Lenticular Iron Truss Bridges in Massachusetts

Built from about 1880 to 1900, these bridges represent a unique design during a time when many bridge companies were competing for contracts in a highly competitive market.

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Of the estimated hundred or so lenticular iron truss bridges built by the Berlin Iron Bridge Company between about 1880 and 1900 in the Commonwealth of Massachusetts, only nine are known to still exist. Only three of these bridges are currently open and in use for vehicular traffic. Of the remaining six, two are closed to vehicular traffic, two have been restored and relocated for use as pedestrian/bikeway bridges, and two have been dismantled and their parts are currently in storage, awaiting reuse/restoration.

Lenticular Truss Bridges

During the latter part of the nineteenth century, the Berlin Iron Bridge Company of East Berlin, Connecticut, manufactured and erected something on the order of 400 lenticular truss bridges in the United States.[1,2] These bridges are sometimes referred to as "pumpkin-seed bridges," "fish-belly bridges," "cats-eyes bridges," "elliptical truss bridges," "double bowstring" or "parabolic truss bridges" because of their unique lens shape. Like many other iron truss bridges of the day, these bridges were, in effect, mass produced since the components were built in a factory, sent to the site and then assembled. Many of the components were used repeatedly for different spans or applications.

According to James, lenticular-shaped bridges had previously been used in Europe as early as 1822.[3] It appears that one of the first uses of this type of design was George Stephenson's iron railway bridge designed in 1822 and built between 1823 and 1824 to carry the Stockton & Darlington Railway over the river Gaunless in West Auckland, England. As shown in Figure 1, the bridge consisted of four spans of 12.5 feet (it originally had three spans — the fourth span was added in 1825) with top and bottom chords of wrought iron and the vertical members of cast iron. The members were built by Burrell & Company of Newcastle. The bridge was opened on September 27, 1825, and was in use until about 1856. The bridge stood intact but unused until 1901, when it was dismantled and moved to storage. In 1928, the bridge was re-erected at the York Railway Museum and is currently on display at the British National Railway Museum.

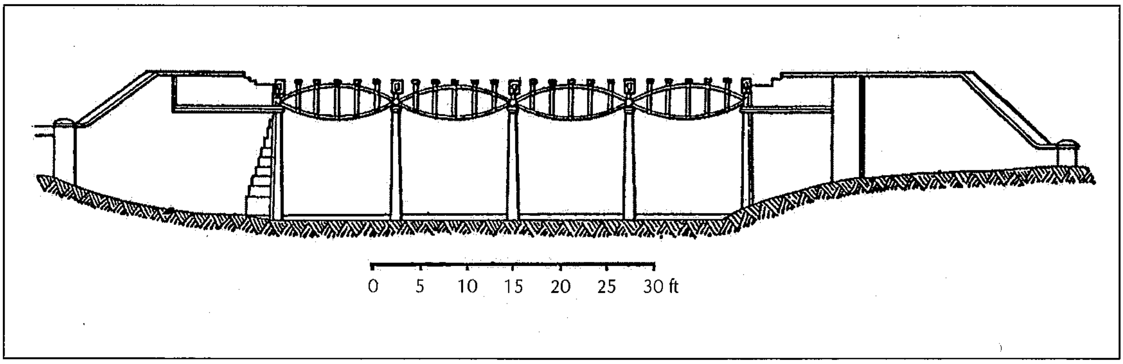

FIGURE 1. Stockton & Darlington Railway Bridge (1823).

One of the most notable bridges of this style was I.K. Brunel's 1855 twin-span lenticular Royal Albert Railway Bridge across the Tamar in Saltash, United Kingdom (see Figure 2). This bridge used tubular upper chords with each span having a span of 445 feet (center to center of the piers). In 1860, the Mainz Bridge was built over the Rhine River in Germany and consisted of at least two large spans and two shorter spans as shown in an early lithograph (see Figure 3). This bridge shows remarkable similarities in form to the lenticular truss bridges built twenty-five years later by the Berlin Iron Bridge Company.

In the United States, Gustav Lindenthal built a lenticular-shaped twin-span bridge across the Monongahela River at Smithfield Street in Pittsburgh in 1883 (see Figure 4). Lindenthal referred to this shape as a "Pauli truss" after the famous German bridge engineer Friedrich August von Pauli (1802–1883).[4] Von Pauli had designed a number of lenticular bridges, referred to as *fischbauchtrager* (fish-bellied) in Germany prior to 1860.[5] Each span

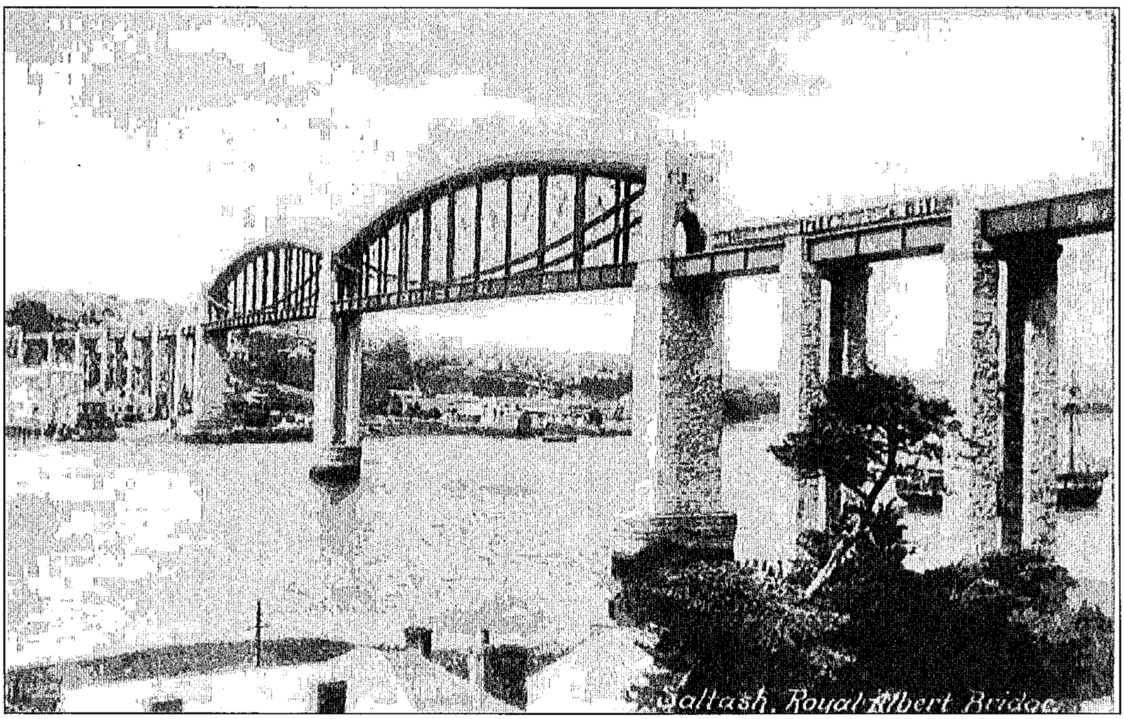

FIGURE 2. I.K. Brunel's Royal Albert Lenticular Bridge (photo circa 1920).

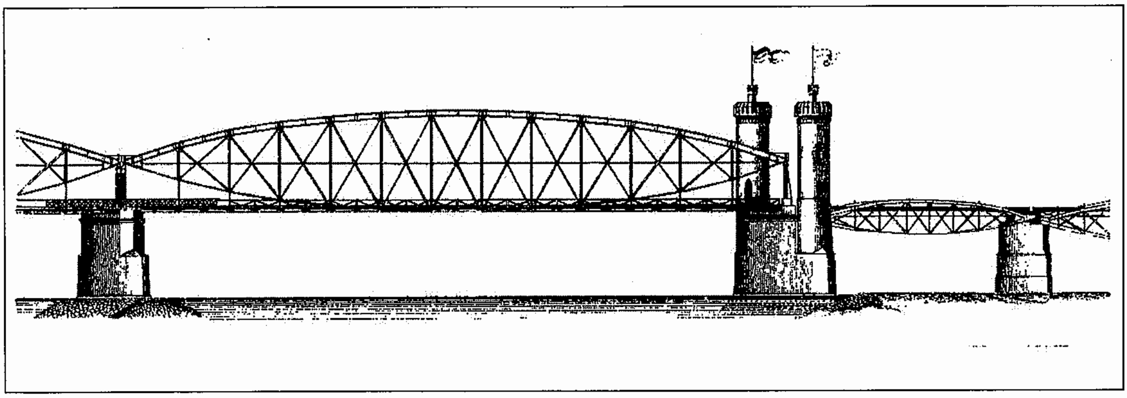

FIGURE 3. Rhine River Bridge in Mainz, Germany.

of the Smithfield Street Bridge originally was constructed using two trusses; a third truss was added to carry additional lanes of traffic in 1891. This bridge replaced an earlier one designed and built by John Roebling, but did not really receive the attention that perhaps Lindenthal had been hoping for. This lack of recognition may have been in part related to the fact that another bridge that opened in 1883, one that may have had considerably more importance at the time — namely, the Brooklyn Bridge. However, the structures of von Pauli, Brunel and Lindenthal were unique, single event, monumental bridges, never to be duplicated in any close form by any other engineer at any other location.

