address, a list of relevant projects and related work history of projects previously completed, the name of a point of contact and should reference VDOT Project EN18-030-R32, B660. The contractor shall submit a copy of this application to the Engineer at the time of application.

II. MATERIALS

The new mortar shall match the historic mortar in color, texture, and tooling. Match the existing historic sand in gradation and color. A wet chemical mortar analysis, utilizing the acid digestion method shall be performed by a qualified laboratory experienced in the analysis of historic mortars to obtain information regarding the sand texture, gradation, and color.

Obtain mortar ingredients of uniform quality from one manufacturer for each cementitious component and from one source and producer for each aggregate.

Masonry cement mortar or preblended mortar mix is prohibited from use on this project.

A. Cementitious Materials

1. Portland cement shall conform to ASTM C150, Type 1.

2. Hydrated lime shall conform to ASTM C207, Type S or Type SA

B. Fine Aggregate

Sand shall be natural or rounded, free of impurities and shall conform to ASTM C144 and applicable portions of Section 202 of the Specifications and shall contain no more than 100 parts per million of chloride ions.

C. Admixtures shall conform to Section 215 of the Specifications except:

1. No calcium chloride or admixtures containing calcium chloride shall be used.

2. No air-entraining admixtures or material containing air-entraining admixtures shall be used.

3. No antifreeze compounds shall be used.

4. No admixtures shall be used without written approval from the Engineer.

5. Generally, coloring agents will not be permitted. When approved by the Engineer, coloring agents shall be inorganic only and compatible with other masonry materials.

D. Water

Water shall conform to Section 216 of the Specifications and shall be clean, potable, and free from acids, alkalis or other dissolved organic materials.

III. PROCEDURES

A. General

Repointing shall be conducted at such times that abutment and pier temperatures range between 40 to 95 degrees F, in the shade, away from strong sunlight in order to slow the drying process, except as provided for herein.

B. Joint Preparation

All loose, unsound and deteriorated stone or mortar material shall be removed from the areas designated by the Engineer to be repaired in a manner and to an extent as to expose sound material. Unless otherwise noted, old mortar to a minimum depth of 2 to 2-1/2 times the width of the existing joint and any loose and disintegrated mortar beyond this minimum depth shall be removed. Generally, joints shall be chipped to a minimum depth of 1-inch and to a maximum depth of 8-inches or less if sound, well-bonded mortar is encountered. Mortar shall be removed cleanly from the joints, leaving a square corner at the back of the cut utilizing hand tools, and power tools as permitted herein.

The use of power saws or grinders shall not be permitted for removal of mortar on head or vertical joints.

Small pneumatic-powered chisels may be used by experienced masons in combination with hand chisels and mash hammers for joint preparation. Where horizontal joints are uniform and fairly wide, the use of a thin diamond-bladed grinder or power masonry saw may be used to assist the removal of mortar with the approval of the Engineer. Should grinders or power masonry saws be permitted their use shall be restricted to cutting along the middle of the joint to enhance the removal of mortar; final mortar removal from the sides of the joints shall be done with a chisel and hammer. Prior to using power tools for joint removal, the Contractor shall satisfactorily demonstrate such methods, techniques and proficiency in use of power tools in the 4-foot-by-4-foot test panel prior to receiving the Engineer's approval.

The Contractor shall perform joint preparation and repointing as follows:

1. Inspect all existing joints. Remove all loose, spalled mortar from joints.

2. All deteriorated joints shall be cleaned to remove oil, grease, dirt, and chemical contamination without damage to, or disintegration of, the stone surface.

3. Pre-wet joints and apply cleaning solution. Allow 3 to 5 minutes dwell time, then scrub surfaces clean with a natural bristle brush.

4. Rinse thoroughly with low-pressure spray (no greater than 200 psi).

5. Wet mortar joints and stone surfaces thoroughly before applying fresh mortar. Allow water to soak in so there is no freestanding water.

6. Install mortar into joints in ¼ inch layers. The back of the entire joint shall be filled and thoroughly compacted by packing the mortar well in the back corners. Each layer shall be thumbprint hard before placing the succeeding layer. Completely fill mortar joints and properly tool exterior surface to match existing joint profiles avoiding hairline shrinkage cracks and tool burning.

7. The joints shall be restored to the full depth prepared conforming to applicable details shown on Plan Sheet 6 of 25.

8. Each work day, clean all excess mortar, as the work progresses. Cleaning shall be accomplished with a stiff natural bristle or nylon brush after the mortar has dried but before it is initially set (1-2 hours). A final cleaning shall be accomplished after joint repair has cured for a minimum of thirty calendar days. Only very low-pressure (100-psi) water washing supplemented by stiff natural or nylon brushes shall be used for final cleaning.

C. Mixing

1. Control batching procedures to insure proper proportions and consistent mortar color by measuring materials by volume. Use cubic foot containers and level the materials to achieve uniform volume. Do not measure materials with shovels.

2. Mix mortar in a paddle type mixer for 3 to 5 minutes adding ingredients as described in the Appendix of ASTM C270.

3. Do not use frozen materials or materials mixed with or coated with ice or frost. When ambient air temperature is less than, or is expected to be less than, 40 degrees Fahrenheit, perform all repair work in accordance with "Recommended Practices and Guide Specifications for Cold Weather Construction" published by the International Masonry Industry All-Weather Council, Washington D.C.

4. To thoroughly mix dry ingredients, add only enough water to produce a damp mix that will retain its shape when pressed in to a ball by hand. Mix from 3 to 5 minutes with a paddle type mixer.

5. Let mortar stand in dampened condition for 1 to 1½ hours to accomplish pre-hydration.

6. All mortar shall be placed within 2½ hours of initial mixing, including pre-hydration time. Re-tempering of the mortar shall not be permitted. The Contractor shall discard mortar not used within 2 ½ hours.

D. Test Panels

Prior to beginning repair of mortar joints, the Contractor shall prepare a test panel using the same techniques and equipment that will be used on the remainder of the project. The test panel shall be a 4-foot-by-4-foot area of the existing abutment as determined by the Engineer to establish an acceptable standard of work for acceptable joint preparation tools and equipment, repaired joint style (horizontal and head joints), mortar texture and color, and final cleaning methods. The test panel shall be preserved for the duration of the mortar joint repair operation to serve as a standard for evaluating and accepting subsequent mortar joint repair work and final completion.

IV. MEASUREMENT AND PAYMENT

Repoint Mortar Joints will be measured and paid for in linear feet of joints raked and repointed. Measurements will be taken along the exposed face of the joints where raking and repointing was completed. The price bid shall be full compensation for the 4-foot-by-4-foot test panel, existing mortar wet chemical analysis, surface preparation, raking, cleaning, repointing with mortar, tooling, resetting and replacing existing stone, removal and disposal of existing material, and all other labor, tools equipment, and incidentals necessary to complete the work and incidentals necessary to repair the masonry joints in the masonry stone bridge substructures in accordance with the contract documents or as directed by the Engineer to complete the work.

Payment will be made under:

Pay Item	**Pay Unit**
Repoint Mortar Joints (Type)	Linear foot