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# A Case Study of the Loop-Welded Eyebars Removed from the Advance Mills Bridge in Albemarle County, Virginia

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Final Report VCTIR 11-R13

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<p>Abstract:</p> <p>As a condition of the Virginia Department of Historic Resources concurring with the decision of the Virginia Department of Transportation to demolish and replace the Advance Mills Bridge in Albemarle County, Virginia, the 2008 “Memorandum of Agreement among the Federal Highway Administration, the Virginia State Historic Preservation Officer, and the Virginia Department of Transportation, Regarding the Route 743 Bridge Replacement in Advance Mills, Albemarle County, Virginia” required that the Virginia Transportation Research Council (now the Virginia Center for Transportation Innovation and Research) conduct a study of the loop-welded (actually forge welded) eyebars prevalent on two pin-connected trusses that were the major spans on the structure. Engineers conducting the required biennial bridge safety inspections of the Advance Mills Bridge for VDOT had reported cracking at the forge line, a flaw frequently found in loop-welded eyebars.</p> <p>The bridge was included as a contributing structure in the Advance Mills Historic District, which was listed on the National Register of Historic Places and Virginia Landmarks Register. For this reason, the study included a history of the various bridges that served Advance Mills over the years, a history of the community itself, as well as the examination of the loop-welded eyebars.</p> <p>The researchers anticipated that the examination of the loop-welded eyebars would be limited to an assessment of the adequacy of a “hands on” inspection in disclosing the extent and severity of the cracking at the forge line. Although the hands-on inspection, supplemented by dye penetrant testing, was found sufficient to define the cracking, unanticipated damage during the demolition of the bridge revealed that even hairline cracks or rust stains along the forge lines were indicative of a more serious flaw: a clean separation at the forge line, in no way similar to a conventional welded connection. This separation at the forge lines of the loops was in keeping with warnings in early design texts that the welding of steel was unreliable. Such distress could be critical in an evaluation of the adequacy of a truss if the bridge were to be left in service. This finding is significant because of the nearly 250 extant metal truss bridges in Virginia, 32 are designated as historic (i.e., eligible for or listed on the National Register) and of these, 15 use loop-welded eyebars as do numerous other extant metal truss bridges in Virginia.</p> <p>This report presents data on the composition and strength of the steel, the effect of the separation on the strength of the eyebar, and findings pertaining to the inspection process and the significance of any cracking that may be found. The study recommends that safety inspections of truss bridges built in the late 19th and early 20th centuries include a careful examination of any loop-welded eyebars and that a hands-on inspection of such eyebars, supplemented by dye penetrant testing, is sufficient to disclose the presence of cracking. Hairline cracks or rust stains along the forge lines should be regarded as evidence of inadequate welds, and appropriate actions should be taken to ensure the safety of the structure. Safety inspectors also should examine portions of the eyebars within the loops for evidence of cracking and those bars obscured by the deck for severe section loss attributable to corrosion. Finally, any pin-connected truss bridges being dismantled should be placed on secure supports after being lifted from their bearings, and during disassembly, the truss should be supported at each panel point to prevent collapse and ensure the safety of workers.</p>				

**FINAL REPORT**

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FROM THE ADVANCE MILLS BRIDGE IN ALBEMARLE COUNTY, VIRGINIA**

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Virginia Center for Transportation Innovation and Research  
(A partnership of the Virginia Department of Transportation  
and the University of Virginia since 1948)

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## ABSTRACT

As a condition of the Virginia Department of Historic Resources concurring with the decision of the Virginia Department of Transportation to demolish and replace the Advance Mills Bridge in Albemarle County, Virginia, the 2008 “Memorandum of Agreement among the Federal Highway Administration, the Virginia State Historic Preservation Officer, and the Virginia Department of Transportation, Regarding the Route 743 Bridge Replacement in Advance Mills, Albemarle County, Virginia” required that the Virginia Transportation Research Council (now the Virginia Center for Transportation Innovation and Research) conduct a study of the loop-welded (actually forge welded) eyebars prevalent on two pin-connected trusses that were the major spans on the structure. Engineers conducting the required biennial bridge safety inspections of the Advance Mills Bridge for VDOT had reported cracking at the forge line, a flaw frequently found in loop-welded eyebars.

The bridge was included as a contributing structure in the Advance Mills Historic District, which was listed on the National Register of Historic Places and Virginia Landmarks Register. For this reason, the study included a history of the various bridges that served Advance Mills over the years, a history of the community itself, as well as the examination of the loop-welded eyebars.

The researchers anticipated that the examination of the loop-welded eyebars would be limited to an assessment of the adequacy of a “hands on” inspection in disclosing the extent and severity of the cracking at the forge line. Although the hands-on inspection, supplemented by dye penetrant testing, was found sufficient to define the cracking, unanticipated damage during the demolition of the bridge revealed that even hairline cracks or rust stains along the forge lines were indicative of a more serious flaw: a clean separation at the forge line, in no way similar to a conventional welded connection. This separation at the forge lines of the loops was in keeping with warnings in early design texts that the welding of steel was unreliable. Such distress could be critical in an evaluation of the adequacy of a truss if the bridge were to be left in service. This finding is significant because of the nearly 250 extant metal truss bridges in Virginia, 32 are designated as historic (i.e., eligible for or listed on the National Register) and of these, 15 use loop-welded eyebars as do numerous other extant metal truss bridges in Virginia.

This report presents data on the composition and strength of the steel, the effect of the separation on the strength of the eyebar, and findings pertaining to the inspection process and the significance of any cracking that may be found. The study recommends that safety inspections of truss bridges built in the late 19th and early 20th centuries include a careful examination of any loop-welded eyebars and that a hands-on inspection of such eyebars, supplemented by dye penetrant testing, is sufficient to disclose the presence of cracking. Hairline cracks or rust stains along the forge lines should be regarded as evidence of inadequate welds, and appropriate actions should be taken to ensure the safety of the structure. Safety inspectors also should examine portions of the eyebars within the loops for evidence of cracking and those bars obscured by the deck for severe section loss attributable to corrosion. Finally, any pin-connected truss bridges being dismantled should be placed on secure supports after being lifted from their bearings, and during disassembly, the truss should be supported at each panel point to prevent collapse and ensure the safety of workers.

## **FINAL REPORT**

### **A CASE STUDY OF THE LOOP-WELDED EYEBARS REMOVED FROM THE ADVANCE MILLS BRIDGE IN ALBEMARLE COUNTY, VIRGINIA**

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## **INTRODUCTION**

The Advance Mills Bridge (Albemarle County Structure No. 6104), which carried Route 743 over the North Fork of the Rivanna River in Albemarle County, Virginia (Figure 1), was a three-span structure composed of a 19-ft steel beam span, a 120-ft pin-connected Pratt through truss, and a 65-ft Pratt pony truss.

The main span of the bridge was a steel through truss constructed in the Pratt configuration. This configuration, first patented in 1844, had diagonals in tension and verticals in compression (except for hip verticals adjacent to inclined end posts). The Pratt configuration is perhaps the most common configuration for truss bridges built in the United States during the later 19th and early 20th centuries. An overview of the Pratt truss configuration and loading was provided by McKeel et al. (2006).



