Thomas W. H. Moseley & His Bridges

Using wrought iron, riveted plate tied arch as a bridge-making solution, Moseley had a successful and prolific career as an innovative bridge-builder in the nineteenth century.

FRANCIS E. GRIGGS, JR.

Thomas William Henry Harrison Moseley located his bridge-building firm in Boston, Massachusetts, from 1861 to 1871. During that period he built several hundred of his patented wrought iron bridges throughout the Northeast. Moseley's firm, which was also coupled with his iron roof business, was one of the earliest producers of wrought iron bridges in the United States. His business preceded the better known Wrought Iron Bridge Company of Canton, Ohio, and the King Iron Bridge and Manufacturing Company of Cleveland, whose founder was an early associate of Moseley when he lived near Cincinnati, Ohio, between 1854 and 1861. Given this early prominence in the bridge building field and his links with the Boston area, it is unfortunate that so little is known of Moseley and his work. The recent rehabilitation at Merrimack College of a Moseley bridge, which had spanned the North Canal in Lawrence, Massachusetts, since 1864, has hopefully served to awaken interest in Moseley and his works.

Early Years

Moseley was born near Mt. Sterling, Kentucky, on November 28, 1813, while his father was away fighting in the War of 1812 with his namesake, William Henry Harrison. He apprenticed "to the first iron furnace built on the Ohio River, known as the Union Furnace" at Hanging Rock near what is now called Ironton, Ohio.[1] At that time, the iron-making industry in the United States was still in its infancy. By the end of the 1850s, however, there were four mills in the Cincinnati/Covington area producing boiler plate. This opportunity to make cast iron, and later wrought iron, gave Moseley an introduction not only to iron making but also to the growing number of uses for iron. He knew of Capt. Delafield's 1839 cast iron arch bridge on the National Road at Brownsville, Pennsylvania, since he had superintended the weighing and shipping of the iron used in that bridge. It was the first iron bridge built in the United States and still stands at its original site. The arches were made up of elliptical cast iron tubes bolted together.

He became interested in politics and in 1840 campaigned for William Henry Harrison in his

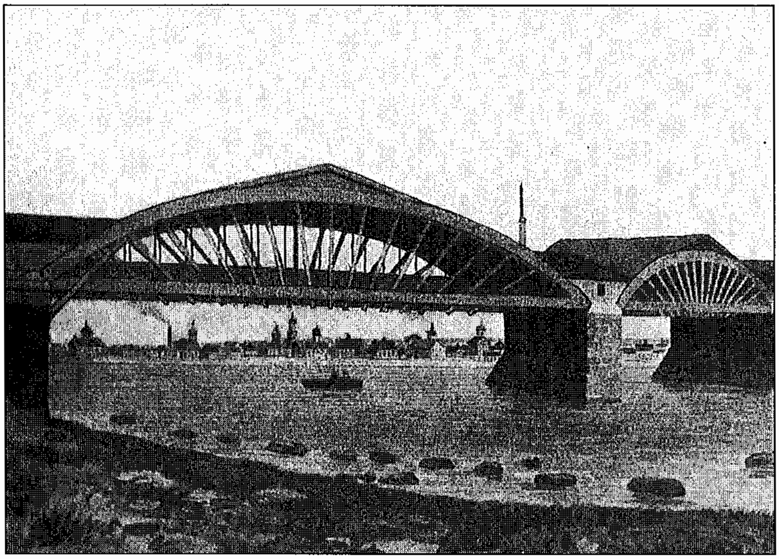

FIGURE 1. Theodore Burr's Trenton Bridge.

run for the Presidency. In 1841, he entered the field of civil engineering by building a turnpike from Paris to Covington, Kentucky. After that, he moved to Columbus, Ohio, "peddling patent-rights and a pump which I myself had patented."[1] He continued his interest in politics by campaigning actively for Henry Clay in the 1844 presidential election. He then went to work on the Little Miami Railroad which was under construction between Cincinnati and Columbus, Ohio. As a reward for his support of the Whig Party, he was appointed Adjutant-General of Ohio in 1845. Apparently, he had been active in the local militia, serving as Captain in the Lancers at one time in the early 1840s. In his role as Adjutant-General it was noted that:[1]

> "It was one of his duties to organize the Ohio Troops for the Mexican War. The war was by no means a wise or patriotic measure in his opinion and, in 1851, he retired from office and went to Cincinnati where he began the development of his inventions relating to mechanics and structural bridge work."

