Covered Bridges as Structural Art
Integrating Covered Bridges into the Civil Engineering Curriculum

Rachel H. Sangree
Johns Hopkins University
Baltimore, MD
HISTORIC AMERICAN ENGINEERING RECORD

PINE GROVE BRIDGE

HAER No. PA-586

LOCATION: Ashville Road and Forge Road, spanning Octoraro Creek between Pine Grove, Little Britain Township, Lancaster County and Oxford vicinity, Lower Oxford Township, Chester County, Pennsylvania

UTM: 18410558,44055367, Kirkwood, PA Quad.

STRUCTURAL TYPE: Wooden covered bridge, two span Burr arch-truss

DATE OF CONSTRUCTION: 1884

BUILDER: Capt. Elias McMellen, Lancaster, PA

PRESENT OWNER: State of Pennsylvania

PREVIOUS USE: Vehicular bridge

PRESENT USE: Vehicular bridge

SIGNIFICANCE: The Pine Grove Bridge was built in 1884 after a destructive flood carried away in 1846 bridge at this site. The county hired Capt. Elias McMellen, a well-respected and prolific Lancaster bridge builder to rebuild it. McMellen constructed over thirty-five bridges in the region. The bridge is a typical example of the vernacular Burr arch-truss, the most common design for covered bridges in this area. The bridge is still open to vehicular traffic.

HISTORIAN: Researched by Lola Bennett and Sarah Maria Rose Dangelas.

Written by Sarah Maria Rose Dangelas, 2003

PROJECT INFORMATION: The National Covered Bridges Recording Project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. HAER is part of the Historic American Buildings Survey/Historic American Engineering Record, a
HISTORIC AMERICAN ENGINEERING RECORD
PINE GROVE BRIDGE
HAER No. PA-586

LOCATION: Ashville Road and Forge Road, spanning Octoraro Creek between
Pine Grove, Little Britain Township, Lancaster County and Oxford
vicinity, Lower Oxford Township, Chester County, Pennsylvania
UTM: 18 410558 4405367, Kirkwood, PA Quad.

STRUCTURAL TYPE: Wooden cove

DATE OF CONSTRUCTION: 1884

BUILDER: Capt. Elias M

PRESENT OWNER: State of Penn.

PREVIOUS USE: Vehicular brd

PRESENT USE: Vehicular brd

SIGNIFICANCE: The Pine Grove Bridge was carried away by Elias McNeil, builder of the modern bridges in the area. Its successful construction is the result of the interest of colonists in its construction. The keystone arch is one of the common designs used for road bridges in the area.

HISTORIAN: Written

Written by Sarah Mar

PROJECT INFORMATION: The National Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. HAER is administered by the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER), a division of the National Park Service, U.S. Department of the Interior. The Federal Highway Administration funded the project. The Chesapeake Bay Bridge-Tunnel (Chesapeake, Chief Engineer) provided assistance at Pine Grove Bridge.

The field work, measured drawings, historical research, and photography were conducted under the direction of Eric DeLony, Chief of HAER, Christopher Marston, Project Leader, and Richard O'Connor, HAER Senior Historian. The field work was supported by Fulbright Foundation (Franklin-Kingston), American Institute of Architects, Lehigh University, and the National Park Service. The engineering support that accompanied the HAER office is a valuable resource in the understanding of the Pine Grove Bridge.

Pine Grove Bridge
Spanning Octoraro Creek
Pine Grove, Pennsylvania

The Pine Grove Bridge and the story of its construction are instructive examples of both the progress and progress of covered bridges. Built in 1884, the Pine Grove Bridge was a covered bridge that carried traffic over the Octoraro Creek. The bridge was designed by Capt. Elias M., a local builder, and was constructed using traditional methods.

The original bridge was destroyed by floodwaters in 1939, and a replacement was built in 1940.

The bridge was listed on the National Register of Historic Places in 1977.

Burr Arch - 1884
HISTORIC AMERICAN ENGINEERING RECORD
PINE GROVE BRIDGE
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DATE OF CONSTRUCTION: 1884

BUILDER: Capt. Elias M McMull

PRESENT OWNER: State of Penn. Vehicular brd

PREVIOUS USE: Vehicular brd

SIGNIFICANCE: The Pine Grove Bridge is an important example of traditional vernacular construction. The bridge was constructed in 1884, and it is an excellent example of traditional Pennsylvania Vernacular architecture. The bridge is significant for its historical and architectural value.

HISTORIAN: Researched by Sarah Mar

PROJECT INFORMATION: The National Historic American Engineering Record (HAER) record includes detailed drawings and photographs of the bridge.