**Figure 1. Advance Mills Bridge at Time of Final Inspection in 2007**

The original construction dates of the Pratt spans of the Advance Mills Bridge are unknown. However, the Pratt pony truss was erected at the Advance Mills site in the early 20th century along with an additional truss span that was washed out in a flood in October 1942. A Pratt through truss was moved from another site and re-erected at Advance Mills in 1943 to replace the washed-out span; from structural and technological evidence, this Pratt through truss was estimated to date from ca. 1890 through ca. 1910. The Advance Mills Bridge was included in the survey of early metal truss bridges by the Virginia Highway and Transportation Research Council (now the Virginia Center for Transportation Innovation and Research [VCTIR]) undertaken during the early 1970s (Deibler, 1975) and in the 1997 update (Miller and Clark, 1997). In neither survey was the bridge determined to be individually eligible for the National Register of Historic Places (National Register). However, it was included as a contributing structure in the Advance Mills Historic District, which was listed on the Virginia Landmarks Register in 2000 and on the National Register in 2002.

### **Decision to Close Bridge to Traffic**

Because of advanced deterioration caused by corrosion and the effects of overloading, the one-lane Advance Mills Bridge was open to traffic with a 3-ton weight limit and was limited to crossing by only one vehicle at a time. Several members in the truss spans had been strengthened by cables since 1994, and the bridge was on a 6-month cycle for safety inspections. However, the findings of the final regularly scheduled safety inspection in April 2007 indicated continued deterioration to such an extent that a decision was made by VDOT and approved by the Albemarle County Board of Supervisors to close the bridge to traffic later that year..

Since the old bridge was within a National Register Historic District, consultation with the Virginia Department of Historic Resources, the state historic preservation office, and other parties was required as part of the environmental review process pursuant to its demolition and replacement. The resulting “Memorandum of Agreement among the Federal Highway Administration, the Virginia State Historic Preservation Officer, and the Virginia Department of Transportation, Regarding the Route 743 Bridge Replacement in Advance Mills, Albemarle County, Virginia” (Memorandum of Agreement [MOA], 2008) required that the Virginia Transportation Research Council (VTRC) (now VCTIR) conduct a study of the loop-welded eyebars. Other consulting parties (i.e., the Albemarle County government, the Friends of the Advance Mills Historic District, the Advance Mills Homeowners Association, and several adjoining landowners) were also signatories to the MOA.

### **Die-Forged Eyebars Compared to Loop-Welded Eyebars**

Eyebars, bars with eyes at each end, encountered in older metal truss bridges were formed by one of the following methods: upsetting and forging, piling, and welding, or loop welding (also known as forge welding). Ketchum (1912), in *The Design of Highway Bridges*, described the first two methods, both of which use die-forging:

The eyes may be formed (a) by upsetting and forging, or (b) by piling and welding. By the first method the bar is upset and the head is forged in a die, after which the bar is reheated and

annealed and the pin hole is drilled. By the second method a “pile” of iron bars is placed on the end of the bar, and the pile is heated and the head is forged in a die. The bar is then reheated and annealed and the pin hole is drilled. Steel eyebars should always be made by upsetting and forging.

The loop-welded eyebars on the Advance Mills Bridge were fabricated from bar stock by heating the end of the bar, bending it around a pin, and forging the tip into a notch on the straight shank of the bar (see Figure 2). The process technically is “forge welding,” defined as “a group of processes in which the parts to be joined, usually iron, are heated to about 1000° C and then hammered or pressed together” (Lapedes, 1978). The more general term “loop-welded” was chosen to describe the eyebars on the basis of its prior usage in Virginia and elsewhere (Virginia Department of Highways, Office of the Bridge Engineer, 1956; Sparks, 2007). Commonly used in the 19th century, loop-welded bars generally were abandoned after the turn of the 20th century because of a tendency for a crack, such as that shown in Figure 3, to form along the forge weld (on the forge line), casting doubt on the adequacy of the bars.

In early metal truss bridges, loop-welded eyebars were frequently used for counters (adjustable diagonal members) but less often used for the main members. In the Advance Mills Bridge, as well as in a minority of extant structures, loop-welded eyebars were used for all tension members, including bottom chords, all diagonals and counters, and hip verticals. The end posts, top chords, and interior verticals are more substantial members required to carry compressive forces without buckling.

Failure of loop-welded bars at the forge line has been noted frequently during inspections of older truss bridges, and the use of loop-welded bars has long been prohibited by more modern specifications. Further, Ketchum (1912) recommended that only iron, not steel, be used for loop-welded eyebars: “Iron bars, both square and round, are often made with loop ends. Steel bars should never be used with loop ends for the reason that welded steel is not ordinarily considered



**Figure 2. Pin-Connected Panel Point With Loop-Welded Eyebars**





**Figure 3. Hairline Crack Along Forge Line of Loop-Welded Eyebars**

reliable.” Waddell (1889) provided an identical warning: “Loop-eyes shall be made of wrought iron, as steel cannot be relied upon to afford a proper weld.”

However, some later works suggested that steel loop-welded bars were occasionally encountered; for example, Urquhart and Rourke (1930), in their *Design of Steel Structures*, included loop-welded bars under a discussion of steel tension members, noting that they were “sometimes made suitable for use as tension members in unimportant structures.”

Much can be gained from a study of the loop-welded bars removed from the bridge. Of nearly 250 extant metal truss bridges in Virginia, 32 are identified as historic (i.e., eligible for or listed on the National Register) (Miller and Clark, 1997). Of this number, 15 bridges—nearly one half—use loop-welded eyebars. Of these 15 bridges, 6 were constructed with a combination of die-forged and loop-welded bars (primarily, using die-forged bars on the lower chords, and loop-welded eyebars elsewhere); and 9 used loop-welded eyebars as the sole eyobar technology. In addition to the high percentage of historic trusses, numerous other extant metal truss bridges in Virginia use loop-welded eyobar technology.

Bridge engineers and historic resource personnel involved in the preservation of historic metal truss bridges would benefit from knowing the extent of the cracking found in the loop-welded bars on the Advance Mills Bridge, the accuracy of the field inspection in assessing the extent of the deterioration, the nature of the loop-welded connection found on the Advance Mills Bridge eyebars, and an estimate of the ultimate strength and composition of the steel in the members.

## PURPOSE AND SCOPE

The purpose of this study was to examine the loop-welded eyebars used as tension members throughout the Advance Mills Bridge to fulfill the requirements of the MOA (2008) attendant to the demolition of that structure and to provide information on the nature of the distress noted during safety inspections to those repairing or restoring old pin-connected truss bridges. Loop-welded bars are not permitted by current AASHTO bridge specifications. They are, however, encountered by historic resource personnel and bridge engineers involved in the disposition of older truss bridges. Although the study focused on cracks at the forge lines of loop-welded bars in the Advance Mills Bridge, the history of the bridge was documented and other information on the properties of the steel was investigated.

The study had several objectives:

- Develop a brief history of the Advance Mills Bridge.
- Evaluate the adequacy of required bridge safety inspection techniques in defining the condition of loop-welded eyebars with regard to cracking.
- Determine the nature and extent of the cracking found in eyebars on the Advance Mills Bridge and evaluate the effect, if any, of failure at the loop forging on the strength of the members.
- Determine the ultimate strength, yield strength, and composition of the steel in the eyebars for comparison with materials specifications and use in structural analyses.
- Compare the data obtained with the design assumptions for the working stress and stress reductions for loop-welded eye bars in the *Notes on Determining the Strength of Old Bridges* by the Virginia Department of Highways (VDH) Office of the Bridge Engineer (1956) to confirm their applicability to the analysis of steel structures built in the late 19th and early 20th centuries.

All data were obtained from the 120-ft Pratt through truss from the Advance Mills Bridge. Thus, the scope of the study was limited to a case study of a single truss by one fabricator: Cambria Steel. Only a limited number of members were salvaged, and since the structure was to be demolished, the testing was less extensive than that recommended for a complete evaluation of a structure being considered for continued use.