He was frequently referred to as General Moseley after this appointment.

He continued to be fascinated by, and even idolized, iron. In 1863 he wrote that:[2]

> "It may be confidently asserted that, except the Gospel, Iron has been the most potent of all agents in the civilization of mankind. It cannot but be observed, that, exactly in proportion as communities, tribes, and nations have learned the uses of this bounteous gift of the Creator, they have advanced in science, in culture, and in Christianity."

He would also describe the iron-making process in poetic terms:[2]

> "The Forge, with its dozen furnaces heating so many huge shafts or anchors; with its ponderous hammers driving into form one or more of these mighty members of the future engine, mill, or ship, with blows which make the very earth tremble; while the sparks hiss and dart hither and thither as from the mouth of a demon; the whole mass of iron, by means of powerful machinery, controlled by the journeyman of Vulcan."

He became interested in bridges in the 1850s. This excerpt from his writings evidences his interest in bridge making:[2]

> "Almost every individual who, as its engineer, has made ten miles of road, has at one time or another conceived a new plan of bridge; for of all the troubles which beset an engineer in constructing and operating a road, it's Bridging is the greatest."

He had been exposed to wooden bridges built by Lewis Wernwag and Theodore Burr, both of whom used arches extensively. Moseley's first bridge in iron can be seen to be a visual derivative of Burr's Trenton Bridge built in 1842 over the Delaware River (see Figure 1).

Burr used wood for his top and bottom chords along with vertical linked iron bars (chains) to transfer his deck load to the arch. He

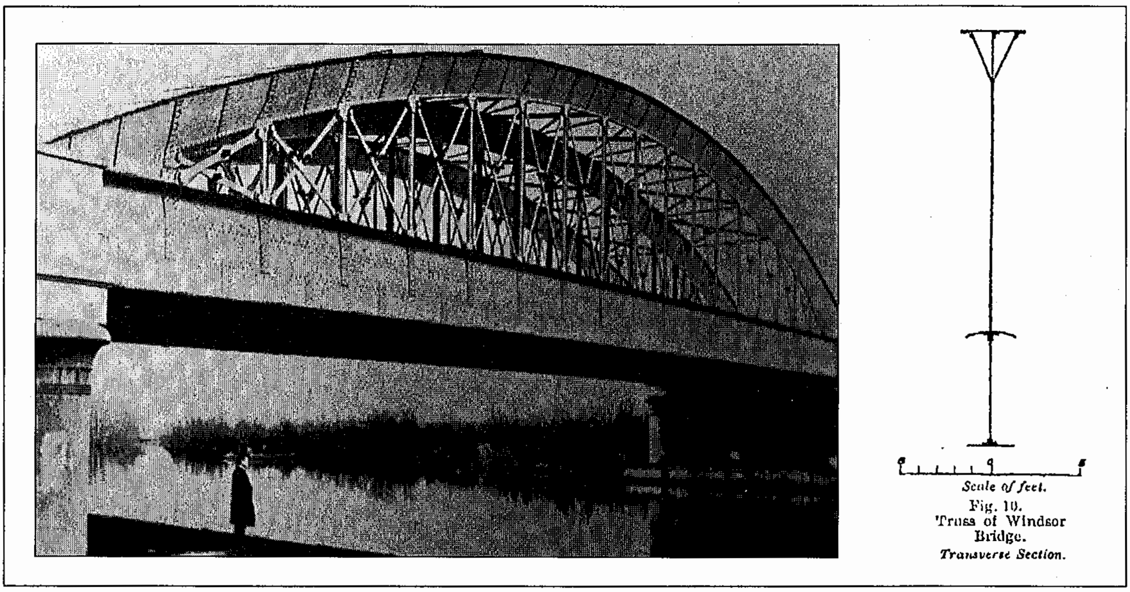

FIGURE 2. Isambard Bunel's Windsor Bridge.

also had additional diagonals connecting the top and bottom chords.

