Covered Bridges of America

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SYNOPSIS

This paper provides an overview of the early nineteenth century evolution of American covered bridges by describing the development of the four main truss types used.

The first National Covered Bridge Conference was held in Burlington, Vermont, USA in June 2003 and this presentation also covers information obtained from that conference on the history and engineering analysis of these structures that typify rural America.

1 INTRODUCTION

The American War of Independence (1775-1783) signified the starting point for bridge building in America. Before then, the colonies on the eastern seaboard were relatively self-contained, communicating more with Europe by sea than overland.

With the establishment of the American nation, the need for good highways to carry trade between its states became quickly evident, and so too did the need for the bridges that would carry those highways across the major rivers that flowed eastward to the seaboard.

The most characteristic of old American bridge profiles seems to date from 1805, when one of the most prolific and skilful of early American bridge builders, Timothy Palmer, erected a three-span arch-truss over the Schuylkill River in Philadelphia, Pennsylvania. This structure would have remained an open frame had not the president of the Schuylkill Bridge Company (the bridge's financiers) insisted that it be completely enclosed in boarding for protection. It was a commonsense approach to the durability problems inherent in timber, and was soon followed all over the country. The creaking, dark, mossy tunnels became one of the earliest characteristics of rural pre-industrial America (Brown (1)).

The Schuylkill River Bridge was a continuous structure consisting of two 150-foot (45.7m) end spans and a 195-foot (59.4m) central span and was also known as the Permanent Bridge, as it replaced a pontoon bridge. Figures 2 and 3 show details of the Schuylkill River (or Permanent) Bridge. The Schuylkill River Bridge was destroyed by fire in 1875.

It is interesting to note that although the Schuylkill River Bridge is generally accepted as the first known covered bridge constructed in America there are some reference sources that mention a bridge (referred to as the Waterford Bridge) constructed by Theodore Burr in 1804, over the Hudson River between Waterford and Lansingburgh, New York, as the first covered bridge built in America. There is no apparent vigorous debate, as the references that mention the Waterford Bridge do not refer to the Schuylkill River Bridge and vice versa.

2 THE COVERED BRIDGE

By 1810, the practice of covering timber truss bridges had become standard. The construction of covered bridges flourished in the United States between 1810 and 1910 and an estimated 10,000 covered bridges were built between 1805 and 1885. Most covered bridges were small, ranging from 100 feet (30.5m) to several hundred feet. Figure 4 shows a typical covered bridge setting.

However, the number of these timber bridges has dwindled to under 850, as their narrow width has made them largely obsolete, they are susceptible to destruction from fire, flooding, high winds, and overloaded vehicles and they are lost to decay and neglect. Also, many covered bridges were burnt during the American Civil War (1861-1865) to keep the enemy from crossing the waterway.

Today, covered bridges are generally owned by a state or a town, and traffic moves through them for free. This is a comparatively recent development. Private ownership and subsequent bridge tolls were common in the early years, along with municipal lotteries authorised by legislature. Tolls were taken to provide money to pay for the upkeep of the bridges. And towns often wound up owning bridges after toll companies folded.

Until the mid nineteenth century, mathematical engineering analysis was not widely practised, and bridges were designed by a combination of intuition, experimentation and practical experience. Models were built and loaded until failure; broken members were replaced with stronger ones until the model could support a load equivalent to the live load of the real bridge plus a safety factor. At the time of the scientifically designed trusses of the 1830s and 1840s, America took the lead in timber bridge design, surpassing earlier European accomplishments of the seventeenth and eighteenth centuries.

These days, covered bridges are considered historical landmarks, romantic structures resembling the past. There were thought to be many reasons why bridges were covered, although not all of these ideas were correct. Some explanations follow:

- To resemble barns so farm animals would feel more at home and not stampede as they were driven across the rushing waters;
- To keep snow off the bridge;
- To keep the oiled planks of the deck surface from becoming dangerously slippery in the rain;
- To cover up the unsightly trusses;
- To provide shelter to travellers caught in a storm.

However, the most plausible reason to cover a bridge was to protect the timber trusses from deterioration due to the effects of the weather. This was the reported reason associated with the first covered bridge constructed in the United States, mentioned earlier. Another positive effect of covering a bridge was that the cross-braced roof provided lateral stability to the top compression chord of the truss, thereby providing increased load-carrying capacity when compared with a non-covered truss bridge.