## METHODOLOGY

As a first step in the study, a field examination to determine the general condition of the truss members on the Advance Mills Bridge was conducted, and files describing earlier historical surveys of truss bridges and evaluations of their historic significance (Deibler, 1975; Miller and Clark, 1997) were reviewed. The physical condition of the structure described in the final bridge

safety inspection report (TRC Solutions 2007) before closure of the bridge was reviewed in detail in determining the course of the study.

To achieve the objectives of the study, three tasks were performed:

1. *Develop a brief history of the Advance Mills Bridge.*
2. *Conduct tests of selected truss members to determine the nature and extent of the cracking found in eyebars and evaluate the effect, if any, of failure at the loop-forging on the strength of the members.* Members, including both those noted as cracked and those noted as whole during the 2007 safety inspection, were selected, and their removal was coordinated with the demolition contractor at the beginning of dismantling operations. Panel joints containing the selected bars were cut from the truss intact and disassembled by the bridge crew of VDOT's Charlottesville Residency. Loop ends, and a portion of the bar shanks from those eyebars meeting at each of the selected panel joints, and the connecting pins were salvaged. The eyebars were cleaned as necessary, and the extent of cracking, if any, was compared with that noted in the inspection reports.
3. *Evaluate the adequacy of the inspection techniques used in the safety inspections of the Advance Mills Bridge.* The cross section of a bar in the cracked area and radiographic inspections were used to provide information on the adequacy of "hands on" safety inspections as a basis for decisions regarding the disposition of the bars. The radiographic evaluations of the loop areas and analyses of the composition of the steel in selected loop eyebars were performed by metals specialists in the VDOT Materials Division Laboratory and by a consulting laboratory. Measurement of the ultimate and yield strengths of the steel was also performed by VDOT's Materials Division to the extent possible.

## **RESULTS**

### **Brief History of Advance Mills Bridge**

Advance Mills is a small hamlet at the intersection of Routes 743 and 641 on the north fork of the Rivanna River in northern Albemarle County, Virginia. The precise date of the first bridge across the Rivanna River at Advance Mills has not been determined. Maps from the era of the Civil War show a crossing slightly upstream of the present highway crossing, but it is uncertain if this crossing included a bridge. By the beginning of the 20th century, a wooden bridge had been constructed near the present highway crossing. A contemporary account described this bridge as having "no sides" and a plank deck, suggesting that the structure was a beam bridge without a railing ("Autobiography of Frederick William Neve," 1967). A structure that is likely the same bridge is visible in a ca. 1906 photograph (see Figure 4) of the Advance Mills vicinity that appeared in a compilation published by the Charlottesville newspaper, *The Daily Progress Historical and Industrial Magazine: Charlottesville, Virginia "The Athens of the South"* (Walker, 1906).



**Figure 4. Advance Mills Village in Early 20th Century. The early bridge that crossed the river on a different alignment than the present bridge is visible between the white buildings in the center of the photograph (from *The Daily Progress Historical and Industrial Magazine: Charlottesville, Virginia “The Athens of the South,”* Progress Publishing Company, Charlottesville, Virginia, June 1906).**

Subsequently, a one-lane metal truss bridge consisting of a short approach span (less than 20 ft long; probably a steel beam span), a main span (120 ft long), and a smaller pony truss span (65 ft long) was erected at the site of the present highway crossing.

Although the exact construction date of this one-lane metal truss bridge could not be determined with available documentation, the technology and construction features of the surviving pre-1943 pony truss (including pin-connected elements, loop-welded eyebars, and A-shaped posts) suggest a construction date between the first decade of the 1900s and ca. 1920 for the pony truss. The A-shaped post configuration suggests a Virginia Bridge & Iron Works design; this company, based in Roanoke, Virginia, constructed similar pony trusses during the early 20th century. Nearly identical pony trusses in Albemarle County attributed to this company include Albemarle County Structure No. 6009 carrying Route 603 over the Lynch River (erected at that location in 1917; possibly an older bridge moved from another location) and Albemarle County Structure No. 6244 carrying Route 795 over the Hardware River (built in 1907) (Deibler, 1975; Miller and Clark, 1997; VCTIR, unpublished data).

The main through truss span of the early 20th century Advance Mills metal truss bridge was washed out during the widespread flooding that struck Central Virginia, Northern Virginia, and the Shenandoah Valley in October 1942. The pony truss, shown in Figure 5, remained.

A replacement for the washed out main span, a Pratt truss of similar dimensions, was brought in from VDOT's Staunton District. The bridge reportedly came from Alleghany County and was erected by convict labor in place of the destroyed span in 1943 (E. Bailey, personal communication, 2009). From its construction technology, this span is estimated to date from ca. 1890 through ca. 1910. At the same time, a replacement 19-ft steel beam approach span was



**Figure 5. Advance Mills Bridge After Flood of October 1942**

constructed at the east end of the 120-ft replacement span. (This approach span was replaced using galvanized beams in 2005.)

As shown in Figure 4, in the late 19th and early 20th centuries, Advance Mills was a small rural commercial community, consisting of several houses with their outbuildings, a mill, a general store, and a bridge. The general store burned in 1946, and a modern store building was built near the old site; the mill burned in 1948 and was not rebuilt. By the last decades of the 20th century, the Advance Mills region, as much of northern Albemarle County, was undergoing increased housing development, with rural residences and subdivisions appearing on what had previously been farmland and woodland. The attendant increases in population, traffic, and vehicle weight put increasing strain on the old bridge. By the last decade of the 20th century, the Advance Mills Bridge was exhibiting serious deterioration, despite considerable expenditures and repeated repairs. The bridge was closed three to five times over a 20-year span for repairs, including replacement of several broken eyebars (D. Pearce, personal communication, 2010).

### **Background of Bridge Replacement and Study**

By the middle of the first decade of the 21st century, the deterioration of the elements of the old truss had progressed to the point that further repair and continued use of the old bridge was determined not to be feasible. In particular, flaws in the loop-welded eyebars generated ongoing concern. In addition, the deterioration of the stringers and floor beams had reached the point where complete replacement of these members would be required for continued vehicular use of the bridge. However, such replacement still would not address the flaws in the eyebars (D. Pearce, personal communication, 2010). Accordingly, the bridge was permanently closed to vehicular traffic in 2007 and a replacement bridge was planned.

As noted, flaws in the loop-welded eyebars generated considerable concern regarding the safety of the bridge and were important factors in the decision to replace the structure. The bridge inspections and repairs during the late 20th and the early 21st centuries had identified several cracked or broken eyebars, which had been replaced or repaired. The bridge inspections also identified a number of examples (visible under the paint covering the bridge elements) of what appeared to be rust formation and cracking along the forge lines of the eyebars. The impending demolition of the old Advance Mills Bridge therefore presented an opportunity to (1) remove the eyebars from the bridge; (2) remove the paint from the eyebars and compare the apparent deterioration and cracking (noted during bridge inspections but obscured by multiple layers of paint) with evidence visible on the bare metal; and (3) perform more detailed testing and analysis of the bars in a laboratory setting.

### **Final Safety Inspection**

Because of its frail condition, the Advance Mills Bridge was scheduled for safety inspections on a 6-month cycle. The final inspection before closure of the bridge took place in April 2007 (TRC Solutions, 2007). This inspection was a hands-on inspection, meaning that the inspector could actually touch that portion of the structure that was being inspected. Cracks were confirmed by the dye penetrant test (DPT), in which a dye is applied at the location where a crack is suspected and wiped off. Dye remaining in a crack confirms its existence and length. The test can be used to evaluate nested bars at the panel points of truss bridges, locations that do not lend themselves to radiographic inspection procedures. The grainy nature of the steel did not allow the use of resonance testing.