By contrast to these few single large-scale structures, the hundreds of smaller lenticular truss bridges built by the Berlin Iron Bridge Company were catalog bridges and their designs were duplicated many times throughout New England and the mid-Atlantic states. In fact, the Berlin Iron Bridge Company built the only lenticular iron truss bridges known to

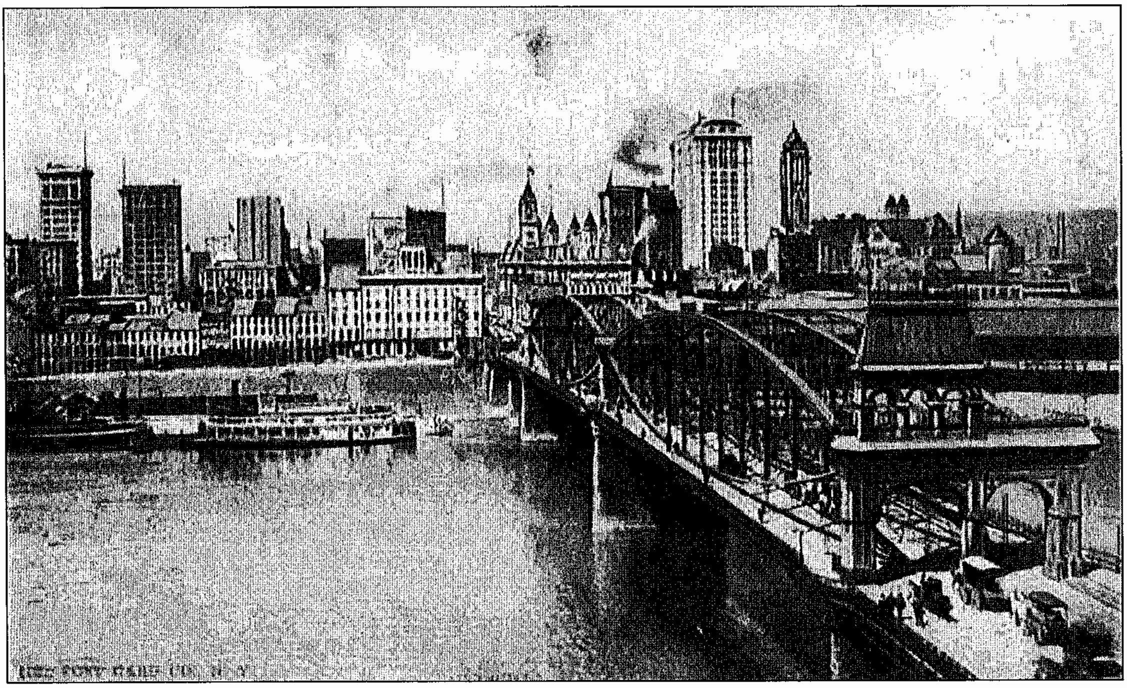

FIGURE 4. Gustav Lindenthal's Smithfield Street Bridge in Pittsburgh.

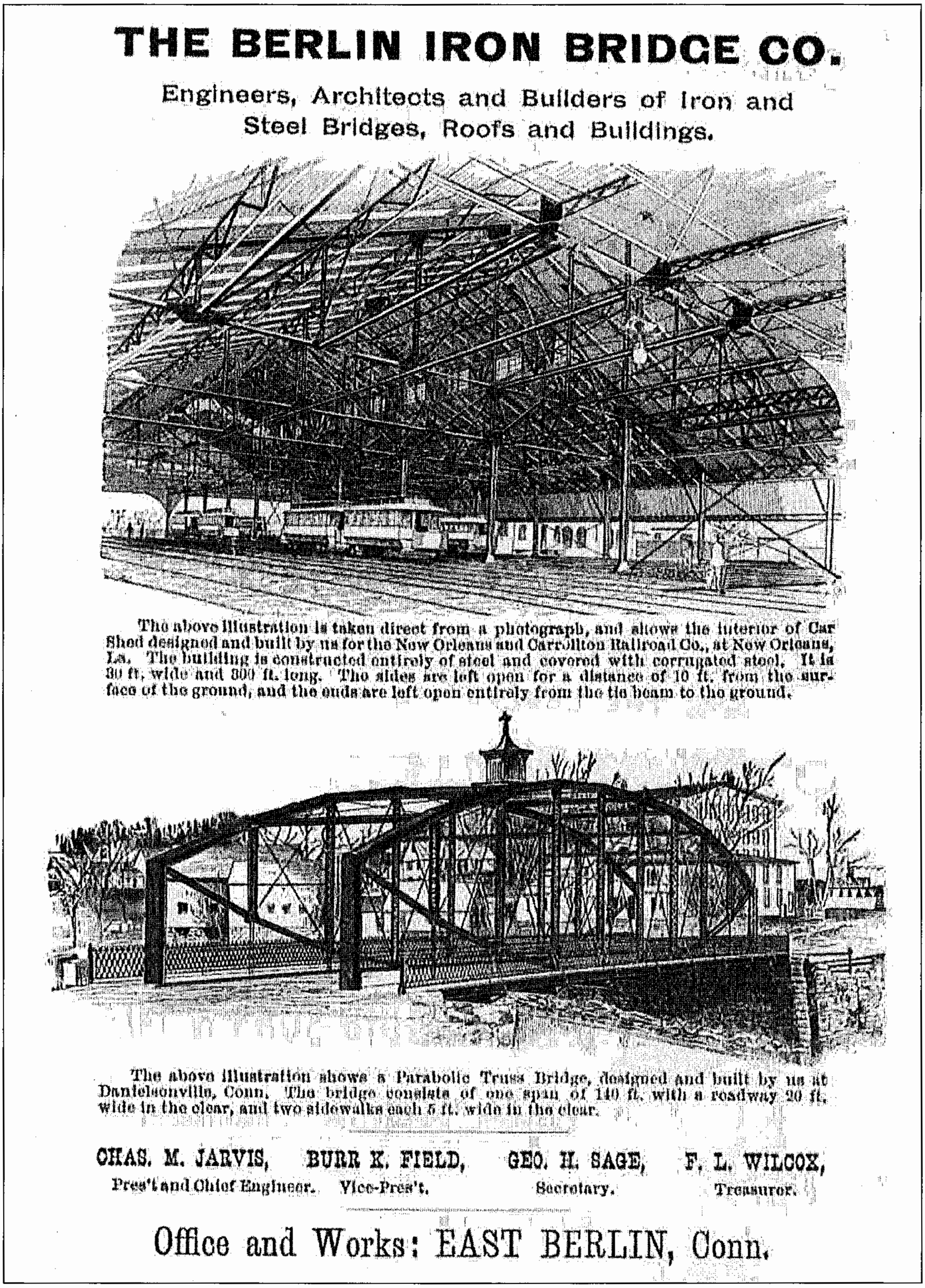

FIGURE 5. Berlin Iron Bridge Company advertisement.

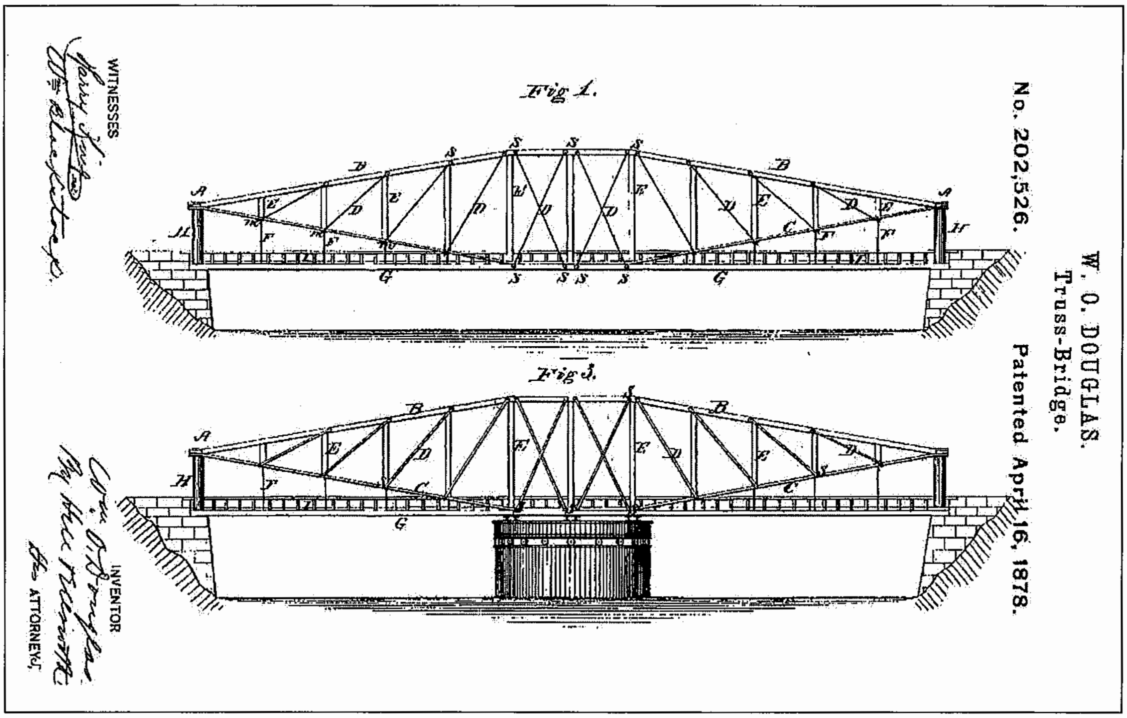

FIGURE 6. Drawings from William O. Douglas's 1878 patent.

have been erected in the United States, aside from Lindenthal's Smithfield Street Bridge. These bridges were only used for vehicular traffic and were generally considered too light to be used for railroad and trolley loads, although it is known that at least one (in Portland, Maine) did also serve as a trolley bridge. Considering that the most common traffic of the era (1880–1900) consisted of horse-drawn carts or wagons, it is amazing that any of the bridges survived through the automobile age and to the present day. Most of the bridges that were lost over the years were not because of failures from overloading; most were swept away during severe floods.

Darnell describes a number of lenticular bridges and gives a detailed account of the history of the Berlin Iron Bridge Company.[1] In addition to the uniquely shaped lenticular truss bridges, the Berlin Iron Bridge Company also built conventional steel truss bridges and even built a few pedestrian suspension bridges (the most notable of which were erected in Keesville, New York, and Milford, New Hampshire). In addition to bridges, the Berlin Iron Bridge Company had a thriving business building roof trusses, water towers and complete steel frames for buildings, as the advertisement shown in Figure 5 illustrates. The company was very persistent in its advertising and routinely placed advertisements in a number of important and influential trade magazines and journals of the day, including the *Transactions of the American Society of Civil Engineers*.