Insistence on careful protection from the weather of these bridges inaugurated the distinctly American covered bridge. Covering bridges became so ingrained within the minds of people that almost every bridge built was covered, even though the cost to do so was higher.

3 TRUSS TYPES

Covered bridges are usually identified and classified by their truss construction, as the primary bridging structure of the covered bridge is the truss system. And by keeping the roof and siding in good condition, they seem to last indefinitely. There are three main truss types used for covered bridge, as shown in Figure 1.

Trusses were designed and patented so they could be sold by the foot for a profit. Theodore Burr (1771-1822) developed a truss that allowed a roadway to run level between the supporting arches. The Burr arch/truss was patented in 1817 and combined parallel arches with a framework of multiple king post timbers and counterbraces, a concept so successful that it became the basis for thousands of American covered bridges (refer Figure 5). The design created great strength and allowed, for the first time, long spans averaging over 30.5 metres (100 feet).

Another covered bridge truss emerged with a design by Ithiel Town (1784-1844), patented in 1820, and represented a major departure in the previous Burr arch/truss configuration. It was known as the 'Town lattice' and comprised identical, parallel, diagonal members crisscrossed over one another. They generally used sawn timber with uniform sections throughout.

Town's strongest competitor was Stephen H. Long (1784-1864), a Colonel with the US Army Topographical Engineers. In 1830 he developed the first truss based on mathematical calculations. Long's patented design had some features resembling the Town lattice, but overall it was a series of boxed 'X' shapes.

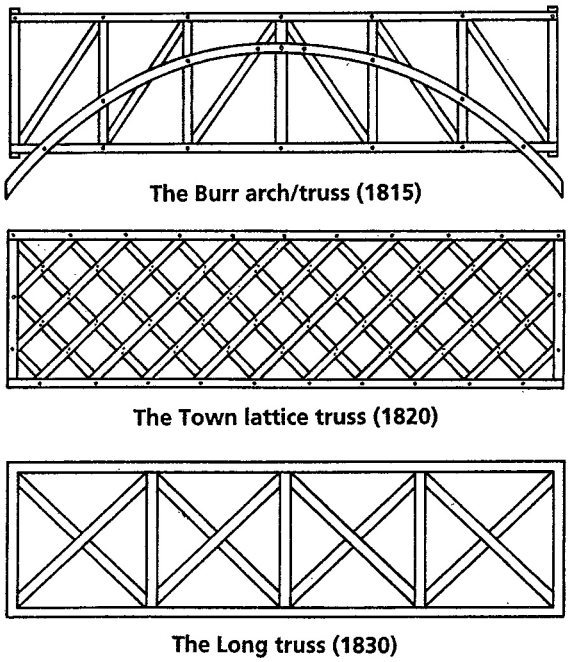

Figure 1: Covered Bridge Truss Types

But after 1840, both the Town lattice and Long truss were largely superseded by the Howe truss (William Howe, 1803-1852). Similar in configuration to the Long truss, all members are timber except the vertical internal tension members, which are adjustable wrought iron rods. A mathematical stress analysis was used for its design. Figure 6 shows a Howe truss covered bridge. The Howe truss was adopted by the railroad industry and became one of the most widely used

trusses for railroad bridges and became the dominant truss form in the period of transition from timber to iron, thus heralding the eventual decline of timber bridge building in America.

When covered bridge building began in the first decade of the 19th century, the designers were not yet known as engineers, and indeed, before the 1840s there was no commonly accepted body of mathematics for stress analysis (Conwill (2)).

Timber used for covered bridge trusses had to be straight, lightweight and sound. Red cedar tended to be the best wood to use in construction. Douglas fir was a favourite in the Northwest and white or yellow pine was used extensively in Pennsylvania. One-piece truss chords were common and economical, felled near the site and hewn on the spot. Fastenings were made of the nearest hardwood, preferably oak, maple or black locust, and soaked in linseed oil for preservation and lubrication. These timber pins (treenails or 'trunnels') were then driven through pre-drilled holes.