Although there was some pressure from local residents to keep the bridge in service, the inspection left no doubt that the bridge was beyond any chance of rehabilitation. Many of the truss members were distorted, some of them sagging or slack, probably attributable to years of carrying overloaded vehicles. Cracks were found or suspected in 12 bars during the inspection of the 120-ft through truss. Cracking ranged from members with visible or hairline cracks, generally at the forge lines, to those with possible cracks indicated by rust stains or inconclusive DPTs. Eight weakened or damaged tension members in the through truss, including verticals, a counter, and several bottom chords, had been retrofitted with cables and/or welded attachments to ensure the strength of the structure. Retrofitting or replacing eight additional members was emphasized as high-priority repairs because of cracking, deformation, wear, or significant section loss. Replacement of all lateral bracing members was recommended. Severe corrosion in the truss members and the stringers and floor beams was cited by the inspectors as a contributing factor in the critical condition of the bridge, as were the hairline cracks in fracture-critical truss members and other damage.

Given the severity of the distress and the extensive repairs recommended by the safety inspectors, closing of the bridge and its replacement comprised the only feasible course of action. VDOT bridge engineers decided to use a modern welded truss system for the replacement structure.

## **Nature and Extent of Cracking in Eyebars**

### **Selection of Truss Members for Testing**

Prior to the demolition of the old Advance Mills Bridge, the bars that showed possible cracking during bridge inspections were identified, marked, and cut approximately 1 ft from the pin connections. The eyebar heads were initially left attached around the pins. These elements were removed from the demolition site and taken to VDOT's Charlottesville Residency, where the pins were loosened and the eyebars were removed from the pins (but kept in the same order as on the bridge). The elements, including the pins, were then transferred to the VTRC (now VCTIR) laboratory. There, the paint was removed from selected eyebar heads and forge lines, and one bar was cut into sections.

Appendix A provides the diagram from the bridge safety inspector's report showing the designation of the truss members (TRC Solutions, 2007). As is common practice, the lower panel points, noted by L, are numbered beginning at 0, and the corresponding upper panel points, U, are numbered in the same way. Thus, L1-U1 is the hip vertical, etc. The members are further distinguished as being on the upstream (U) or downstream (D) truss. Thus, UL1-UU1 is the hip vertical on the upstream truss. Redundant members (i.e., more than one member between the same two panel point [or joints]) are numbered from downstream to upstream, and each member in each truss has a distinctive notation.

Appendix B is a schedule of those eyebars in which cracks were detected or suspected to exist during the final safety inspection (TRC Solutions, 2007), and Appendix C lists those members selected for further testing.

Subsequently, bars that showed varying degrees of deterioration, ranging from obvious separation to no apparent separation, were submitted to the VDOT Materials Division Laboratory for further examination and testing.

### **Mishaps During Removing and Disposing of Trusses**

Despite the emphasis placed on the MOA (2008) and its requirement for saving selected loop eyebars for study, the contractor's efforts were more focused on removing and disposing of the trusses as expediently as possible. Unfortunate events, attributable to the contractor's haste and inexperience, significantly affected the scope and course of the research. The contractor decided to remove the longer through truss span as a single unit by removing the deck and joists and lifting the span by cables attached at the hips, as shown in Figure 6.

Although portions of the deck were left in place to stiffen the tension members, the bracing proved inadequate to prevent distortion of the rails and bowing of some of the relatively slender diagonals. Nevertheless, the truss was placed on its prepared bed (Figure 7) with only minor damage.

Subsequent movement of the truss to provide more clearance for construction operations resulted in the further distortion shown in Figure 8, eliminating the suitability for testing of



**Figure 6. Lifting Entire Through Truss From Its Bearings**



**Figure 7. Through Truss Removed From Bridge, With Only Minor Distortion of Members**





**Figure 8. More Severe Distortion Resulting From Racking of Truss After Its Move to Facilitate Construction**

several eyebars bent during the moving. Joints including eight selected members did remain intact and were marked for salvage.

Dismantling of the trusses began while no personnel from VDOT or VCTIR were onsite. Contractor personnel decided to dismantle the trusses one-half at a time, cutting the center upper chords first, without supporting the truss at its panel points. The result (Figure 9) was the total collapse of the bridge and the bending of most of the bars above the bottom chords. Panel points



**Figure 9. Total Collapse of Truss Because of Inadequate Support During Dismantling**

containing those members that had been selected for detailed examination (Figure 10) were cut from the bridge and stored onsite to be picked up and disassembled by the bridge crew at VDOT's Charlottesville Residency. Lead paint on the truss members had to be removed mechanically at points near the joints prior to cutting of the members.

Prior to pick up of the panel joints at the site, they were run over by a piece of grading equipment working on the approach roadway, further distorting many members and fracturing several at the forge lines (Figure 11). The effects of this series of incidents on the findings of this study, both good and bad, are noted in the "Discussion" section.



**Figure 10. Panel Point With Member (silver tag) Selected for Study. Lead paint was mechanically removed from members prior to cutting.**



**Figure 11. Eyebars Damaged by Grading Equipment**

Although a discussion of the difficulties encountered during the dismantling of the Advance Mills Bridge is outside the scope of this study, a review of several steps might be useful to those dismantling other historic bridges. It is acceptable to move the truss intact by lifting it by connections at the top hip panel point if the lower chord is braced against bending. Once removed from its bearings, the truss should be placed on substantial supports set in a convenient location. Prior to disassembly, the truss should be supported at every panel point, and during disassembly, the truss should be stabilized by cranes to prevent its collapse and ensure the safety of workers

## DISCUSSION

### Adequacy of Field Inspections

One objective of this study was to evaluate the adequacy of a hands-on inspection supplemented by a DPT in determining the extent and severity of cracking in loop-welded bars. Many of the cracks were described as being of “hairline width,” whereas rust stains along one forge line were noted on others. Findings of the inspections were verified first by cutting the eyebar at a point on the suspected crack (Sections A and B in Figure 12) and at a second point just beyond the termination of the visual indication of the crack (Section C) and second by comparing the cracking reported in the April 2007 inspection with radiographic evaluations performed on selected members in the VDOT Materials Division Laboratory.

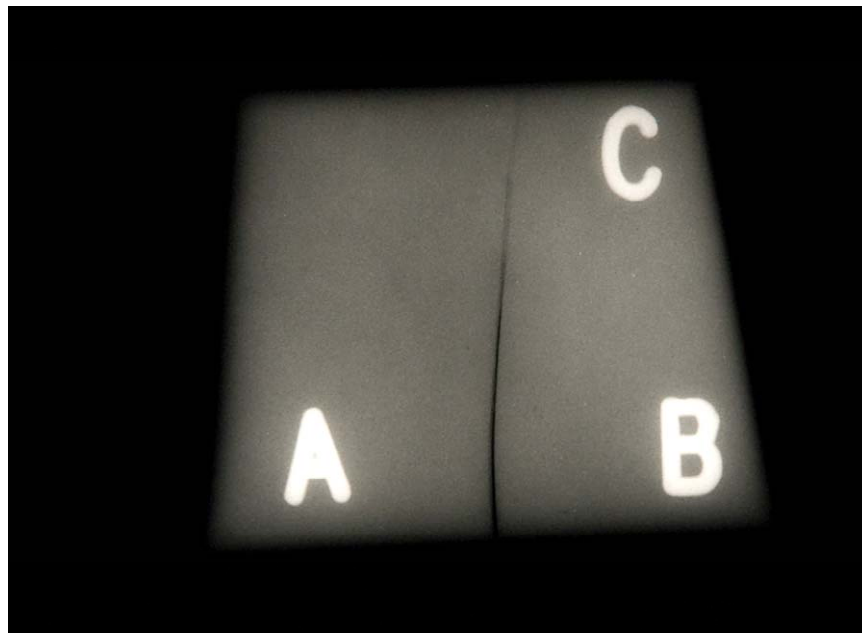
Figure 13 indicates the presence of the forge line running the full length of the specimen, and the radiograph in Figure 14 shows an apparent separation extending almost to the uncracked Face C, with the forge line visible to that face. Figure 15, Cross Section A-B, clearly indicates the presence of a tight but visible crack where it was indicated by the inspector. There was



Figure 12. Eyebar Cut at End of Separation and Beyond End of Visible Hairline Crack



**Figure 13. Forge Line Through Entire Length of Cleaned Specimen**



**Figure 14. Radiograph Confirming Presence of Crack Through Most of Length of Specimen**

however, no evidence of cracking at Section C (Figure 16). The lack of separation is visible at Face C and, along with other radiographs, confirms the adequacy of a rigorous hands-on safety inspection.