The Patents of William O. Douglas

A patent (No. 202,526) was issued by the U.S. Patent Office on April 16, 1878, to William O. Douglas, of Binghamton, New York, for a truss bridge. This bridge was described in the patent as "a combination of two or more elliptical trusses connected as herein described with the floor and joints and necessary flooring to form a through deck or swing bridge." Two of Douglas's patent drawings showing a suspended deck design (*i.e.*, deck tangent to the lower chord) are shown in Figure 6. A number of these bridges had been built by the predecessor of the Berlin Iron Bridge Company, the Corrugated Metal Company, out of its small manufacturing plant located in

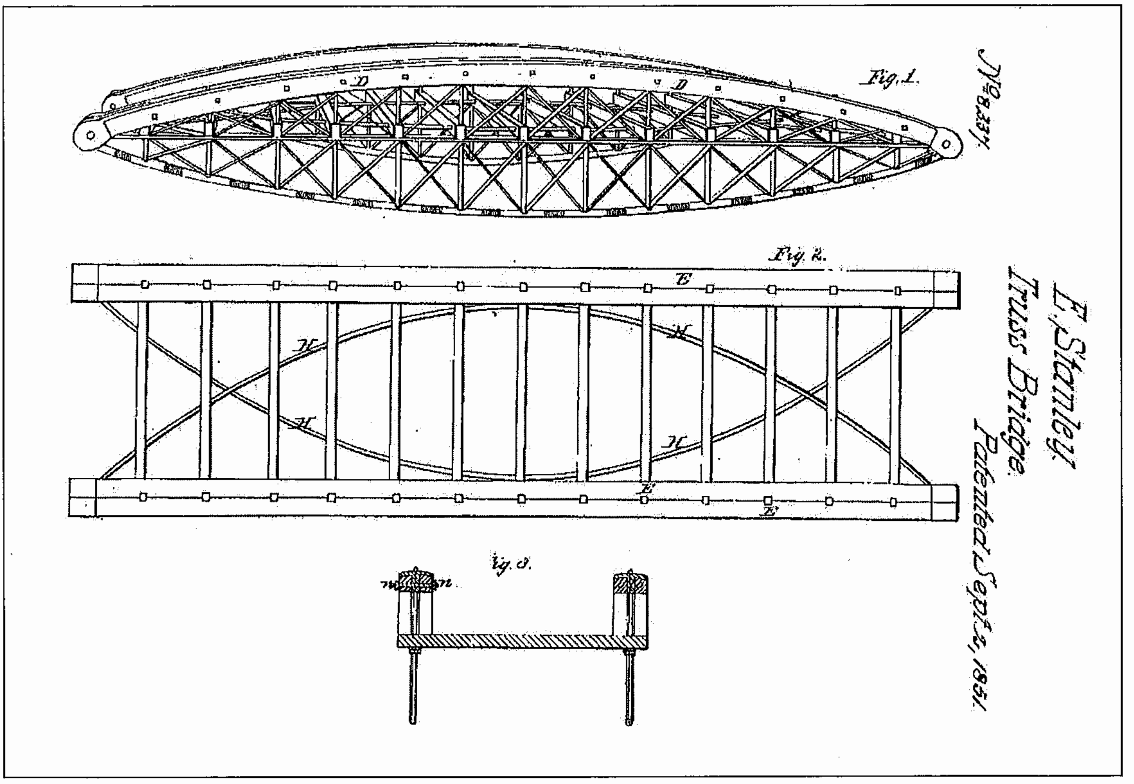

FIGURE 7. Patent drawing of the 1851 Stanley "truss bridge."

Berlin, Connecticut. The smallest of these bridges consisted of three panels, with a span of only about 40 feet. Earlier patents for lenticular-shaped bridges (sometimes referred to as "oval" or "parabolic" or "elliptical" in the patent documents) with similar features to those of Douglas's design had previously been issued by the U.S. Patent Office:

- on March 27, 1849, to James Barnes (No. 6,230); on September 2, 1851, to Edwin Stanley, N.Y. (No. 8,337);
- on August 21, 1855, to Horace L. Hervey and Robert E. Osborn (No. 13,461);
- on March 28, 1871, to Ferdinand Dieckmann (No. 113,030); and,
- on October 22, 1872, to George E. Harding (No. 132,398).

Only Stanley's patent drawing shows any close resemblance to the lenticular shape used by Douglas as shown in Figure 7.

It is interesting to note that Douglas had published his suggestion for his bridge design in an 1877 printing of the *Scientific American Supplement*, showing an illustration of his proposed design (see Figure 8). Douglas referred to his design as "an elliptical truss bridge," noting that:[6]

> "In a bridge as above illustrated in Fig. 2, we have the arch and suspension principles united, forming an elliptical truss. The thrust of the arch equipoises and is equipoised by the pull of the cable."

He further noted that:

> "The roadway is suspended to the two chords so that the arch carries one half of the load and the cable the other, under which circumstances the thrust and the pull at the top of end posts will be equal. The end posts have only to support the dead load of the bridge."

Douglas's public disclosure of his design (on July 14, 1877) predates his patent application

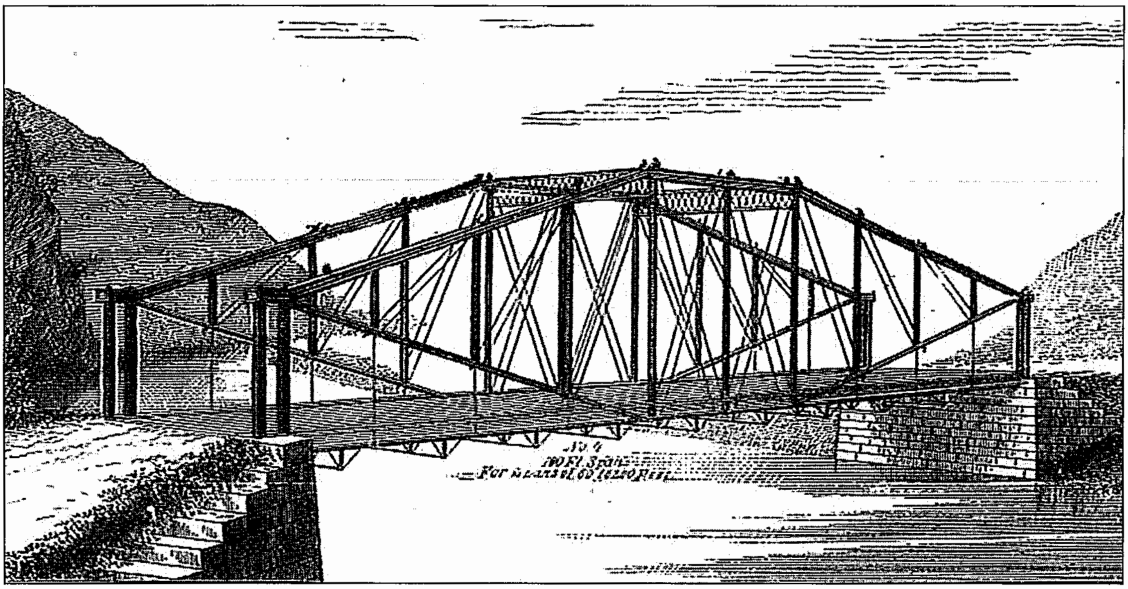

FIGURE 8. Douglas's suggestion for an elliptical truss bridge (1877).

(March 28, 1878) by nearly eight months. This article is the only known publication by Douglas or any other engineer associated with the Corrugated Metal Company or the Berlin Iron Bridge Company related to the lenticular design during this era.

It appears that the first lenticular bridge built by the Berlin Iron Bridge Company was a four-panel pony truss bridge apparently built in 1879 and erected at Waterbury, Connecticut, spanning the Naugatuck River. This bridge is still standing and is still in use as a vehicular bridge. Bridges were built principally throughout the northeast; surviving examples can still be seen in Massachusetts, Vermont, New Hampshire, Rhode Island, Connecticut, and New York, New Jersey and Pennsylvania. It is also known that several bridges were built in Ohio, but it seems that none have survived there. Interestingly enough, there are at least six existing lenticular truss bridges in Texas. These bridges are the only ones known to have been sold and built west of the Mississippi River, and they are thought to have been the work of an extremely enthusiastic freelance salesman in Texas.

The name of the Corrugated Metal Company was changed to the Berlin Iron Bridge Company sometime around 1880 and, according to company literature, the company provided almost 90 percent of the iron bridges roadway bridges throughout New England from 1880 to 1890. Designs for the bridges included both pony truss and through truss configurations. In addition to the suspended deck design shown in Figure 5, Douglas also suggested mid-deck and underdeck designs as illustrated in Figure 9. All of the extant lenticular truss bridges in Massachusetts are of the suspended deck style. A second U.S. patent (No. 315,259) was granted to Douglas for improvements on his design on April 7, 1885. The primary improvements that Douglas incorporated into this patent were the use of floor line tension chords and strut braces. The floor line tension chord was often simply a wrought iron rod running the length of the truss and connected to the end posts on either end. A turnbuckle was used to adjust the tension.

Douglas died around 1890, but the Berlin Iron Bridge Company continued to be very productive under the leadership of several good men. Early advertisements run by the company indicate the following principals: Charles M. Jarvis, President and Chief Engineer; Mace Moulton, Consulting Engineer; Burr K. Field, Vice President; George H. Sage, Secretary; and F. L. Wilcox, Treasurer.

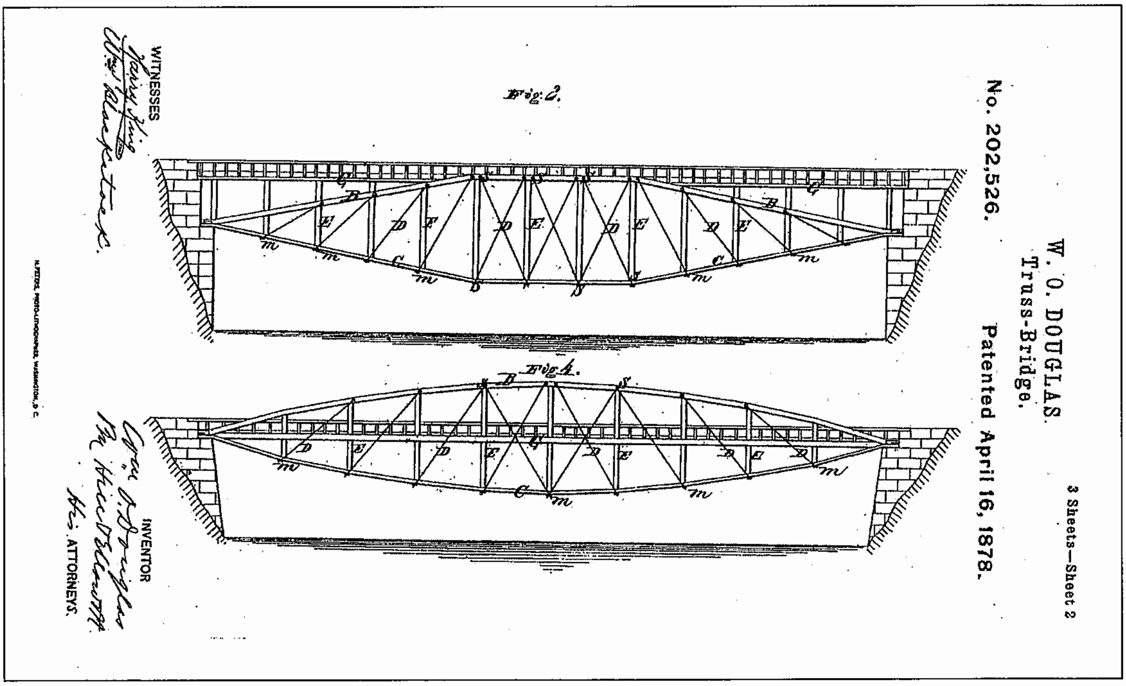

FIGURE 9. Other deck configurations covered by the Douglas 1878 patent.