Moseley apparently read the English and American technical journals of the day since he was familiar with Robert Stephenson's Britannia Bridge made of wrought iron plates riveted together into a huge rectangular tube. He considered it to be "a gigantic monument to the brute force of labor and money."[2] It did, however confirm his "predilection for wrought iron plates as the best material; but his [Stephenson's] plan lacked my *sine qua non* in a bridge, the Arch."[2] He also knew of Thomas Telford's cast iron arch bridges which were built in England, Scotland and Wales.

Moseley's First Bridge

In 1853, while building a road in Kentucky, he hit on his idea of a wrought iron, riveted plate, tied arch as a solution to the bridge problem. He may have been influenced by Frederick Harback's iron truss, which had cast iron upper compression chords and wrought iron plates riveted together for the lower tension chord. In 1846, Harback had built his first bridge, a 30-foot span, on the Pittsfield & North Adams Railroad outside Pittsfield, Massachusetts. This bridge was in the Howe Truss form and was visited by Squire Whipple in 1848 when he was about to build four iron bridges for the Newburgh Branch of the New York and Erie Railroad. Whipple wrote that he found Harback's bridge to be "excessively heavy throughout and not adopted to the intended purpose."[3]

Harback went on to build several bridges on the Cleveland, Columbus and Cincinnati Railroad between 1848 and 1850. Moseley was working in this area at the same time and may have seen some of Harback's trusses. While he was not fond of pure trusses, believing that "no bridge should be considered safe without the arch,"[2] he may have picked up on Frederick Harback's riveted wrought iron tube idea since Harback had built several of his bridges in Ohio. He may also have been aware of W. C. Harrison's patent issued in England in 1847 for a bowstring that was similar in truss layout to Whipple's except that it used a rectangular riveted wrought iron tube for both the top and bottom chord.

It is not known if Moseley was aware of Isambard Kingdom Brunel's arch bridges at Windsor, England, and at Newport that used riveted wrought iron plates in a triangular shape for the arch or compression member. As can be seen in Figure 2, Brunel had his top chord oriented with the point down, while Moseley had the point of his triangular tube in an upward direction. There are no illustrations in the literature that indicate that Moseley was aware of Brunel's work since the first mention of these two bridges is in Brunel's biography written by his son and printed in 1870.

By 1853 Moseley had "so far succeeded in his bridge building that a company was formed and works established in Cincinnati as a rapid demand was created not only for the bridges but for iron roof."[1] Moseley moved to Newport, Kentucky, just across the river from Cincinnati, where he lived until 1861.

In 1854, for the sum of $2,100, Moseley built his first 60-foot span bridge, using hand iron working tools, across Bank Lick Creek on the Bank Lick Turnpike 7 miles outside Covington, Kentucky. He had built and test loaded this bridge earlier in the year and after successful tests sold it to the turnpike company. The *Railroad Record* of April 2, 1855, described the bridge as follows:[4]

> "Gen. Moseley has just completed a bridge of 60-foot span. The arch has a spring of 12 feet, being a segment of a circle 95 feet in diameter. The roadway is 19 feet wide, sufficient for two tracks. There are three arches as described, one at each side, and one in the centre [sic]. The bridge proper, including the arches, the iron beams to support the roadway, and iron braces between the arch and beam, weighs *three and one half tons.* It was tested recently with a weight of 55 tons and there was no visible deflection. The bridge is calculated to be capable of sustaining a weight of 200 tons. The whole forms a beautiful structure of great strength and very cheap, portable on account of its light weight. . . The bridge is the first structure of its kind, but will not be the last. The principle brought into exercise is a very simple one. It is an arch, not depending, as in the stone bridge, upon its own weight or that of the superincumbent mass to keep it in position; but spanning the chasm in light and airy proportion, and yet of greater strength and durability, than the heaviest structures of masonry, and of little weight and of wonderful solidity."