4 COVERED BRIDGE INFORMATION

The following Table 1 has been derived from a listing of covered bridges presented in McKee (3). The total number of extant covered bridges in the United States is 844.

State	Extant Covered Bridges
Pennsylvania	216
Ohio	139
Vermont	100
Indiana	92
New Hampshire	54
Oregon	51
New York	30
West Virginia	17
Georgia	15
Kentucky	13
Alabama	12
Iowa	12
California	11
Maine	10
Massachusetts	10

State	Extant Covered Bridges
Virginia	10
Connecticut	6
Illinois	6
Maryland	6
Michigan	6
Washington	6
Missouri	5
Tennessee	5
Wisconsin	4
Delaware	2
North Carolina	2
Minnesota	1
New Jersey	1
South Carolina	1
Texas	1

Table 1: Extant Covered Bridges in the United States

It is suggested that the 1829 Bath/Haverhill bridge in New Hampshire, a two-span Town lattice truss bridge, is the oldest covered bridge still in use in the USA.

The vast majority of covered bridges are single lane structures. The covered bridges designed for two-lanes, referred to as 'double-barrel' bridges, have a third truss along the centreline of the structure. There are only six of these bridges still in existence in America.

To a much lesser extent than the four main truss types, other trusses were used for covered bridges such as the Warren truss, Pratt truss, Paddleford truss, Haupt truss, Smith truss, Partridge truss,

King truss, Queen truss, Post truss, Wheeler truss, Multiple King Post truss, Brown truss, Wernwag truss, Bowstring truss, Childs truss, and McCallum truss.

The Powerscourt Covered Bridge (1861) in Huntingdon County, Quebec, Canada has the distinction of being the only remaining example of a McCallum arched truss in the world, and perhaps the only one ever built on a public roadway. This truss type was patented in America in 1851 for railway use. It is interesting to note that two McCallum truss road bridges were constructed in New South Wales, at Cowra (1870) and Casino (1874).

The longest single-span covered bridge in the world is the Bridgeport Bridge in Nevada County. California. It was constructed in 1862, has a span length of 71 metres (233 feet) and uses a combination of Howe truss and timber arch to support it.

The last covered bridge in the United States built solely for economic reasons, with no thought of nostalgia, was the Irish Bend Bridge in Benton County, Oregon, which dated from 1954 (Conwill (2)).

5 STRUCTURAL ENGINEERING ANALYSIS

The majority of covered bridge construction in the United States occurred between 1810 and 1910, well before any published standard for bridge design. The current standard used for bridge analysis and design is the American Association of State Highway and Transportation Officials (AASHTO) Standard Specification for Highway Bridges, which first appeared in 1931. Even with the introduction of this design standard, there is little guidance relating to the analysis of existing covered bridges or the design of new covered bridges. In response to this need and for the care and preservation of covered bridges the Federal Highway Administration has recently released a document entitled ‘Covered Bridge Manual’. A specialty team of consulting engineers, with experience in over 100 covered bridges prepared the manual.

The Department of Transport in each American state usually require a bridge that is being repaired and/or restored to be upgraded to an HS20 load rating. This loading is the standard for most interstate highway bridges and qualifies the bridge to carry all legal traffic vehicles. In most cases, a covered bridge that was originally designed for a 6 or 12 ton traffic load will require substantial strengthening in order for it to be upgraded to the HS20 rating.

How the Burr arch/truss actually works is a topic of debate amongst bridge engineers in North America. One school of thought has it that the arches do the work, while the other believes it is the parallel chord trusses. A recently reported structural analysis showed the arch to be dominant in carrying the dead load of the bridge, while the truss primarily provides resistance against concentrated live loads.

The Town lattice provides for another intriguing analysis. The classic configuration of Town lattices uses pairs of chord members on each side of the criss-crossed web members leading to six vertical planes of truss members. Each intersection of lattice is fastened with usually two trunnels (timber pins) in the lattice-only connections and either three or four at the chord intersections. Determination of the actual forces and stresses in the individual components, especially the trunnels, is extremely difficult and time consuming.

The Burr arch/truss and the Town lattice truss were not originally designed using structural analysis principles, as Theodore Burr and Ithiel Town were not bridge engineers. As such, these trusses are 'belts and braces' designs and hence difficult to analyse.