**Figure 15. Face A-B Showing Tight Crack**



**Figure 16. Close View of Crack at Forge Line**

### **Integrity of Loop Forgings**

The damaging of the eyebar samples by the grading equipment, although a mishap, provided valuable information on the characteristics of the loop forging. In a “using lemons to make lemonade” scenario, the transverse loading on the eyebar fractured the forged connection on several members, as on the one shown in Figure 17. It can be seen that the surfaces separated along the forge line with none of the characteristics of a truly welded connection.

Rusting at portions of the forge line on some bars, as shown in Figure 17, indicates that the separation is progressive because of corrosion, possibly affecting the performance of the bar. It is realized that the transverse loading by the track hoe has no relation to the service loading on the eyebars, but the nature of the failure at the forge line does indicate the meaning and the importance of the hairline cracks and rust stains noted during the safety inspection.



**Figure 17. Fractured Forge Line of Bar Broken by Grading Equipment. Rust in upper portion indicates preexisting crack.**

The warnings, cited earlier, that steel welds are not reliable indicates that care must be taken into account in making welded repairs on steel eyebars produced in the late 19th and early 20th centuries.

### **Strengths of Eyebars**

Tensile tests were employed to determine, to the extent possible, the effects of the forgings on the ultimate strength of the members. Unfortunately, only two eyebars from the collapsed truss, Nos. 4 and 5, each with a partial crack along its forge line, were deemed sufficiently straight and undamaged to be suitable for testing. The bars were tested using a salvaged pin from the Advance Mills through truss. Figures 18 through 23 show the bars as removed from the bridge, radiographs confirming the existing cracks and indicating the forge lines, and fractures after strength testing.

Photographs of both bars show the forge lines and the existing cracks, which would have been clearly visible to an inspector. The radiographs confirm the cracking and provide faint traces of the forge lines beyond the cracks. Not surprisingly, each of the bars failed at its forge line. Both fractures were similar to those caused by the accidental loading shown earlier, and rust on the forge line indicates the extent of preexisting cracks.

The strengths obtained during load testing, shown in Appendix D, were high, however, with maximum loads of 39,910 lb for Bar 4, which was relatively intact, and 33,380 lb for Bar 5; the respective tensile strengths were 40,787 psi for Bar 4 and 48,766 psi for Bar 5. The tensile strength was computed by dividing the maximum load by the cross-sectional area of the bar shank ( $0.8184 \text{ in}^2$ ).



**Figure 18. Crack Extends Short Distance on Bar 4. Extension of forge line is generally covered by paint.**



**Figure 19. Radiograph Confirms Small Crack in Bar 4. Remainder of forge line is visible, but faint.**



**Figure 20. Forge Line of Bar 4 After Strength Testing. Small area of rust indicates previous crack along forge line.**



**Figure 21. Bar 5 As Removed From Bridge. Visible crack extends along left side of forge line. Uncracked forge line is visible to right of crack.**



**Figure 22. Radiograph of Bar 5 Showing Partial Length Crack. Forge line is faintly visible beyond crack.**

It should be pointed out that these stresses do not represent the allowable working strength of the steel itself but instead the ultimate load of the eyebar itself when the entire forge line had fractured. Data indicating the ultimate tensile and yield strengths of the steel are shown in Appendix E. The single tension test of an eyebar sample performed by the VDOT Materials Division Laboratory in accordance with ASTM Standard A615 determined that the steel had an ultimate tensile strength of 60,253 psi and a yield strength of 38,000 psi. From the values in Appendix D, it appears that the condition of its loop-welded connection does limit the ultimate strength of an eyebar. It is worth noting that none of the cracked bars on the Advance Mills Bridge had been allowed to fracture completely at the forge lines. All were reinforced by cables to prevent the displacement that might accompany a total failure of the loop weld.

For checking eyebar adequacy, the *Notes on Determining the Strength of Old Bridges* employed by the VDH Office of the Bridge Engineer (1956) uses working stresses based on those in AASHTO's *Standard Specifications for the Design of Highway Bridges* (AASHTO,





**Figure 23. Forge Line of Bar 5 After Strength Testing. Rust indicates existing crack.**

1949) based on structural carbon steel conforming to the requirements of ASTM A7-46 (withdrawn in 1967) to determine the area of hip verticals and hangers. VDH increased the allowable steel working stress by 1/9 from the specification value of 18,000 to 20,000 psi for die-forged or riveted members. In the case of loop-welded truss members, however, the working stress was reduced to 14,000 psi.

Sparks (2007) cited the following notional strength values (those commonly accepted for design) based on the *AASHTO Manual for Condition Evaluation of Bridges* for steel produced in the following years (AASHTO, 1994):

- *Pre-1905*:  $F_y = 26,000$  psi;  $F_u = 52,000$  psi for bridges built 1896-1905; for bridges built prior to 1896,  $F_u = 48,000$  psi
- *1905 to 1936*:  $F_y = 30,000$  psi;  $F_u = 60,000$  psi
- *1936 to 1963*:  $F_y = 33,000$  psi;  $F_u = 60,000$  psi.

Using the convention of setting the working stress at 55% of the yield strength, in conjunction with the pre-1905 value of  $F_y = 26,000$  psi, the VDH more conservative value for the working stress to be used with loop-welded bars, i.e., 14,000 psi, is justified.

The values obtained from the single strength test reported in Appendix E exceed the notional values for pre-1905 steel and comply with those for steel produced from 1905 to 1936 and 1936 to 1963 as well as those provided by Ketchum (1912) for “medium steel.” The latter values complied with the requirements for steel specified in ASTM A7-46. It should be noted, however, that variability of strength values, common for steel produced at the time the Advance Mills through truss was fabricated, would dictate more extensive testing if the structure were to remain in service. A useful reference for the evaluation of those truss bridges to be retained in

service is the *Guide to Evaluating Historic Iron and Steel Bridges* (Sparks, 2007) and other references cited in this report.

The actual strength of any loop-welded bar would be dependent on the quality of the forging, section loss attributable to corrosion, and the actual load placed on the member attributable to overload or its resulting deformations.

### **Failures Within the Loop Eye**

Although failures of the forged connections of loop-welded eyebars have been observed frequently, fractures of eyebars within the loop eyes have also occurred. Fractures within the loop, which often appear to occur in the relatively slender eyebars such as counters, may have been caused by increases in the stresses in the members attributable to frequent overloads. Several instances of deformations of the truss, possibly caused by overloads or debris impact, also were observed in which one of a pair of eyebars was slack, overloading the remaining member and possibly redistributing the loads within the structure.

### **Corrosion**

During the examination of the bridge it became evident that inspection and maintenance of those portions of the pinned connections that were under the deck, where the access to the bars at the panel points was obscured, were difficult. Examination of those members disclosed much more severe corrosion and section loss, such as shown in Figure 24, than that found on the outside members. Evaluation of these members during inspections requires special effort to ensure their adequacy, as they are hidden from view.