In September of the same year the *Railroad Record* reported on a test of a model Moseley made in the company of U.S. Army officers. The model had a 4-foot span and weighed only 20 pounds. It reported that 58 ingots of lead, weighing 70 pounds each, were placed on the model along with a man weighing 170 pounds. The *Railroad Record* stated that:[5]

> "The parties present, including ourselves were perfectly satisfied and expressed the conviction that double that weight could be put upon it with perfect safety. The huge pile of lead resting on the slight airy structure seemed almost fabulous."

The *Railroad Record* report on the bridge also noted that:[5]

> "For army purposes, this bridge from its lightness, facility of construction and capability of being packed in little room, has many and decided advantages. It will support with perfect safety, as has been shown both by models and the bridge in Covington, full *twenty* times it weight without deflection."

In the spring of 1856 the *Railroad Record* reported on a test of a 49-foot span railroad bridge Moseley built at Morrow, Ohio, on a side track of the Little Miami Railroad. After describing the details of the bridge the *Record* wrote that:[6]

> "The first test to which the bridge was subjected was the crossing of a 26 ton locomotive with a heavy train of 40 cars, mostly eight wheeled. As the locomotive crossed the bridge, the foundation settled about an inch causing a corresponding settling of the whole structure. The long train that followed produced no further effect than to show the natural elasticity of the bridge. The next test was the crossing of a 19 ton locomotive, alone and with train, at rates of speed varying from 5 to 30 miles per hour. . . While on the bridge, and running at speed, the brakes were applied to the train, and the wheels perfectly locked dragged over the bridge. . . This is the most severe test to which a structure can be subjected, and

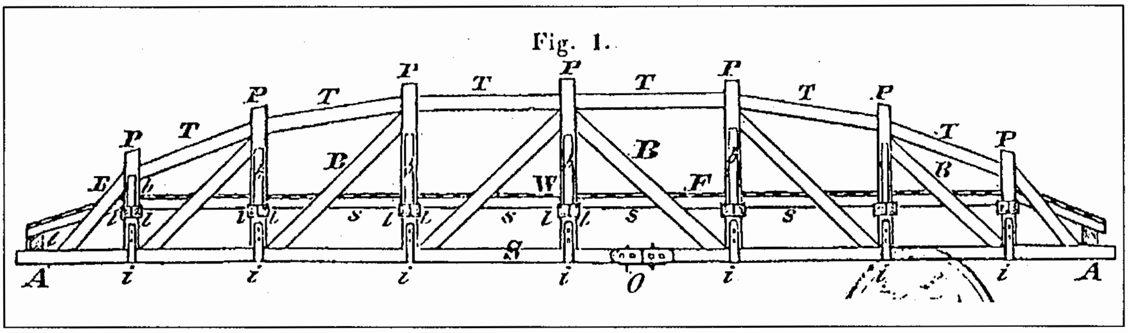

FIGURE 3. First patented bowstring truss by George W. Long in 1830.

much more so that it is practically expected to undergo."