When considering the combined concerns of advancing age of the covered bridges, the need to protect the travelling public, and the awareness of historic preservation, developing accurate and appropriate methods of structural analysis and load rating of covered bridge trusses is crucial.

6 PRESERVATION OF COVERED BRIDGES

6.1 General

A profound reason for preservation is to maintain links to our past. We can read about our beginnings to learn who we are and where we came from, but the actual places and things provide a sense of scale to make history real (Nelson (4)).

Several state highway departments have initiated historic bridge programs. Where it has been tried, the repair of historic bridges has proven less costly than replacement. Ensuring the preservation of bridges, however, requires commitment (DeLony (5)).

To preserve historic bridges, special cooperation of historians and people in transportation with bridge engineering experience is needed. It is also essential to have an informed public, who recognise the significance of historic bridges and care that the best examples are saved for the enrichment of posterity.

There are a number of covered bridge societies in the United States, formed on a state basis. The Vermont Covered Bridge Society, Theordore Burr Covered Bridge Society of Pennsylvania, New York State Covered Bridge Society, Oregon Covered Bridge Society, Indiana Covered Bridge Society, Ohio Historic Bridge Association, Kentucky Covered Bridge Association and National Society for the Preservation of Covered Bridges are a number of organisations established to encourage public interest and local participation in historic covered bridge preservation. They are instrumental in the preservation and documentation of the timber covered bridges and have members from around the world.

Historic bridges can be preserved without endangering or inconveniencing the general public. Many historic bridges that do not meet AASHTO standards are still perfectly serviceable. For example, AASHTO requires a 30-foot wide bridge deck. This width is impossible to achieve on many historic bridges built for narrower and one-lane roads. However, these bridges may be upgraded and used for one-way traffic, provided other routes serve the town. Figure 7 shows such a case, whereby an adjacent bridge and the historic covered bridge provide separately for one-way traffic. They can also be used for pedestrians only, with an adjacent bridge devoted exclusively to traffic.

Although glued laminated timber has been used successfully in the repair of historic covered bridges and in the reconstruction of others, an "in kind" rehabilitation, using similar species and grade of solid timber, as the original, represents the preferred option.

Strengthening methodologies should be designed to conform to 'The Secretary of the Interior's Standards for the Treatment of Historic Properties 1995'. This document specifies four distinct, but

interrelated, approaches to the treatment of historic properties – Preservation, Rehabilitation, Restoration, and Reconstruction.

Recent timber bridge strengthening developments include glass fibre reinforced polymer (GFRP) materials and epoxy adhesives. GFRP reinforcing bars, embedded in timber, are intended to be used specifically to increase axial capacity of truss members and GFRP plates are to be bonded to the bottom face of floor beams to increase bending capacity. These methods are non-intrusive and comply with the guidelines of the abovementioned standard document.

6.2 Burlington Charter

The Burlington Charter for the Preservation of Historic Covered Bridges was approved on 6th June 2003 at the First National Best Practices Conference for Covered Bridges, held in Burlington, Vermont, USA.

Covered bridges are vitally important cultural, economic, educational, aesthetic, and historic resources. Although public support for preserving them is strong, many are vulnerable to the effects of deterioration due to neglect, limited funding, and limited knowledge of appropriate treatments. Consequently, their structural, material, and functional integrity is often at risk. This charter establishes the following goals for ensuring the long term safeguarding of historic covered bridges:

- To preserve the historic structural and material integrity of covered bridges to the maximum extent possible, consistent with public safety;
- To identify, document, and preserve examples of covered bridge design, ingenuity in timber and masonry construction, and unique practices or solutions to specific problems; and to encourage future generations to summon similar ingenuity;
- To retain covered bridges for in active use for transportation, with the least possible compromise to their structural and material integrity;
- To identify, document, and preserve all surrounding features that define the historic character of covered bridges and their settings, including approach roads, historic cultural landscapes, and views;
- To interpret and publicise individual covered bridges and the overall importance of the covered bridge to the history of transportation, engineering, and community life;
- To establish partnerships among bridge owners; local, state, and federal governments; non-profit organisations; design and construction professionals; craftspeople; and others in order to provide the best opportunities for cooperative stewardship of covered bridges;
- To undertake research to develop tools essential to the preservation of historic covered bridges, including studies of appropriate treatments of historic materials; methods of structural analysis; techniques for repair and strengthening; and the economic benefits of preserving historic covered bridges;
- To develop management practices that ensure timely identification of needs and prioritisation of treatments;
- To encourage government agencies and other public and private entities to provide adequate and effective funding to implement the above goals.