There was some minor controversy regarding the originality of Douglas's design, especially in so far as the uniqueness of the lenticular shape was concerned.[3] However, it is clear that the Berlin Iron Bridge Company was the only promoter and manufacturer of this style of bridge. The Berlin Iron Bridge Company, under the leadership of Charles M. Jarvis, acquired the rights to Douglas's patent, which accounts for the exclusive promotion of this style of bridge by the company. Additionally, the company must have had excellent salesmen or agents who were most likely paid on commission, many of whom may have had a special affinity to this style of bridge (especially since the company designed and built other more conventional truss bridges). No other lenticular bridges built by any other bridge manufacturer of the era are known to have been designed, built or even advertised. This style of bridge was unique to the Berlin Iron Bridge Company.

Although there is no way to be certain, it is likely that the design of the bridges during this period was by the simple method of graphical analysis (for example, as described by Shreve[7]). This approach would be consistent with design of other, more conventional bridges. In Chapter X of his book, Shreve provides an example of the design of a lenticular truss:[7]

> "The form of this peculiar truss, known also as the Pauli System. . . is not capable of supporting any greater weight than a Bow String Truss of equal depth and length, and practically possesses many disadvantages."

Unfortunately, there are no records available to verify the design approach used by the Berlin Iron Bridge Company. Was Douglas or any of the other engineers associated with these bridges familiar with Shreve's text or other similar structural design books of the era? It is likely that they were familiar with these books and probably did base their designs on the state of the practice for that time period.

Surviving Lenticular Bridges in Massachusetts

Table 1 presents a summary of the surviving lenticular bridges in Massachusetts. Several of the bridges are documented in the *Catalog of*

TABLE 1.
Surviving Lenticular Truss Bridges in Massachsetts

No.	Bridge	Year	Town	Type*	Spanning
1	Golden Hill Rd.	1885	Lee	P	**
2	Pumpkin Hollow Rd.	N/A	Great Barrington	P	***
3	Fort River	ca. 1880	South Amherst	P	Fort River
4	Gilbert Rd.	1888	West Warren	P	Quaboag River
5	Blackstone Bikeway	1887	Millbury	P	Blackstone River§
6	North Canal	N/A	Lawrence	P	North Canal
7	Galvin Rd.	1884	North Adams	T	Hoosac River
8	Bardwell's Ferry Rd.	1882	Shelburne	T	Deerfield River
9	Aiken St.	1883	Lowell	T	Merrimack River

Notes: * P = Pony Truss; T = Through Truss.
** Bridge dismantled and in storage.
*** Bridge dismantled; trusses in open storage.
§ Formerly across the Westfield River in Westfield.

the Historic American Engineering Record. Figure 10 shows the location of the nine remaining lenticular truss bridges in Massachusetts. (The numbers shown in Figure 10 refer to Table 1.) All of the remaining bridges are deck bridges of either the pony truss or through truss configuration and all are single-span bridges (with the exception of

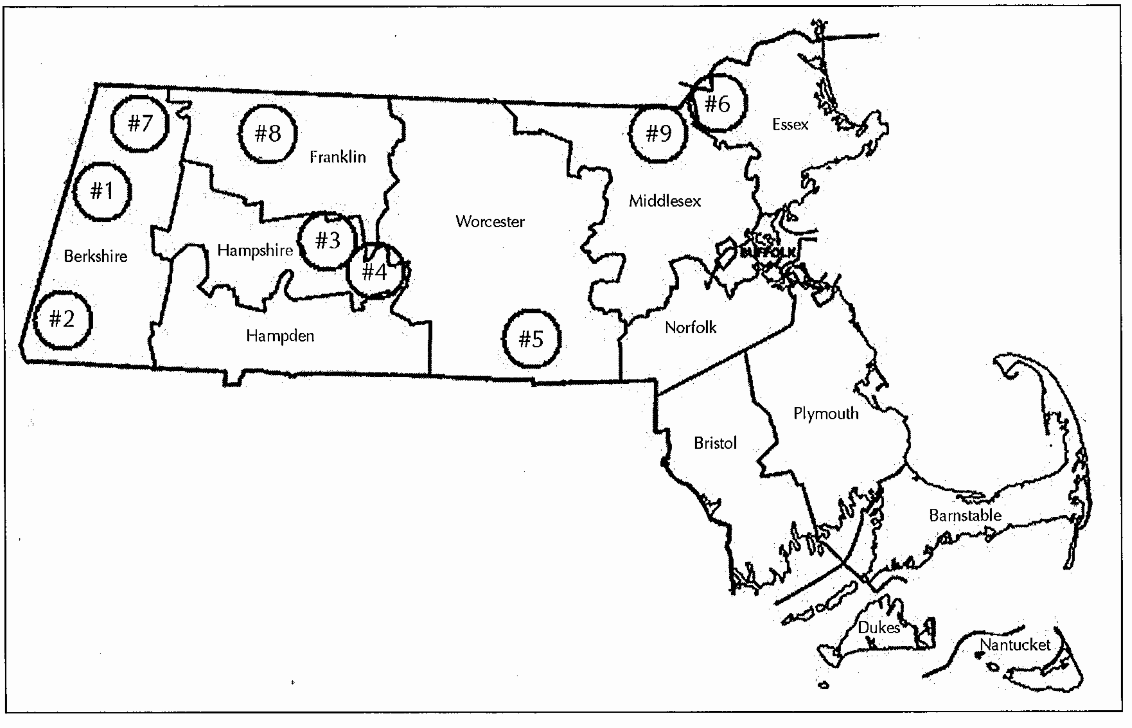

FIGURE 10. The location of the extant lenticular truss bridges in Massachusetts.

TABLE 2.
Characteristics of Surviving Lenticular Truss Bridges in Massachsetts

No.	Bridge	Number of Panels	Span (L) ft.	Mid-Span Height (H) ft.	Aspect Ratio (L/H)
1	Golden Hill Rd.	5	80	8	10.0
2	Pumpkin Hollow Rd.	4	58	8	7.2
3	Fort River	4	60	8	7.5
4	Gilbert Rd.	5	72	8	9.0
5	Blackstone Bikeway	6	74	8	9.2
6	North Canal	5	83	8	10.4
7	Galvin Rd.	7	103	18	5.7
8	Bardwell's Ferry Rd.	13	198	30	6.6
9	Aiken St.	11	153	32.8	4.6

the Aiken Street Bridge in Lowell which has five spans). Table 2 notes the specific characteristics of each bridge.

Surviving Pony Truss Bridges

There are six surviving bridges of the pony truss configuration. Only one of the bridges (the Gilbert Road Bridge in West Warren) is currently being used for vehicular traffic. One of the bridges (the Fort River Bridge in South Amherst) is a pedestrian bridge. One (the Northwest Road crossing in Millbury) is being used as part of a bike trail. One is closed (the North Canal Bridge in Lawrence). Two bridges

FIGURE 11. The Golden Hill Bridge at its old location in Lee.

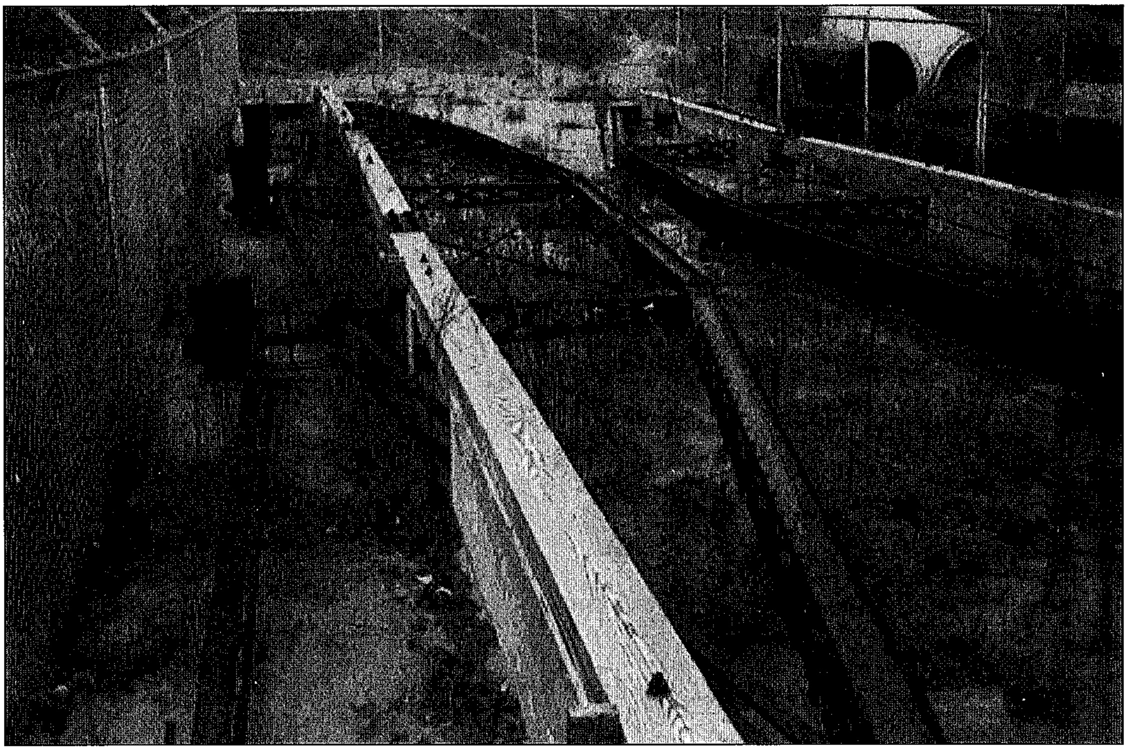

FIGURE 12. The Pumpkin Hollow Road Bridge parts in Great Barrington.

(the Golden Hill Road Bridge in Lee and the Pumpkin Hollow Road Bridge in Great Barrington) have been removed and dismantled. Remaining parts (trusses) of the Pumpkin Hollow Bridge are held in open storage.

Golden Hill Road (Tuttle) — Lee. The Golden Hill Road (Tuttle) Bridge is a five-panel, 80-foot-long pony truss that used to span the Housatonic River in Berkshire County (see Figure 11). The bridge was built in 1885 and is believed to be a virtually unaltered example of the 1885 Douglas patent. The bridge is a typical example of a pony truss and is believed to be one of the longest span pony truss bridges built. The bridge has a mid-span depth of 8 feet and uses all pin connections for the main truss members. Like nearly all lenticular bridges built by the Berlin Iron Bridge Company, the end posts and upper chords are composite open sections constructed of riveted plates and angles and the lower chords are simple eye plates. The bridge has been dismantled and is now in storage. Plans are being developed to reconstruct the bridge as a pedestrian bridge on the campus of the University of Massachusetts at Amherst.