The seven men who witnessed the test were of the "opinion [that] the Tubular Wrought iron Arch applied to the purposes of Bridging, is the strongest and best arrangement of material that they have yet seen, and they deem the Arches to be eminently suited to the purposes of Railroad Bridging."[6] They added they were "quite satisfied that the Tubular Arch is the best form that we have seen to give the greatest strength from the least material. And we believe that iron bridges must become pre-eminently *the railroad bridges* of the country."[6] The same *Record* reported that one of Moseley's bridges has been tested two weeks previous in Butler County "and gave the most perfect satisfaction."[6]

He was issued patent no. 16,572 on February 3, 1857, for a bowstring "truss bridge." The bridge was fabricated entirely of wrought iron plate, bar and strap stock at a time when Squire Whipple, the premier iron bridge builder of this time, was constructing bowstring trusses made of cast and wrought iron. Riveting wrought iron plates into shapes for bridge building had been developed by English engineers, but it was still a developing technology in the United States. In addition to Harback's bridges, James Millholland had built a riveted wrought iron plate girder bridge for the Baltimore and Susquehanna Railroad in Maryland, in 1847.

The first patent for a bowstring truss (see Figure 3) had been issued to George Washington Long, the brother of the better known bridge builder Stephen H. Long. His truss, called an *elliptical frame bridge*, was made of wood but he indicated that it could be built with iron. He had a single diagonal in compression similar to what has become known as a Howe Truss.

Whipple's and Moseley's patent drawings are shown as Figures 4 and 5. Note that both consist of arches with the string (lower chord) being in tension and made of wrought iron. Whipple's top chord, however, was made of cast iron segments while Moseley's was made of continuous riveted wrought iron plates arranged in a triangular pattern. The main visual difference between the two is in the diagonals. Whipple makes use of what, at the time, were called braces and counterbraces, while Moseley's diagonal pattern defies description, being a series of straps on something approaching a radial pattern. Whipple's bridge was a true truss while Moseley's would be classified as a tied arch.

Brock, in his fine series on early bridge patents, described Moseley's bridge as follows (see patent drawing Figure 5):[7]

"The Arches *A A* of his bridge are of compound character and are built up of wrought iron in such a manner to give the arch very long spans without excessive weight. A transverse section of this arch exhibits the form of an isosceles triangle, the base *B* of which is the chord of the arch. The plates *P* of the arch break joints with each other for the purpose of strength. For the purposes of additional strength to the triangular arch, a vertical plate *R* is used dividing the triangle, and bolted thereto. Moseley asserts that under a strain exerted in any direction upon