**Figure 24. Extreme Section Loss in Lower Chord Eyebar**

## Characteristics of the Steel

Appendix E also presents analyses of the components of the steel determined by x-ray fluorescence and chemical analyses to determine the carbon and sulfur contents of the steel.

The component analysis determined by VDOT's Materials Division for the bar using x-ray fluorescence was as follows:

- Fe (iron): 99.35%
- Mn(manganese): 0.44%
- Ti (titanium): <0.02%
- Cu(copper): 0.01%
- Cr (chromium): <0.01%
- V(vanadium): <0.01%
- Ni(nickel): <0.02%
- W(tungsten): <0.01%.

According to Urquhart and O'Rourke (1930): "Ordinary steels contain from 0.3 to 0.7 per cent manganese. . . . In small amounts manganese has practically no direct effect on the properties of iron and steel." Thus, the effects of the manganese content found in the samples and the contents of the other trace elements are considered inconsequential.

The x-ray fluorescence test cannot determine the carbon or sulfur content of the steel. Since these elements can have important effects on the properties of the metal, additional chemical analyses were performed at Inco Test, a consulting laboratory, to determine the amounts of these elements. Testing in accordance with ASTM E1019 indicated a carbon content of 0.22% and a sulfur content of 0.049%. This is consistent with the maximum values for the sulfur content cited by Waddell (1889) and Ketchum (1912).

Carbon is an important characteristic that differentiates iron and steel. Processing iron ore into steel removes the carbon from the ore and leaves nearly pure iron. Carbon is then added to the iron to make steel. It is usually added to structural steel in amounts "varying from about 0.1 to 0.25 per cent" (Urquhart and O'Rourke, 1930). Higher carbon contents that were occasionally used to increase the strength of the steel could have an adverse affect on the weldability of the metal. Neither Waddell (1889) nor Ketchum (1912) addressed the allowable percentage of carbon, although both warned that steel cannot be welded reliably. The effects of carbon content on the suitability of the steel for welding was not a factor, beyond the fabrication of loop-welded eyebars, in riveted and pin-connected structures of that era, although rivets had a lower carbon content to be softer than structural steel. Welding is, however, sometimes used today in their repair or renovation.

High sulfur content is detrimental to the quality of structural steel. Urquhart and O'Rourke (1930) stated: "In large amounts, sulfur decreases the strength and ductility of steel and is apt to cause rapid corrosion. It makes the steel brittle when hot. Most specifications limit the maximum sulfur content to about 0.05 per cent."

The sulfur content of the steel sample from the Advance Mills Bridge is not considered a major factor in its widespread corrosion.

## CONCLUSIONS

- *The results and conclusions of this study should be viewed as those of a case study of a single truss of steel probably provided by a single producer. The variability of properties in steels produced in the same time frame as the Advance Mills through truss (estimated at ca. 1890 through ca. 1910) would call for a more extensive program of tests if the bridge in question were to continue in service.*
- *The final safety inspection report and the documentation provided by this study showed widespread serious distress throughout the Advance Mills Bridge, leading to the conclusion that there was no alternative to its replacement. Efforts to rehabilitate the bridge would have resulted in the almost complete duplication of a functionally obsolete structure.*
- *The hands-on inspection of the through truss supplemented by the DPT where the presence of cracking was suspected provided a sufficiently accurate assessment of the condition of the members.*
- *The presence of separation in forge-welded areas of the loop-welded eyebars was verified by close examination, cutting of the bars at locations in and beyond the visual crack, radiographic testing, and the accidental damage inflicted at the construction site.*
- *Examination of the faces of the two sections of clearly separated metal at the forge-weld area indicated that the joint was in no way similar to a truly welded connection. This is consistent with the prohibitions by Waddell and Ketchum against the use of steel in loop-welded eyebars. Testing of the bars in tension showed reasonably high tensile strengths, and photographs of the fractured faces showed that the faces, though not welded, were reasonably intact.*
- *All indications of such cracking, including cracks indicated by the DPT test, hairline cracks, and rust stains along the forge lines, should be regarded as indications of an inadequately forged loop.*
- *Examination of the faces showing rusting and clean steel within the same forge-welded areas indicated that separation of the connection was progressive and might lead to total failure of the forged joint.*
- *Fractures of eyebars within the loop eyes have also occurred. Such fractures, which appear to occur in relatively slender eyebars such as counters, may have been caused by increases in loads in the members attributable to the effects of frequent overloads. Several instances of deformations of the through truss attributable to overloads or debris impact also were*

observed in which one of a pair of eyebars was slack, over loading the remaining member and possibly redistributing the loads within the structure.

- *Panel points under the deck were obscured and required very thorough inspection to evaluate corrosion across the faces of the eyebars. Corrosion of the truss members was more extensive at panel points below the deck.*
- *X-ray fluorescence testing and chemical analyses to determine the components of the steel in the Advance Mills Bridge and supplemental tests to determine the carbon and sulfur contents were consistent with specified values.*
- *Strength testing of the steel showed it to be of good quality, with yield and ultimate strengths complying with the requirements of structural steels specified in ASTM A7-46.*
- *Assumptions in the Notes on Determining the Strength of Old Bridges (VDH, 1956) regarding the use of working stresses based on the requirements of structural steel specified in ASTM A7-46 and the reduction in the working stresses for loop-welded eyebars were correct based on examinations and strength testing of a sample from the Advance Mills Bridge.*
- *Decisions regarding the safety of a historic pin-connected truss with loop-welded eyebars must begin with a careful inspection of the structure to determine its adequacy. Disposition of a historic truss bridge is a complex process requiring input from several entities including VDOT's Structure and Bridge Division, Environmental Division, and district structure and bridge and environmental personnel, who must ensure that the contractors fully understand the nature and importance of the work to be performed. Recommendations for the disposition of historic structures are presented in VDOT's Management Plan for Historic Bridges in Virginia (Miller et al., 2001).*

## **RECOMMENDATIONS**

1. *VDOT's Structure and Bridge Division and district structure and bridge offices should ensure that bridge safety inspectors carefully examine steel truss bridges with loop-welded eyebars built in the late 19th and early 20th centuries for cracking along forge lines and that portion of the eyebar within the loop to detect possible cracking caused by increased stresses attributable to overloading of the structure. A hands-on inspection supplemented by a DPT is sufficient to disclose the presence of cracking.*
2. *VDOT's Structure and Bridge Division and district structure and bridge engineers evaluating loop-welded eyebars should regard hairline cracks or rust stains along the forge lines of the bars as evidence of an inadequate forge weld. Although replacement of the member might not be required, continuing observation is advised during future inspections. Cabling may be required.*

3. *VDOT's district structure and bridge personnel should ensure that those eyebars obscured by a bridge deck are examined carefully for severe section loss attributable to corrosion.*
4. *During pre-construction meetings, VDOT's district structure and bridge engineers and district construction engineers should ensure that both the contractor and VDOT inspection personnel understand that once a truss that is to be salvaged has been removed from its bearings it must be placed on proper supports matching its bearing points; that prior to its disassembly it is supported at each panel point; and that during disassembly it is stabilized by cranes. Sufficient stabilization is required regardless of the disposition of a truss to prevent collapse and ensure the safety of workers.*

### **ACKNOWLEDGMENTS**

The examination of the loop-welded eyebars on the Advance Mills Bridge, which involved field work closely coordinated with the contractor's work schedule over a long period, along with administrative and laboratory work involving several entities within VDOT, required contributions by many people. The authors are extremely grateful for their willing assistance. Without them the research could not have been performed.