Resolved: Participants of the First National Best Practices Conference for Covered Bridges hereby adopt this Burlington Charter for the Preservation of Historic Covered Bridges. Be it further resolved that we respectfully ask the U.S. National Park Service to develop guidelines that apply and adapt the Secretary of the Interior's Standards for Preservation, Rehabilitation, Restoration, and Reconstruction to historic covered bridges in a manner consistent with these goals and objectives,

and to present these guidelines at the Second National Best Practices Conference for Historic Covered Bridges, at a time and place to be announced.

7 HAER PROJECT

The Historic American Engineering Record (HAER) was established in 1969 to create a graphic and textual archive of America's industrial and engineering achievements of historic interest.

The HAER project is concerned with documenting a selection of fifty of the most significant covered bridges in North America. It is a three-year program, and is close to completion. Field teams produce the following documentation:

- Measured and interpretive drawings;
- Engineering analysis reports;
- Written historical reports;
- Large-format photographs.

Once completed, the final products will become part of the Historic American Buildings Survey (HABS)/HAER collection at the Library of Congress, in Washington, DC. This documentation will also serve as a basis for other components of the project:

- A US National Park Service theme study to consider covered bridges meriting consideration as National Historic Landmarks;
- A website and interactive presentation of covered bridge documentation;
- A travelling exhibit on covered bridges;
- An updated edition of the World Guide to Covered Bridges;
- A study linking covered bridge construction and restoration practises to local and regional timber framing techniques;
- A Best Practices Handbook;
- Conferences, which bring together covered bridge experts and enthusiasts to determine and evaluate covered bridge preservation, repair and maintenance issues.

8 COVERED BRIDGES OF CANADA

Covered bridges were also constructed in Canada. The following Table 2 has been derived from a listing of covered bridges presented in McKee (3). The total number of extant covered bridges in Canada is 168.

Province	Extant Covered Bridges
Quebec	97
New Brunswick	68
Ontario	2
British Columbia	1

Table 2: Extant Covered Bridges in Canada

Government covered bridges were built in Quebec and New Brunswick, which had large supplies of good timber. Quebec really started the trend amidst a special set of cultural circumstances. In

Quebec, throughout the 19th century, many French political leaders rejected modern industrial society in favour of an agrarian model, but to support their growing population it was necessary to expand the land base in agriculture. In 1887, nationalist Premier Honore Mercier created a Department of Colonisation to offer government support for land settlement plans. Roads and bridges were included in this support, and the bridges were covered ones.

The Department of Colonisation modified the Town lattice truss so that it could be built cheaply by unskilled labour. Metal spikes took the place of wooden treenails (or 'trunnels') at the joints. Plans came from an engineer in Quebec City, the construction superintendent was an agent of the Department of Colonisation, and the settlers often provided themselves as unpaid labour. Seventy-one of these "colonisation bridges" still stand in Quebec, and they were built into the mid 1950s.Some however were built by paid contractors instead of by settlers.

New Brunswick also had a colonisation movement, though less extensive than that of Quebec. New Brunswick, too, built covered bridges by government plan, up until 1958. The province also built many non-covered, creosoted timber trusses, these as recently as 1972. Little is known of the history of New Brunswick's covered bridges, but although engineers in Fredericton, the province capital, drew up the plans, it seems local contractors in the craftsman tradition mostly built them.

9 CONCLUSION

Covered bridges represent a visual testament to North American civil engineering and symbolise small-town America.

Although they are a scene from yesteryear they can still play a role today and many of these historic covered bridges are being restored and maintained as functioning structures, thanks to an increasing interest in historic preservation, tourism and the efforts of many dedicated bridge enthusiasts.