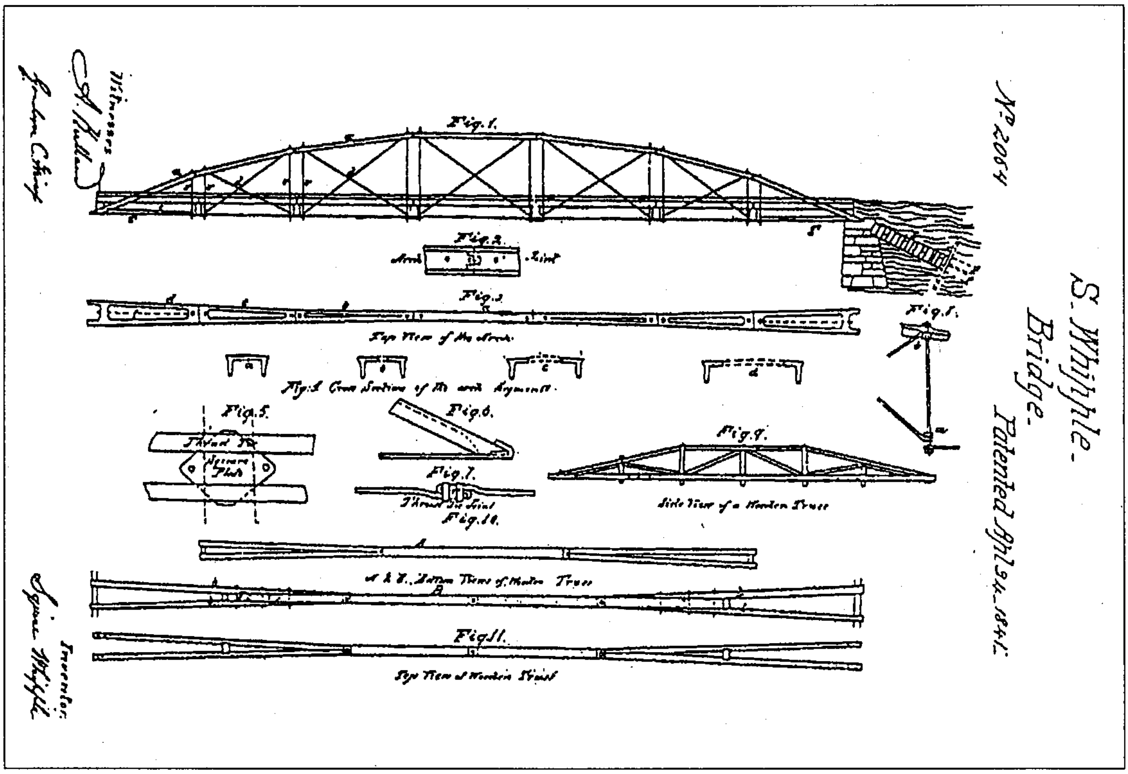

FIGURE 4. Squire Whipple's bowstring truss (1840).

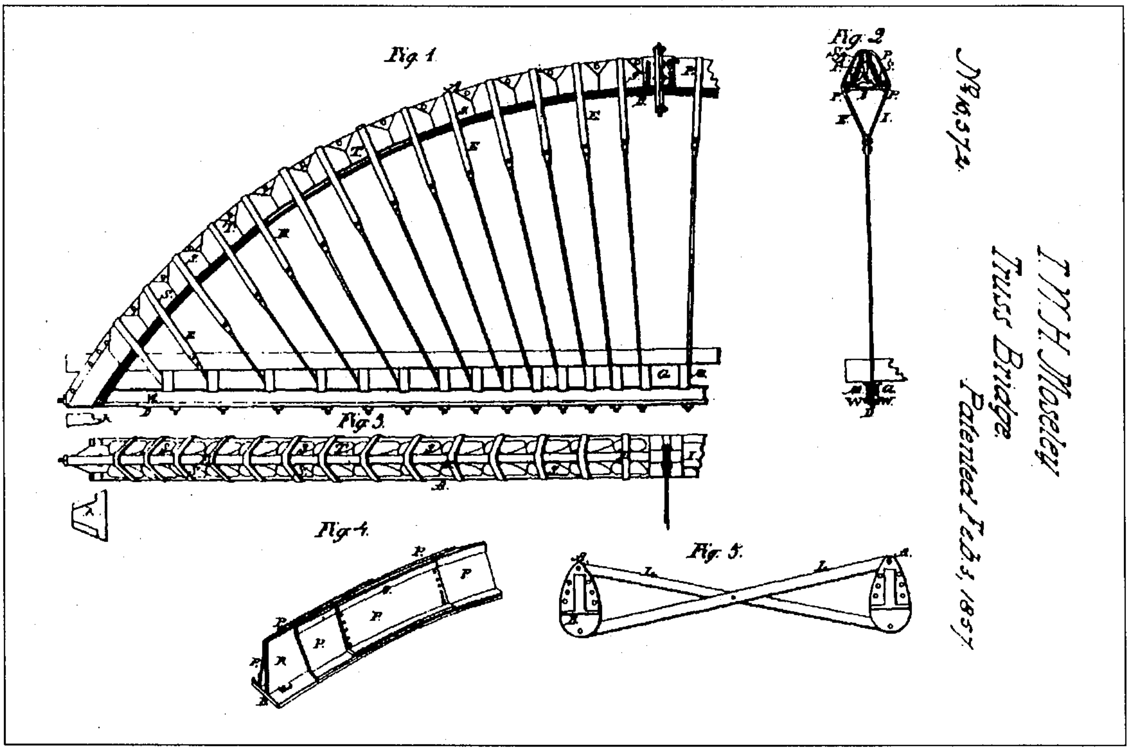

FIGURE 5. T.W.H. Moseley's bowstring arch (1857).