Pumpkin Hollow Road — Great Barrington. The Pumpkin Hollow Road Bridge was originally located in Great Barrington and is believed to have been built around 1885. The bridge was removed several years ago and is currently in storage in Great Barrington. The bridge is a four-panel pony truss configuration with a span of 58 feet and a mid-span depth of 8 feet. Figure 12 shows a photograph of the remaining trusses. The bridge is unique in that it is the only remaining lenticular bridge in Massachusetts in which the end chord connections at the end posts are not pinned; instead, they are bolted through special cast iron end post corner elements (while a number of other lenticular bridges in New Hampshire and New York have similar bolted end post connections, this feature seems to have been fairly rare in Massachusetts).

Only the trusses of the Pumpkin Hollow Bridge were saved when the bridge was dismantled and are apparently all that remain of the bridge. However, they appear to be essentially intact and unaltered from their original construction. The vertical posts are construct-

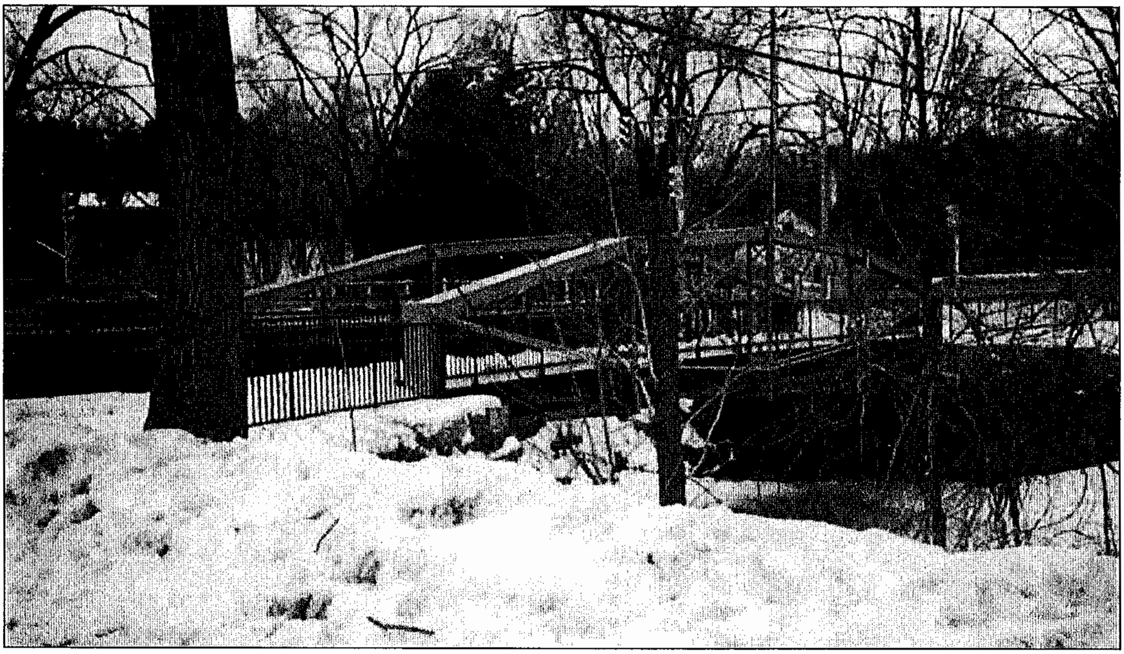

FIGURE 13. The Fort River Bridge in South Amherst.

ed of built-up members and are tapered, much like the Golden Hill Road Bridge.

Fort River — South Amherst. The Fort River Bridge is a 60-foot-long span that crosses the Fort River in South Amherst (see Figure 13). The bridge originally carried vehicular traffic as part of South Pleasant Street (which is now Route 116 between Amherst and South Hadley), but in 1997 the bridge was rebuilt as a pedestrian bridge by the Town of Amherst. The bridge is thought to have been built around 1880 and is the only surviving lenticular bridge in Massachusetts that carries the iron bridge plate indicating that it was built by the Corrugated Metal Company, the predecessor of the Berlin Iron Bridge Company. The Fort River Bridge is a four-panel pony truss with a mid-span depth of 8 feet, giving an aspect ratio of 7.5.

Like all the other pony truss bridges examined for this study, the vertical posts are constructed of riveted angles and plates to create an open lattice form. However, the vertical posts have parallel sides, which is an early configuration used by the manufacturer and which distinguishes it from all other pony truss bridges that were examined. The use of tapered verticals appears to have replaced the parallel verticals so that lighter top chords could be used. The bridge uses pinned connections at the end posts and all other connection points to tie the upper chord and lower chords together. The lower chord is constructed from pairs of 1- by 2-inch eye bars. The Fort River Bridge is very similar in design to the Pumpkin Hollow Bridge in terms of overall aesthetics, but varies significantly in the actual design of both the individual elements and especially in the use of bolted end connections.

Gilbert Road — West Warren. The Gilbert Road Bridge is the only surviving lenticular pony truss bridge that is still in service to carry vehicular traffic. Constructed in 1889, the bridge is a 72-foot span that carries Gilbert Road across the Quaboag River. The bridge is a five-panel pin-connected design with a mid-span depth of 8 feet (see Figure 14). The end posts are topped with an ornate ball-shaped finial and what appears to be the original lattice guardrail. These features give the bridge a slightly more decorative appearance than the other bridges. Like all the other pony truss bridges, the top chords and end posts are composed of a built-up open box section. The upper chord has a width of 14 inches and a

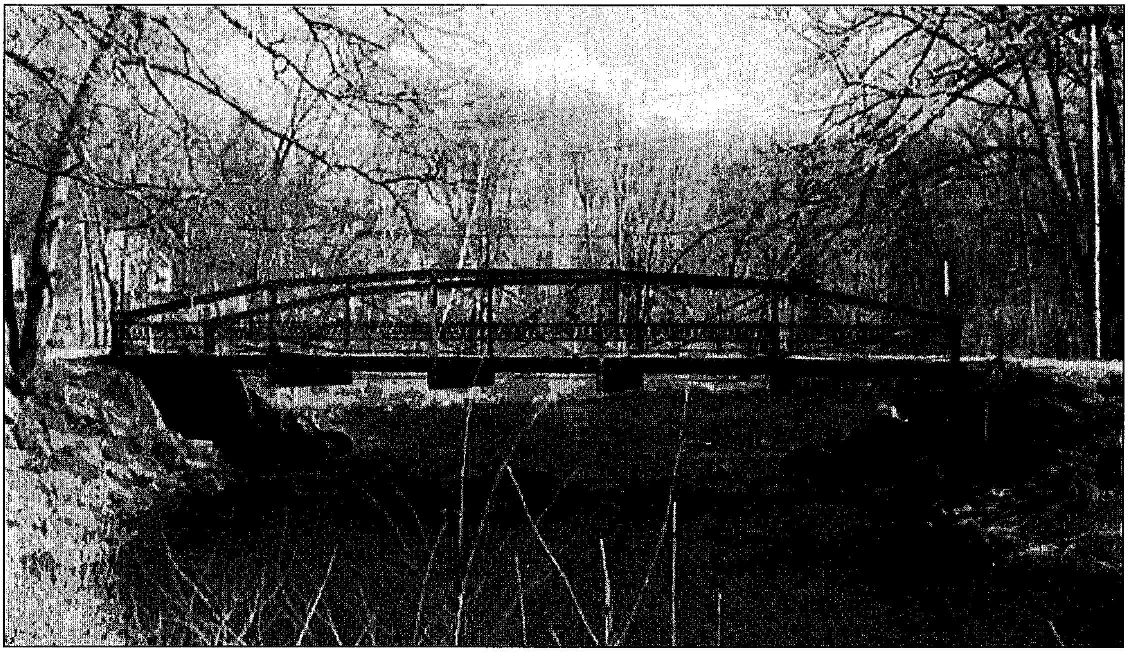

FIGURE 14. The Gilbert Road Bridge in West Warren.

depth of 7.5 inches and is constructed from angles and plates. The lower chords consist of pairs of 1- by 3-inch eye bars. The verticals web posts are tapered built-up lattice members. The bridge is entirely pin connected. This bridge is almost identical in design to the Pumpkin Hollow Bridge, with the exception of the end post top and bottom chord connections.

Northwest Road (Blackstone River Bikeway) — Millbury. The Northwest Road Bridge was originally located in Westfield, Hampden County, and spanned the Little River. In 2001, the bridge was removed and relocated by the Massachusetts Highway Department to Millbury, where it currently is being used as part of the Blackstone Bikeway over the Blackstone River (see Figure 15). The bridge was constructed in 1887 and has a span of 74 feet. The bridge has a pin-connected six-panel pony truss configuration with a mid-span depth of 8 feet. The end posts and upper chords are composed of a built-up open box section consisting of four 1.75-inch angles and a 4-inch plate and two 7-inch plates. The lower chords consist of pairs of 1- by 3-inch eye bars. The vertical members connecting the upper and lower chords are tapered and consist of four 1.75- by 1.75-inch angles with riveted flat bars forming an "X." Diagonal bracing is 1.25-inch-diameter rods. Overall, the bridge is almost identical in construction to the Gilbert Road Bridge.

North Canal — Lawrence. The lenticular bridge spanning the North Canal in Lawrence is a five-panel pony truss. Very little is known about the history and construction of this bridge. The bridge is currently closed and has been extensively modified, with at least one of its top chord members replaced (see Figure 16). On the south end, the original top chord, which consists of riveted plates and angles, has been replaced with welded plates and channel sections. The bridge has a total span of 83 feet and is completely pin connected. The lower chords appear to be original 1- by 4-inch flat eye bars. The mid-span depth is 8 feet. The bridge has tapered vertical members connecting the top and bottom chords and appears very similar in design to both the Gilbert Road and Northwest Road bridges.