The Pine Grove Bridge was constructed in 1884 and is significant for its historical and architectural value. The bridge is an excellent example of traditional Pennsylvania Vernacular architecture. The bridge is significant for its historical and architectural value.

Burr Arch - 1884

The Historic American Engineering Record (HAER) record includes detailed drawings and photographs of the bridge.

The fieldwork, measured drawings, historical research, and photography were completed under the direction of Eric DeLorme, Chief Engineer, and with the assistance of Lisa Stadelman, project manager; Robert O'Connor, HAER Northeast Region; and John D. unsigned, who provided assistance at Pine Grove Bridge.
DEAD LOAD PLUS QUARTER-POINT LIVE LOAD

The forces shown in Figure 33 are the linear combination of the quarter-point live load and dead load results, with the dead load reaction dominating. This loading produces the greatest stresses of any case considered (Table 18). The largest stress, 489 psi, occurs at the left end of the arch, but this is well below current maximum design values. The force at this location is also 175 percent greater than the largest force in the truss, which again speaks for the arch's structural dominance. The greatest shear stress also occurs under this loading case, but it, too, is safely below allowable limits.

Table 17. Maximum Values of Arch-Trust due to Quarter Point Live Load.

<table>
<thead>
<tr>
<th>Arch Max Compressive Stress (psi)</th>
<th>98</th>
<th>Ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans Max Compressive Stress (psi)</td>
<td>67</td>
<td>Panel 0, left</td>
</tr>
<tr>
<td>Max Tensile Stress (psi)</td>
<td>122</td>
<td>Post 4, above diagonal, left</td>
</tr>
<tr>
<td>Max Deflection (in)</td>
<td>0.06</td>
<td>Post 4, left</td>
</tr>
</tbody>
</table>

Note the significant tensile forces calculated in the diagonals just to the right of the loading (that decrease toward mid-span since the diagonal/post connection is designed for bearing in compression only, tensile loads in the diagonals are not possible and must be disregarded). This condition was not anticipated, and the model was not designed to "hit" "compression only" points. In fact, however, only a few critical cases in which it does not include the dominant dead load. This may not be a problem when considering the total dead-plus-live-load condition, however. As long as the net forces in the diagonal members are compressive, the model will remain useful.

Primary forces by the diagonals and posts until, on the right side, the arch achieves enough of an angle that it can efficiently carry the shear at the ends.

Figure 32. Axial Forces in Arch-Trust due to Quarter Point Live Load.
primarily by the diagonals and posts until, on the right side, the arch achieves enough of an angle that it can efficiently carry the thrust at the ends.

Note the significant tensile forces calculated in the diagonals just to the right of the loading that decrease toward mid-span. Since the diagonal/post connection is designed for bearing in compression only, tensile loads in the diagonals are not possible and must be disregarded. This condition was not anticipated, and the model was not designed to handle "comprehensive forces". It is, however, only a theoretical case in that it does not include the dominant dead load. This may not be a problem when considering the total dead-plus-live-load condition, however. As long as the net forces in the diagonal members are compressive, the model will remain useful.

Figure 32. Axial Forces in Arch-Transfer to Quarter Point Live Load.

Table 17. Maximum Values of Arch-Transfer to Quarter Point Live Load.

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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600</td>
<td>100</td>
<td>0</td>
<td>0.06</td>
</tr>
</tbody>
</table>

DEAD LOAD PLUS QUARTER-POINT LIVE LOAD

The forces shown in Figure 33 are the linear combination of the quarter-point live load and dead load results, with the dead load reaction dominating. This loading produces the greatest stresses of any case considered (Table 18). The largest stress, 489 psi, occurs at the left end of the arch, but this is well below current maximum design values. The force at this location is also 37.5 percent greater than the largest force in the truss, which again speaks for the arch's structural dominance. The greatest shear stress also occurs under this loading case, but it, too, is safely below allowable limits.
Back to the Future

Historical structures draw engineering students into design aesthetics.
Covered Bridges as Structural Art
Integrating Covered Bridges into the Civil Engineering Curriculum
Covered Bridges as **Structural Art**
Integrating Covered Bridges into the Civil Engineering Curriculum
efficiency  economy  elegance

3 Dimensions of Structural Art:
scientific  social  symbolic
David P. Billington

The TOWER and the BRIDGE
The New Art of Structural Engineering
EN.560.141
Perspectives on the Evolution of Structures