The study, first suggested by Bernard Kassner and Wallace McKeel, Jr., was included as a requirement of the MOA regarding the demolition of the bridge by Antony Opperman, preservation program manager in VDOT's Environmental Division. Mr. Opperman's continued interest and advice throughout the ensuing project are greatly appreciated. The contributions of Kenneth Shirley, Culpeper district construction engineer, and David Pearce, maintenance engineer, were most helpful. As the former district bridge engineer, Mr. Pearce's knowledge of the maintenance history of the Advance Mills Bridge was invaluable. Reminiscences provided by Edward Bailey, a retired VDOT employee who observed the rebuilding of the bridge in 1943, provided interesting historical background information

Berlie Botkin, Jr., project inspector, kept the research team closely apprised of scheduled activities at the site, and Richard Childs, VCTIR research associate, monitored and conducted much of the field work involving marking and securing the eyebars selected for testing. Transport of the selected joints to the Charlottesville Residency was coordinated by Mauris Mackenzie, area construction engineer at Charlottesville, and Michael Burton, the VCTIR concrete laboratory manager. There, the joints were disassembled expertly by Barry Weathersbee and the Culpeper district bridge crew. The expertise of VCTIR's photographer, Edward Deasy, is evident in the quality of the detailed photographs of the damaged eyebars. Our writings benefited greatly through the expertise of VCTIR's editor, Linda Evans.

The authors benefited greatly from the advice of William Via, Jr., structural materials program engineer in VDOT's Materials Division, who provided valuable information on the characteristics of early structural steel and the radiographs that verified the findings of the field inspections. Larry Lundy, concrete program manager in VDOT's Materials Division, managed the analytical testing program that was essential in determining the composition of the bridge

steel, its strength, and the effect of a crack at the forge line on the load capacity of an eyebar. Harikrishnan Nair was instrumental in tracking and reporting the test results. Contributions by VDOT's Materials Division greatly enhanced the technical value of the report.

The authors are also grateful for the advice and assistance of Helen Ross, architectural historian and preservation manager, and Richard Crofford, environmental manager, both of VDOT's Culpeper District, and Charles Babish, state materials engineer. Several other individuals at VCTIR, namely, Michael Perfater, former acting director of research operations; Amy O'Leary, associate director; and Jose Gomez, director, read the report and provided meaningful comments and suggestions for its improvement.

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## APPENDIX A

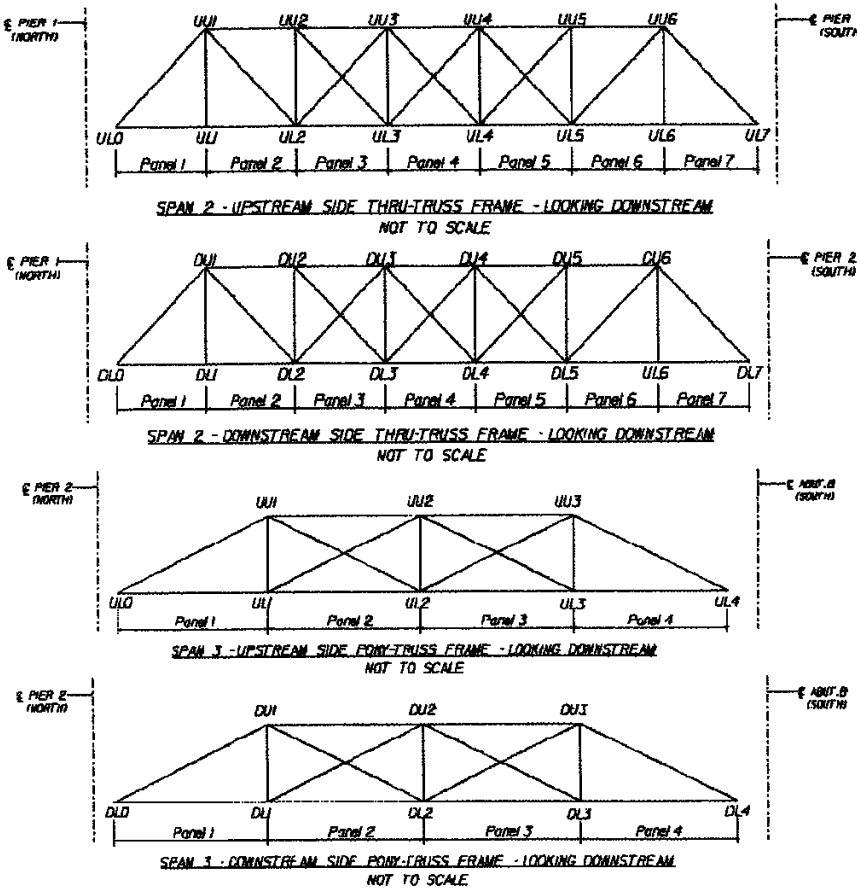
### DESIGNATION OF TRUSS MEMBERS, ADVANCE MILLS BRIDGE (Page 28 of Safety Inspection Report, TRC Solutions, 2007)

virginia Department of Transportation

Structure and Bridge

### BRIDGE INSPECTION REPORT – COMMENTARY

Agency ID: 0626104-0000000000831      Date of Inspection: 04/23/2007

<b>TRUSSES</b>	<p><b>Joint assignments are as follows:</b></p>  <p><b>Joint Name Explanation - Examples:</b>  <u>UL6</u> = <u>U</u>pstream frame <u>U</u>pper-chord <u>6</u>th point.  <u>DL6</u> = <u>D</u>ownstream <u>L</u>ower-chord <u>6</u>th point.</p> <p>Accordingly, the members are designated using the above defined joints. For example, <u>DU5-DL4</u> is the diagonal member between joints DU5 &amp; DL4 in the downstream thru-truss frame. Additionally, the redundant members between two joints are numbered from downstream to upstream. For example, between DL4 &amp; DL5, there are four eye-bars that comprise this horizontal bottom chord. So, these members are designated Member 1 (most downstream) to Member 4 (most upstream).</p>
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**APPENDIX B**  
**SUMMARY OF CRACKED BARS**  
**THROUGH TRUSS, SPAN 2, ADVANCE MILLS BRIDGE**  
**(TRC Solutions, 2007)**

**Upstream Through-Truss**

DPT = confirmed by Dye Penetrant Test

1. **UL0-UL1** bottom chord. Member has minor rust stain at forge line @UUL1. Outside bar is bent and slack.
2. **UU2-UL3** diagonal. A very fine hairline crack extends along forge line, outside face, member 1, @ joint UU2. (DPT)
3. **UU4-UL5**, diagonal. The eye has crack 1/2" long by 1/16" wide @ joint UU4. Member has been retrofitted w/ circular steel rod.
4. **UL4-UU5** Diagonal. At outside face, member 2 (outside bar) a fine hairline crack (L= 1 1/8" ) extends along forge line, @ joint UU5,
5. **Same joint & bar as above.** A very fine hairline crack (L=2 1/8") extends along forge line, inside face member 2, outside bar, @ U5 (DPT, **PHOTO 27**)
6. **UL5-UU6** diagonal. A hairline crack extends along forge line, L= 1 1/8", outside bar (member #2) @ joint UU6 (DPT)
7. **UU6-UL6** verticals. Cracks extend along forge lines, inside bar 1/2" W by 2"L and outside bar (L= 1") @ joint UU6.