Surviving Through Truss Bridges

In addition to the six pony truss bridges described above, there are three surviving lenticular through truss bridges, two of which

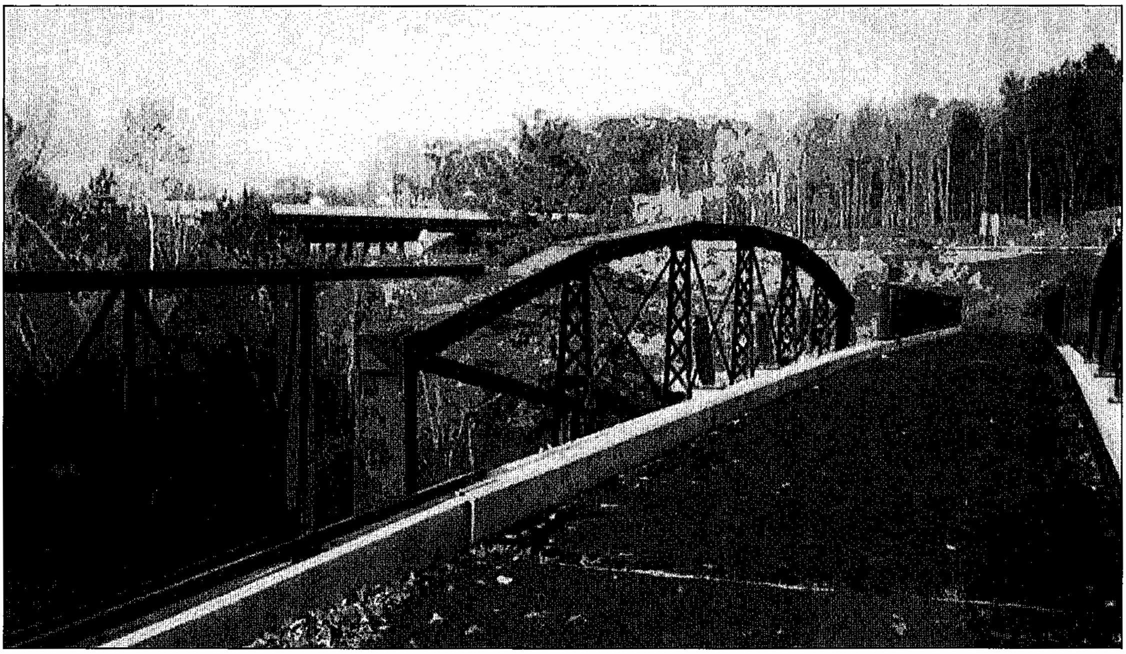

FIGURE 15. The Northwest Road Bridge in Millbury.

(the Bardwell's Ferry and Aiken Street bridges) are still in active use for vehicular traffic. The other one (the Galvin Road Bridge) is currently closed and awaiting removal and restoration. The through truss bridges were generally used for longer spans and are much

FIGURE 16. The North Canal Bridge in Lawrence.

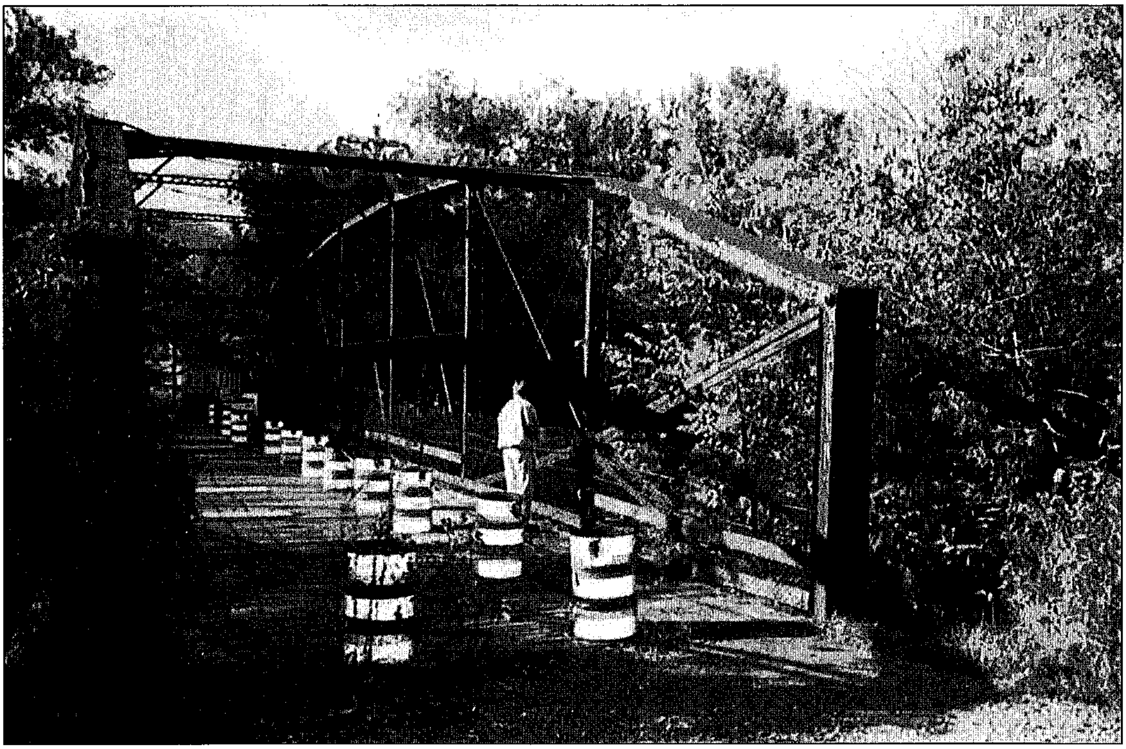

FIGURE 17. The Galvin Road Bridge in North Adams.

larger in every detail than the pony truss bridges.

Galvin Road — North Adams. The Galvin Road (Blankinton) Bridge is located on Galvin Road in Berkshire County. It spans the Hoosac River (see Figure 17). It is an excellent example of Douglas's 1885 patent as applied to a through truss. The bridge was constructed in 1884 and, therefore, likely incorporated the 1885 improvements on Douglas's 1878 patent. The bridge has a span length of 103 feet and consists of seven panels. The mid-span depth of the bridge is 18 feet. The end posts and the upper chords consist of open box sections, built up of three plates and four angles, giving overall dimensions of 16 by 8 inches. The lower chords consist of pairs of 1- by 3-inch eye bars. The entire bridge is pin connected at each chord segment connection point. The vertical members consist of parallel sections of paired angles with flat plate cross members that form an open lattice. Diagonal bracing rods within each pin are 1.5-inch-diameter wrought iron rods. The Galvin Road Bridge has been dismantled and is currently in storage at the University of Massachusetts at Amherst. The bridge will be rebuilt for pedestrian use on the university campus.

Bardwell's Ferry Road — Shelburne. The Bardwell's Ferry Bridge is a 198-foot-long pin-connected through truss bridge, built in 1882. It spans the Deerfield River between the towns of Shelburne and Conway in Franklin County. It is the longest single-span lenticular truss bridge in Massachusetts. The bridge consists of thirteen panels and the design follows closely the Douglas patent of 1878 (see Figure 18). It has a mid-span depth of 29 feet. The end posts and upper chords are built-up open box members, consisting of riveted plates and angles giving dimensions of 18 by 12 inches. The lower chords are constructed from 1- by 3-inch eye bars. The vertical members consist of parallel sections consisting of four channels connected with flat plates to form an "X."

In 1997, the bridge underwent extensive restoration. However, the original form of the bridge appears to have been maintained and the bridge currently exists very close to the configuration as originally constructed. The

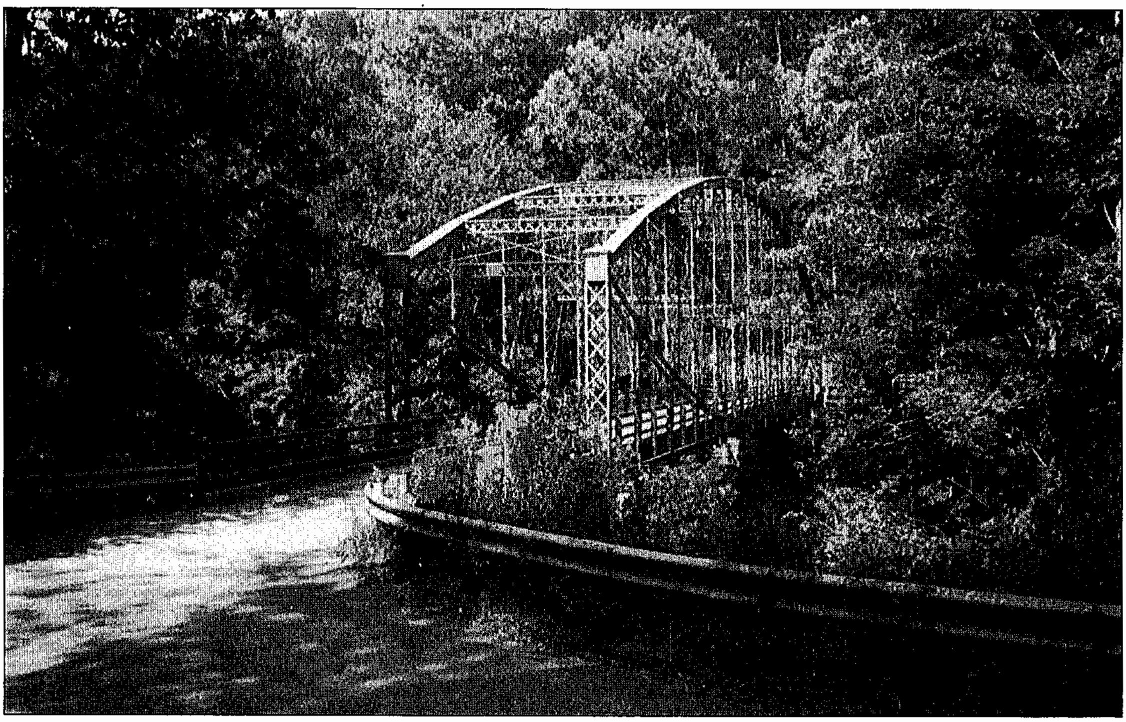

FIGURE 18. The Bardwell's Ferry Bridge in Shelburne.

Bardwell's Ferry Bridge is one of the longest single-span through truss bridges built by the Berlin Iron Bridge Company using the traditional lenticular truss panel design. Other, longer-span lenticular trusses were built by the company in Pennsylvania and New York using a "Warren truss" style of bracing within the lenticular shape. In 1988, the Bardwell's Ferry Bridge was designated as a Historic Civil Engineering Landmark by the American Society of Civil Engineers.