10 REFERENCES

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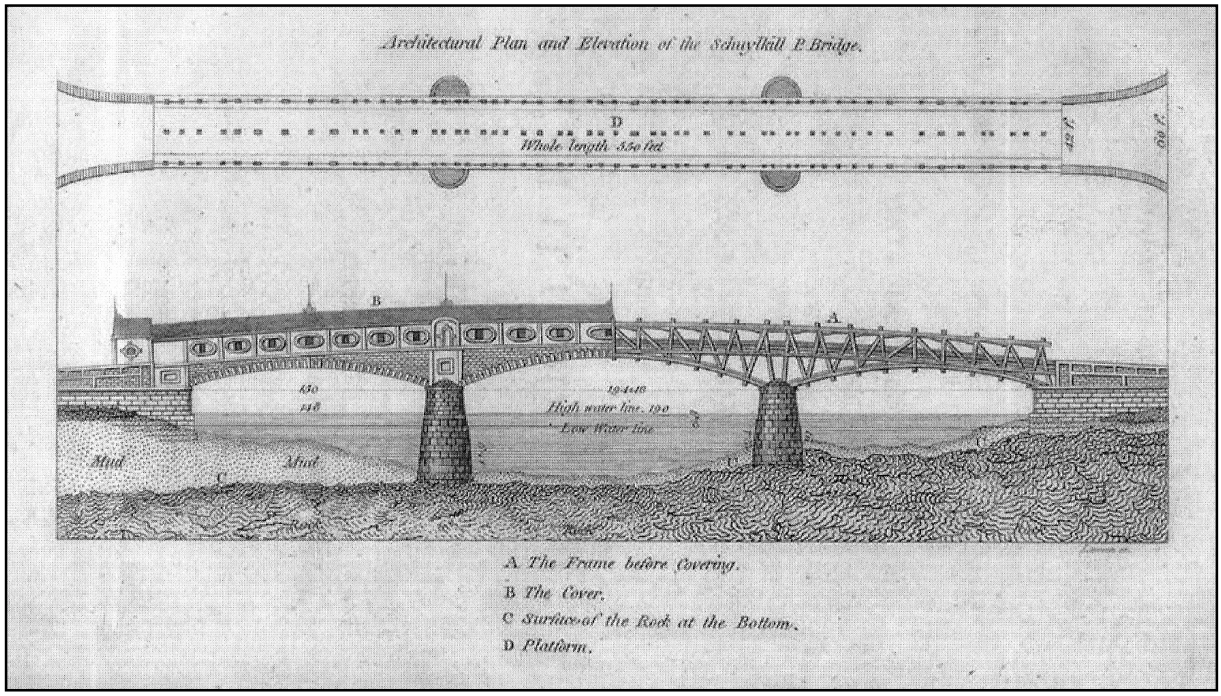

Figure 2: Schuylkill River Bridge, Philadelphia, Pennsylvania (1805)

Figure 3: Schuylkill River Bridge, Philadelphia, Pennsylvania (1805)

Figure 4: Hammond Bridge, Vermont (Town lattice truss, 1842)

Figure 5: Medora Bridge, Indiana (Burr arch/truss, 1875)