**Downstream Through-Truss**

1. **DL1-DU1** vertical, rust stain extends along forge line, L = 2", outside bar, member #1 @ joint DL1.
2. **Same bar (upper joint) as above.** A hairline crack extends along forge line, outside member @ joint DU1 (DPT)
3. **DU2-DL3**, diagonal. A rust stain extends along forge line, L =1/2", upstream eyebar, member 2 @ joint DL3
4. **DL2-DU3**, diagonal. Counter has been broken at looped segment @ joint DU3. Member cabled & plate welded to counter @DU3.

5. **DL3-DU4**, diagonal. A hairline crack extends along forge line,  $L = 4''$ , outside bar, member #1 @ DL3 (DPT)
6. **Same diagonal (member 2)**, A possible hairline crack extends along forge line,  $L=1/2''$ , inside member (#2) @ joint DU4 (inconclusive DPT)
7. **DU3-DL4**, diagonal. A hairline crack extends along forge line,  $L = 4 \frac{1}{2}''$ , running to edge of member, outside member (#1), @ joint DL4, (DPT, **PHOTO 24**)
8. **DU4-DL5**, diagonal. A hairline crack along forge line extends to edge of member @ joint DU4. (**PHOTO 28**)
9. **DL5-DL6**, bottom chord. Member 1 (outside bar) has a full width transverse hairline crack ( $2 \frac{1}{2}''$  L) that extends approximately  $1/8''$  into the bottom face of the member @ joint DL6. Member is engaged and in tension. (DPT, (**PHOTO 23**))
10. **DL5-DU6**, diagonal. Inside bar, #2, has a hairline crack along forge line @ joint DU6. Member is engaged and in tension. (DPT)
11. **DL6-DU6**, vertical. Outside face of outside bar, #1, has a very fine hairline crack ( $L=1/2''$ ) @ joint DU6. Member is engaged and in tension. (DPT, **PHOTO 26**)
12. **Same member as above (lower joint)**. A hairline crack ( $L= 1 \frac{1}{2}''$ ) extends along forge line @ joint DL6. (**PHOTO 25**)

## APPENDIX C

### TRUSS MEMBERS SELECTED FOR TESTING, ADVANCE MILLS BRIDGE

#### Upstream Truss

##### **Joint UL1**

1. Bottom Chord UL0-UL1

##### **Joint UU5**

2. Diagonal UL4-UU5, outside bar (member 2)

#### Downstream Truss

##### **Joint DL1**

3. Vertical DL1-DU1

##### **Joint DL4**

4. Diagonal DU3-DL4, outside bar (member 1)

##### **Joint DU4**

5. Diagonal DL3-DU4, inside bar (member 2)
6. Diagonal DU4-DL5

##### **Joint DL6**

7. Bottom Chord DL5-DL6, outside bar (member 1)
8. Vertical DL6-DU6, outside (member 1)



**APPENDIX D**  
**EYEBAR STRENGTH TESTS**

**Sheet 1 of 2**

**VIRGINIA DEPARTMENT OF TRANSPORTATION**

**MATERIALS DIVISION**

**REPORT ON SAMPLE OF STEEL**

T.L.-25 x1s  
Rev.1-98

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Report No.	RS 57655	RICHMOND, VA.	03/05/2010
Route No.	: 743	F.H.W.A. :	
Project No.	: - - ,	County :	
Sample No.	:	Residency :	
<b>Material</b>	<b>: 27 1/2" EYEBAR</b>	Quantity :	INVESTIGATION
Submitted by	: W. VIA	At :	ELKO
Date Sampled	:	Date Received :	
Manufactured by:		At :	
Consigned To	:	At :	

---

Physical Tests

Area of section sq. in. : .8184

Maximum Load lbs. : 39,910

Tensile Strength psi.: 48,766

Remarks : Bridge taken out of service on Rt 743 Advance Mills. Albemarle County

**Tested at ELKO MATERIALS TESTING FACILITY in accordance with**

Report on file at Central Office Materials Division's Physical Lab

Tested By : A. CABLE

Reported as : TESTED

By : *K. K. Williams*

Date : 03/05/2010

Charles A. Babish, PE  
State Materials Engineer



Sheet 2 of 2

VIRGINIA DEPARTMENT OF TRANSPORTATION

MATERIALS DIVISION

REPORT ON SAMPLE OF STEEL

T.L.-25.xls  
Rev.1-98

Report No.	RS 57656	RICHMOND, VA.	03/05/2010
Route No.	: 743	F.H.W.A. :	
Project No.	: - - ,	County :	
Sample No.	:	Residency :	
<b>Material</b>	<b>: 20" EYEBAR</b>	Quantity :	INVESTIGATION
Submitted by	: W. VIA	At :	ELKO
Date Sampled	:	Date Received :	
Manufactured by :		At :	
Consigned To :		At :	

Physical Tests

Area of section sq. in. : .8184  
Maximum Load lbs. : 33,380  
Tensile Strength psi. : 40,787

Remarks : Bridge taken out of service on Rt 743 Advance Mills. Albemarle County

**Tested at ELKO MATERIALS TESTING FACILITY in accordance with**

Report on file at Central Office Materials Division's Physical Lab

Tested By : A. CABLE

Reported as : TESTED

By : *K. K. Williams*

Date : 03/05/2010

**Charles A. Babish, PE**  
State Materials Engineer

APPENDIX E

CHARACTERISTICS OF STEEL, ADVANCE MILLS BRIDGE

Sheet 1 of 2

VIRGINIA DEPARTMENT OF TRANSPORTATION

MATERIALS DIVISION

Corrected Report  
see remarks

T.L.-25.xls  
Rev.1-98

REPORT ON SAMPLE OF STEEL

Report No.	RS 57728	RICHMOND, VA: 07/29/2010
Route No.	: 743	F.H.W.A.:
Project No.	: - - - ,	County:
Sample No.	: 6	Residency:
Material	: EYEBAR (STRAIGHT SECTION)	QTY: INVESTIGATION
Submitted by	: LARRY LUNDY	At: ELKO MATERIALS
Date Sampled	:	Date Recvd:
Manufactured by	:	At:
Consigned To	:	At:

<u>Physical Tests</u>		<u>X-ray Fluorescence</u>
Grade	:	Fe : 99.35 %
Area of Section sq. in	: 0.75	Mn : 0.44 %
Yield Load lbs.	: 28,500	Ti : <0.02 %
Yield Strength psi.	: <b>38,000</b>	Cu : 0.01 %
Maximum Load lbs.	: 45,190	Cr : <0.01 %
Tensile Strength psi.	: <b>60,253</b>	V : <0.01 %
Elongation %	: 25	Ni : <0.02 %
Theoretical Weights	:	W : <0.01 %
Remarks	: Added X-ray information. Bridge taken out of service on Rte. 743; Advance Mills, Albemarle Co.	

Tested at ELKO MATERIALS TESTING FACILITY in accordance with ASTM A615  
Report on file at Central Office Materials Division's Physical Lab

Tested By : J. HADDON

Reported as : TESTED

By : *K. K. Williams*

Date : 07/29/2010

**Charles A. Babish, PE**  
State Materials Engineer



# Inco Test

3200 Riverside Drive • Huntington, WV 25705-1771  
(304) 526-5447 • FAX (304) 526-3904

**Certificate Number :** Z10000083

**Date:** 17-Aug-10

**Customer:** Han Krishnan Nair  
Materials Division, VDOT  
1401 East Broad Street  
Richmond, VA 23219

**Phone:** (804) 328-3059  
804-328-3136

**Description:** Chemistry per customer request. Per ASTM E1019.

**PO #**

Method	Element	Concentration
CS344	C	0.22
CS344	S	0.049

ALL RESULTS in percent weight (%), per ASTM E1019

END OF TEST DATA

**This Laboratory is NADCAP Accredited**

Approved:  
*T.W. Wilson*  
Troy Wilson  
Team Leader