Aiken Street — Lowell. The Aiken Street Bridge was built in 1883 (the same year as Lindenthal's Smithfield Street Bridge in Pittsburgh) to span the Merrimack River in Lowell. The bridge consists of five identical spans, each having a length of 152 feet, with a mid-span depth of 32.8 feet (see Figure 19). It is the longest surviving multispan lenticular bridge and is the only remaining bridge with more than three individual spans. The design is similar to the Washington Street Bridge in Binghamton, New York, which consists of three spans of 170 feet each crossing the Susquehanna River. Each span of the Aiken Street Bridge consists of eleven panels. The full span length of the bridge is 675 feet, which presents an impressive sight in Lowell. It is the only multispan lenticular bridge in Massachusetts and the only lenticular bridge in the state that caries a pedestrian walkway on both sides of the bridge outside of the trusses. (This bridge was also described by Bennett and Kaminski.[8])

The end posts are constructed as open box sections from four angles and three plates with overall dimensions of 24 inches wide by 16.5 inches deep. The top chords consist of an open box section constructed similar to the end posts with four angles and three plates with dimensions of 18 by 14 inches. Even though the individual spans are shorter than the Bardwell's Ferry Bridge, the end posts and top chords are heavier (presumably to accommodate the additional weight of the outer walkways). The bottom chords consist of four 1.625- by 4.5-inch flat eye bars. The vertical web posts are constructed from 3- by 5- by 0.438-inch angles with 0.25-inch flat lattice bars. The diagonal bracing consists of pairs of 1.75- or 1.875-inch round wrought iron bars. The bridge was renamed the Joseph R.

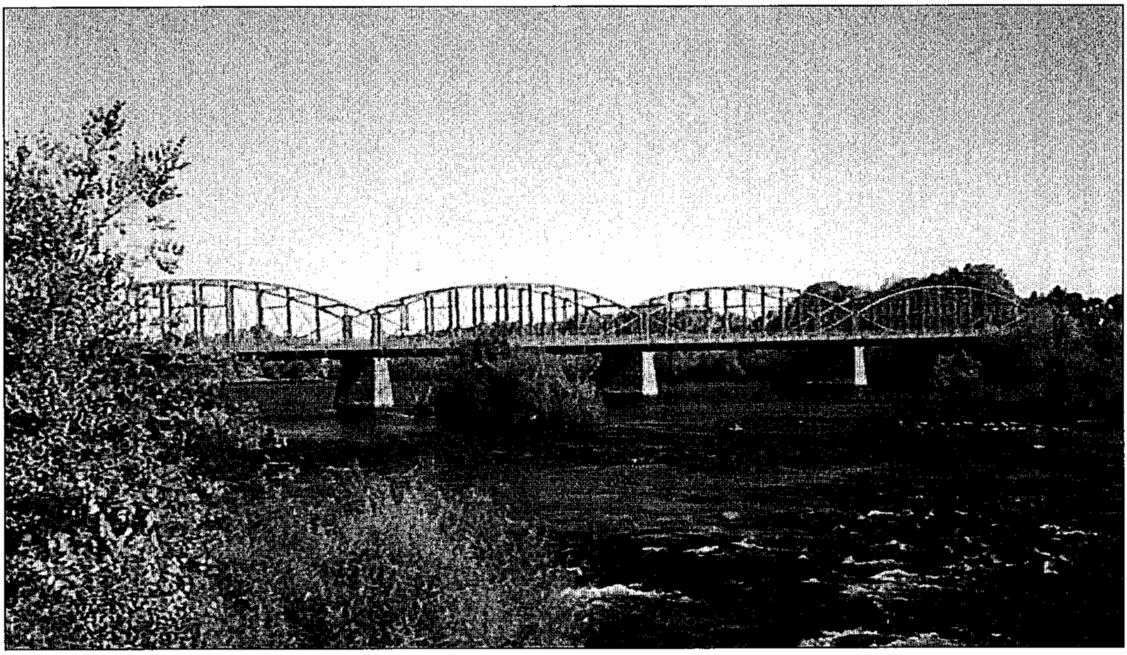

FIGURE 19. The Aiken Street Bridge in Lowell.

Ouelette Bridge in 1954 in honor of a Lowell soldier killed in the Korean War and who was a recipient of the Medal of Honor.

Description of Individual Components

The design of the individual elements of these bridges was exquisitely simple, yet functionally sound and lent itself to economic fabrication at the plant. The use of riveted plates, angles and channel sections to build the end posts, top chords and vertical web posts is characteristic of all these bridges. The construction brings to mind a child's Erector set and one can easily imagine the individual top chord elements, vertical posts, lower chords, bracing bars and other smaller components being transported to the site by horse carts. Assembly at the site would have been relatively easy and fast, even by today's standards. There are relatively few variations in components among the surviving bridges, and the components suggest a simple modular design concept. After all, the market for iron bridges at the end of the nineteenth century was highly competitive and, therefore, any means to reduce fabrication costs would have been exercised.

In comparison with typical bridge sections of today, the components for a lenticular pony truss bridge were relatively light and could have been handled by workers at the site. Using the Fort River Bridge in South Amherst as an example, a 14.75-foot-long upper chord section would weigh about 640 pounds; an 8-foot-long vertical web post would weight about 130 pounds; and a 14.75-foot-long lower eye chord would weight about 105 pounds. Each of these members were constructed of individual components riveted together. The weight of the upper chord was such that it would likely have been handled by a tripod or boom and jib. The other elements could easily be placed by two workers.

Figure 20 shows a side view of a typical bridge and identifies individual components. Table 3 provides a summary of the bridges' key elements. (Descriptions of individual bridge members are given in English units to be consistent with the period of construction.) The segmental upper chords are used as compression members and the lower chords as tension members; the two come together at the end post connection. So, in effect, it is sometimes said that this unique style of bridge combined the attributes of an arch

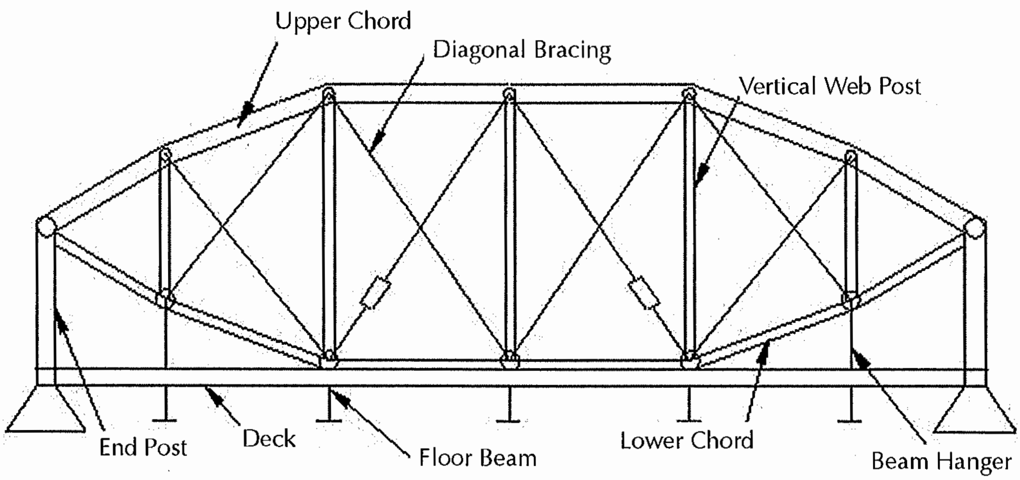

FIGURE 20. Components of a lenticular bridge.

bridge and of a suspension bridge into a single structure. The lower chord member, if allowed to hang freely, would take on the shape of a catenary, much as an early chain bridge and subsequent wire cable suspension bridges.

End Posts & Upper Chords. End posts and upper chords were generally constructed as built-up members, using standard dimension angles and plates riveted into sections with one open side. This type of construction is illustrated in Figure 21. End posts are open box sections with the interior vertical face being the open side. In all cases, flat bar bracing elements are provided along the open face. These bracing elements were either attached as horizontal members or were attached diagonally in a "Z" pattern. These elements were also riveted. End posts of the Bardwell's Ferry Bridge are somewhat unique in that they are actually constructed as open box sections with flat bar "X" bracing. This style of end post design has been seen on very few bridges. There was clearly a cost savings to the Berlin Iron Bridge Company in using this approach and it is surprising that this style of construction is not seen more often. The only thing that keeps these members from being fully built-up tubular sections is that that are open on one side.

The sizes of angles, plates and flat bars used on different bridges were related to the style and span of the bridge. For example, the overall dimensions of the end posts sections of the Bardwell's Ferry Bridge are 18 by 12.375 inches, built up from 2- by 2- by 0.375-inch angles and 18- by 0.75-inch and 12- by 0.25-inch plates. By comparison, the end posts of the Pumpkin Hollow Road Bridge, which is the lightest, are built up from 1.5- by 1.5- by 0.25-inch angles and 10- by 0.125-inch and 5.25- by 0.125-inch plates having overall dimensions of 10 by 5.375 inches.

Top chords were essentially built as extensions of the end posts and were constructed in almost an identical manner as inverted troughs. In most cases, the transition from the end post to the top chord was made by a connection at the top of the end post that consisted of a riveted plate that was placed inside the exterior angles of the end post and top chord on either side. A pin was then positioned to extend through the entire section to serve as a connection for the eye end of the lower chord. On some pony truss bridges, the connection between the end post and the top chord was made using a special cast iron connector with the lower chord extending through and then held with a nut. A comparison of these two styles of end post–top chord connections is

TABLE 3.
Summary of Key Bridge Elements

No.	Bridge	Upper Chord (in.)	Lower Chord (in.)	Central Diagonal Bracing Bars (in.)	Vertical Web Posts
1	Golden Hill Rd.	16 × 8.25	1 × 3	1.25	Parallel
2	Pumpkin Hollow Rd.	10 × 5.25	1 × 3	1.25	Tapered
3	Fort River	16 × 8.5	1 × 2	0.75	Parallel
4	Gilbert Rd.	14 × 7.5	1 × 3	1.5	Tapered
5	Blackstone Bikeway	14.25 × 7.5	1 × 3	1.25	Tapered
6	North Canal	16 × 8.25	1 × 4	1.25	Tapered
7	Galvin Rd.	16 × 8	1 × 3	1.5	Parallel
8	Bardwell's Ferry Rd.	18 × 12	1 × 3	0.75	Parallel
9	Aiken St.	18 × 12	1.625 × 4.5	1.75	Parallel

shown in Figure 22. A third style of end post-top chord connection was occasionally used, as in the case of the Aiken Street Bridge. In that connection, the top chords were actually narrower than the end posts and fit inside at the pinned connection.

Lower Chords. The lower chords in every bridge were constructed using flat stock wrought iron eye bars with the eye ends used to create pin connections at each panel connection point. The size and number of individual elements composing the lower chords was also related to the style and span of the bridge. Sizes and numbers ranged from pairs of 1- by 3-inch sections for the shorter span pony truss bridges, to two pairs of 1.625- by 4.5-inches for the Aiken Street Bridge. The lightest lower chord members are the 1- by 2-inch bars used on the Fort River Bridge.