Why do buildings and bridges look the way they do today? Students will be provided the tools to answer this question for themselves through a study of the history of the design of buildings and bridges throughout the world from both engineering and architectural/aesthetic perspectives.
• The Washington Monument and the Eiffel Tower
• The Eiffel Tower and the St. Louis Gateway Arch
• Telford, Brunel, and British Metal Forms
• Eads, Eiffel, and the Forth Bridge
• John Roebling and the Brooklyn Bridge
• History and Aesthetics in Suspension Bridges
• Covered Bridges

• Chicago and the Skyscraper
• New York and the Skyscraper
• Robert Maillart and the Origins of R/C
• Freyssinet, Finsterwalder, and the Origins of P/S Concrete
• Cable-Stayed Bridges
• Roof Vaults and National Styles
• The Swiss Tradition of Bridge Design
• New Bridge Forms: Maillart and Menn
• New Building Forms: Maillart and Isler
• Baltimore Structures
• Green Buildings from Fathy to Yeang
• High, Wide, and Far: Structural Engineering Today
“The ... scientific criterion ... essentially comes down to making structures with a minimum of materials and yet with enough resistance to loads and environment so that they will last.”
scientific  social  symbolic
scientific   social   symbolic

Efficiency: constructing a long-span bridge with a minimum number of piers in the waterway
Efficiency: constructing a long-span bridge truss with a simple arch - truss system
Efficiency: Constructing a long-span bridge truss without traditional wooden joinery and arches
Efficiency: Constructing a long-span bridge truss with effective counterbraces (to provide stiffness without an arch)
Efficiency: Constructing a long-span bridge truss with a simplified method of prestressing the counterbraces
“The second, or social criterion, comprises mainly analyses of costs as compared to the usefulness of the forms by society.”
scientific  social  symbolic
Permanent Bridge (1806)
Timothy Palmer
“And it is sincerely my opinion, that the Schuylkill bridge will last 30 and perhaps 40 years, if well covered. You will excuse me in saying that I think it would be sporting with property, to suffer that beautiful piece of architecture . . . which has been built at so great expense and danger, to fall into ruins in 10 or 12 years!”

-A Statistical Account of the Schuylkill Permanent Bridge, 1806
Within a year of the discovery of gold at Sutter’s Mill at Coloma in 1848, the population of California tripled. The urgent demand for roads and bridges was initially met by the establishment of privately financed ferries, turnpikes and toll bridges. In 1850, John T. Little of Castine, Maine, built California’s first covered bridge at Salmon Falls. By 1860, there were at least one hundred toll bridges in the gold mining region of California. The majority of these were timber truss bridges and, presumably, many of them were covered. Over time, however, the covered bridges were replaced with new structures, or lost to floods, fires, vandalism, neglect or decay. By 1938 there were still thirty covered bridges in California. That number dropped to 17 by 1954. Today there are 9 historic covered bridges in California.

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4 California also has several non-authentic or non-historic covered bridges that have appeared in recently published books, including: Alviso Creek Bridge (1974); Jocoby Creek (1969); Castillian (1960); Roaring Camp (1957) and Brookdale (1909).
5 See HAER No. CA-314, Knights Ferry Bridge and HABS No. CA-155, Knights Ferry Covered Bridge
6 See HAER No. CA-310, Power House Bridge.
7 See HAER No. CA-156, Westoma Covered Bridge.
8 See HAER No. CA-312, Honey Run Bridge.
Covered Wood Railroad Bridges

Some of the earliest railroad bridges were timber structures because wood was abundant, cheap, and easy to work with. In 1830, Lewis Wernwag built the first wood railroad bridge in the

Presumably hundreds of covered railroad bridges were built in the nineteenth century. In 1841, one English traveler noted, “The timber bridges of America are justly celebrated for their magnitude and strength. By their means the railways of America have spread widely and extended rapidly.” By the late nineteenth century, most railroad bridges were being built of iron or steel. In 1957, there were only twenty-nine surviving timber truss railroad bridges in the country. Today there are eight. The Sulphite Railroad Bridge is the only surviving deck truss covered bridge in the United States.
“...the third criterion, the **symbolic**, consists of *studies in appearance*, along with a consideration of how elegance can be achieved within the constraints set by the scientific and social criteria.”
Guillaume Apollinaire

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T O U JOURS
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LEM ANDS
Acknowledgements

Thanks to David Billington, Ben Schafer, Sanjay Arwade, and Steve Buonopane who developed some of the slides and images used in this presentation.

Thanks to FHWA for funding the National Covered Bridges Recording Project and to HAER for creating a truly beautiful and useful resource.
scientific  social  symbolic
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\[ M(x) \propto x^2 \]