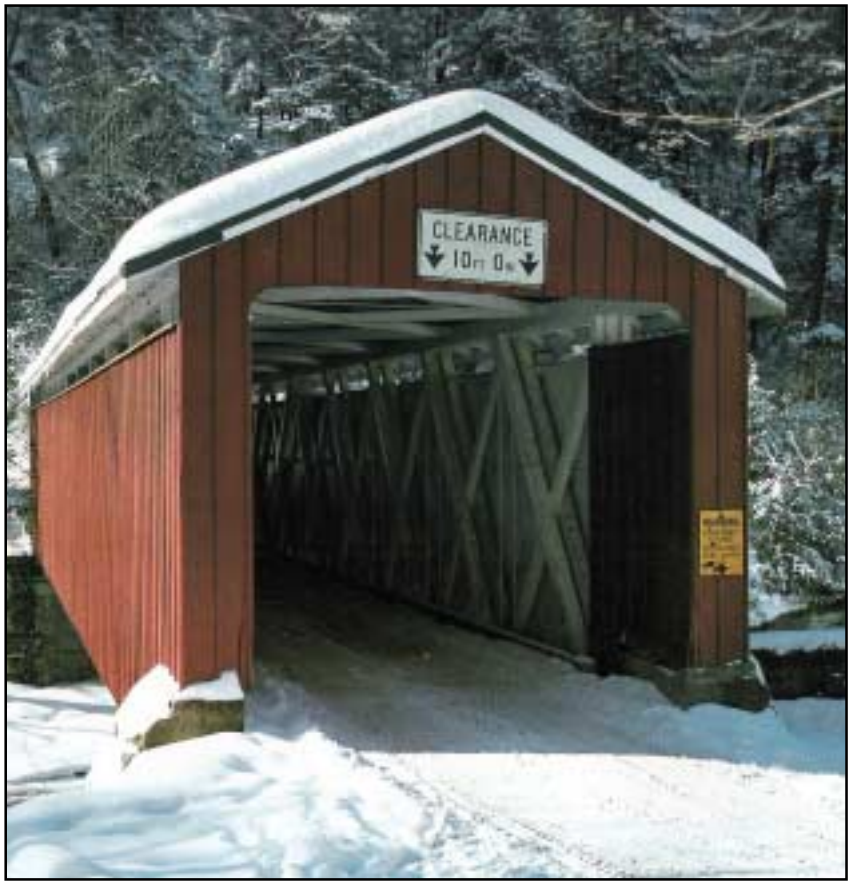

Figure 6: McConnell's Mill Bridge, Pennsylvania (Howe truss, 1874)

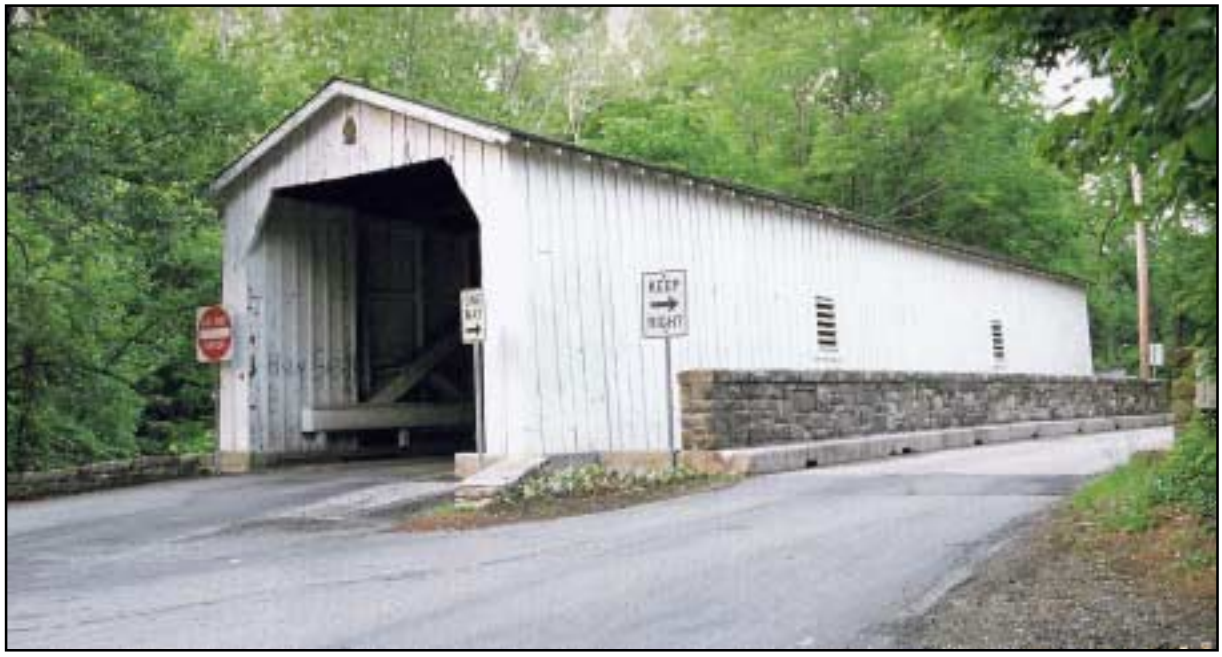

Figure 7: Green Sergeants Bridge, New Jersey (Queen truss, 1866)