Vertical Web Posts. Vertical web posts connecting the upper and lower chords are the simplest of all the built-up members and were fabricated from four angle sections with riveted flat bar diagonals. Web posts were either tapered or were constructed with parallel sides as shown in Figure 23. Tapered web posts were connected to the pins at the upper chords on the inside of the chord, while parallel web posts were connected to the upper chords on the outside of the chord. The only remaining pony truss bridges with parallel web posts are the Fort River and the Golden Hill Road bridges. All of the other pony truss bridges use tapered web posts. Parallel web posts are used on all of the surviving through truss bridges.

Diagonal Bracing. Diagonal bracing bars were used in the center of panels and consist-

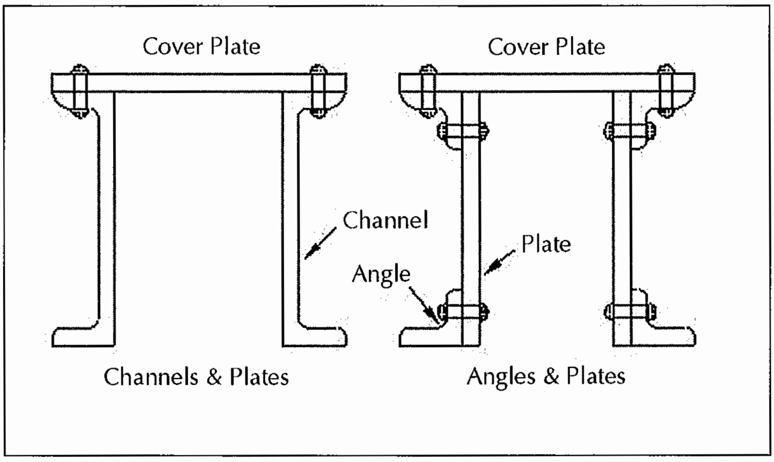

FIGURE 21. End post and top chord construction.

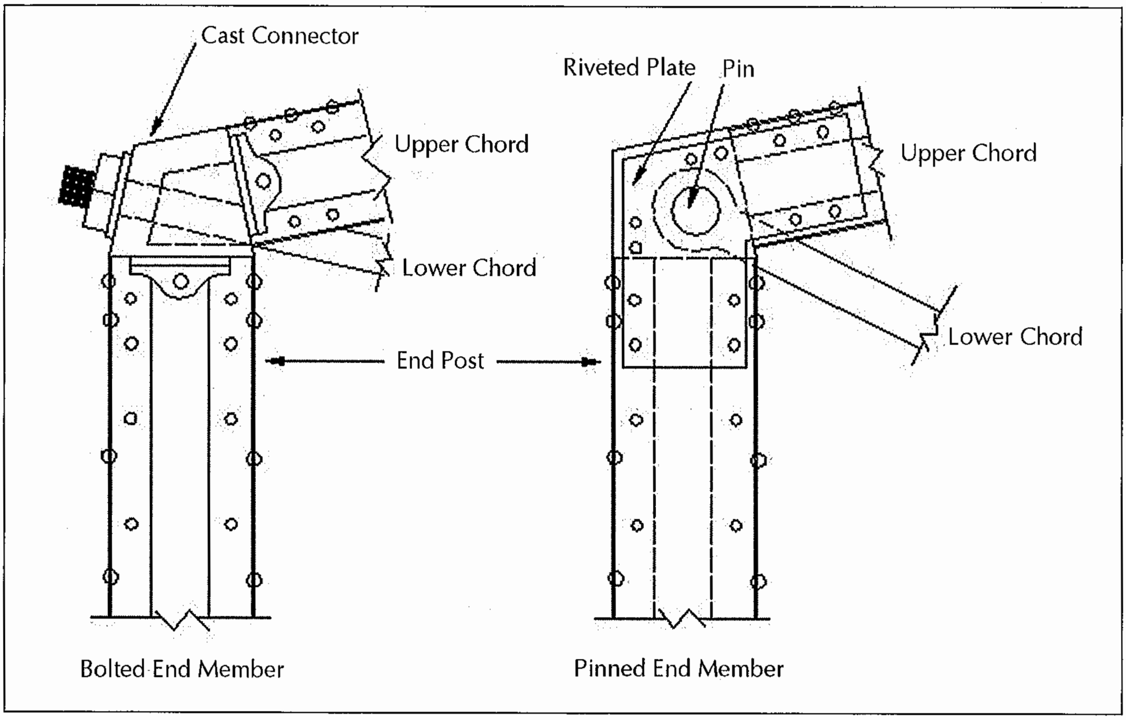

FIGURE 22. A comparison of pinned and bolted end posts.

ed of round iron rods wrapped around pins at connections. The diameters of the bars ranged from 0.75 to 1.5 inches. In many cases, different size bars were used on the same bridge, with the larger diameter bars used in the central panels and progressively smaller bars used on the panels closer to the end of the bridge. Normally, the bars included a turnbuckle to allow for the construction and so that tension could be applied.

Floor Beams. Floor beams on the bridges were again constructed as riveted sections built-up from angles and plates. The top edge of the beams was parallel with the bridge deck, but in many cases the lower edge was tapered, being deeper at the center than at the edge. The central plates appear to all have been fabricated from a single plate. In almost every case of the bridges examined, the individual pieces that were used to fabricate any section were full-length elements.

Beam Hangers. Beam hangers were fabricated from square stock with threaded ends. The hangers were suspended over the lower pins at connection points. These hangers then extended downward through notches cut in the flanges of the floor beams and were connected to a lower plate that supported the beam.

It is clear from the examination of each of these bridges in Massachusetts (and a number of other bridges throughout New England) that many of the individual members were of stock dimensions and that bridge designs were essentially standardized so that various combinations of stock elements could be used to achieve the required span that was needed for a particular site. This method seems especially to be the case for pony truss bridges and accounts for the variation in aspect ratios that have been observed — that is, all six remaining pony truss bridges have mid-span heights of 8 feet, but have span lengths ranging from 58 to 83 feet, yielding aspect ratios ranging from 7.2 to 10.4.

Summary

The nine surviving lenticular truss bridges designed and constructed by the Berlin Iron Bridge Company represent the last structures of their type of perhaps over a hundred such bridges that were built throughout Massa-

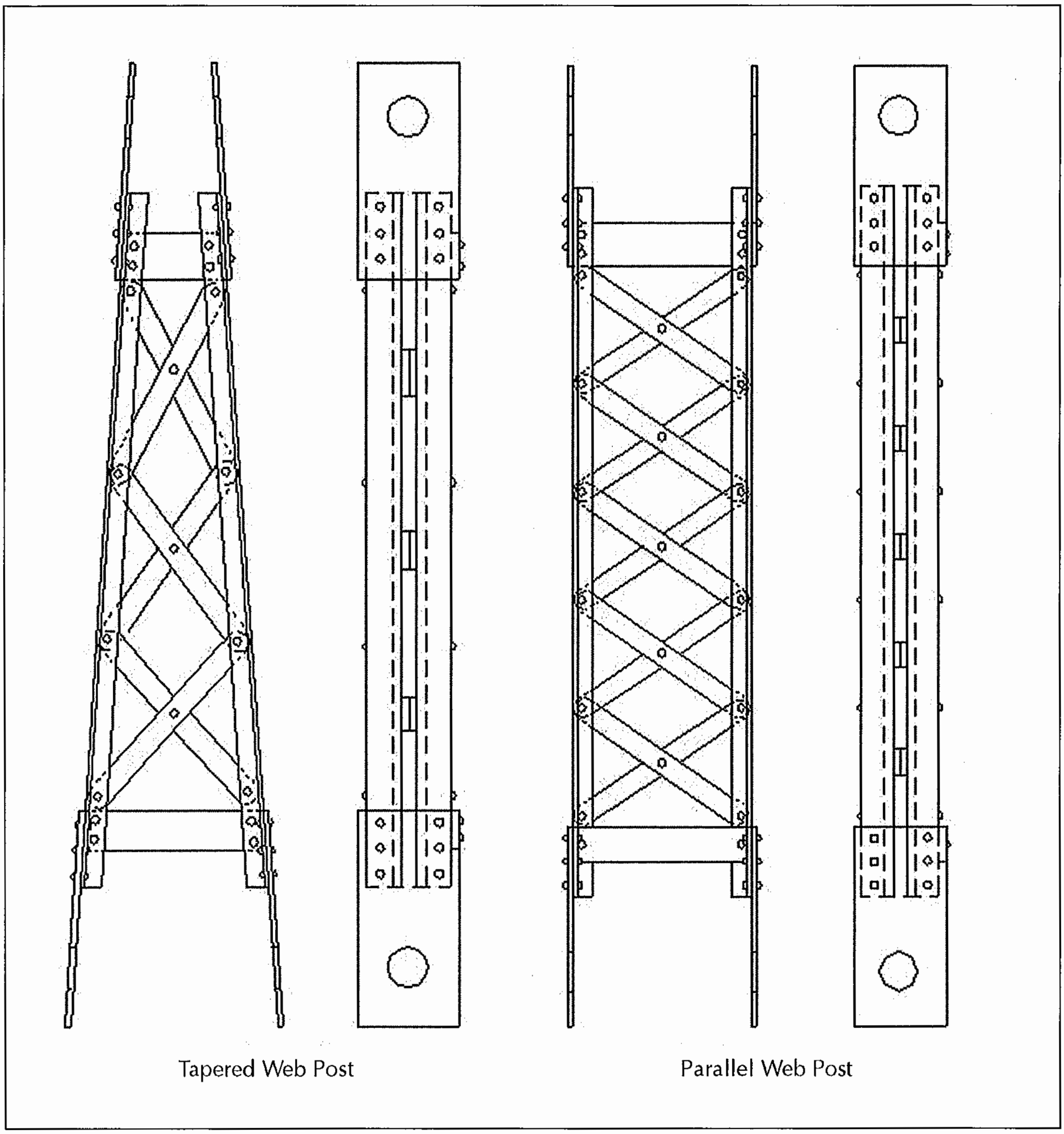

FIGURE 23. Different vertical web post construction methods.

chusetts between about 1880 and 1900. These bridges represent an important era in bridge history at a time when bridge construction was highly competitive and during which the transition was being made from the use of iron to the use of steel. The bridges have a unique shape and were the only lenticular bridges built in the United States by a prominent bridge building company of the late nineteenth century. The bridges provide a look into late nineteenth century bridge design and construction and every effort should be made to preserve them for future generations to study and appreciate.

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Engineering and, in particular, the history of lenticular truss bridges about five years ago. While his research has focused on in-situ testing of soils and foundation design, more recently his interests have included historical aspects of foundation engineering and the preservation of wrought iron bridges.

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