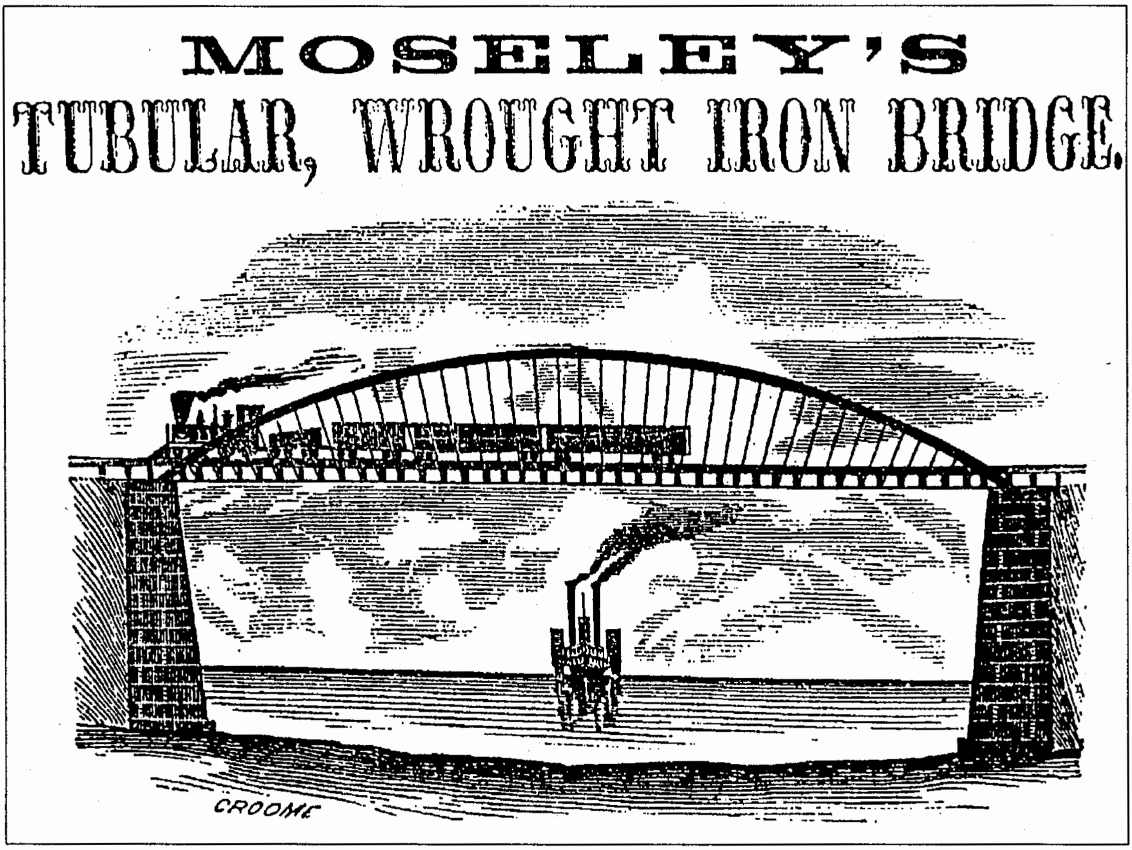

FIGURE 6. Moseley's advertisement.

this compound arch there is less risk of buckling of either of the plates than in any other structure for the purpose. In order to prevent all risk, however, of buckling, loose pieces or saddles *s-s* are used, resting, upon the plates *B*, and also bearing against the plates *P*, supporting each other by their edges, which come into contact as seen at *T*. Over the upper edges of the saddles, and receiving part pressure thereof, are the stirrups *E* of the suspension rods *F*. The floor of the bridge rests upon the chord *M*, supported by the suspension plate *D*. This plate is not fastened to the lower chord *M*, and the effect of which is that every load draws upon the whole arch in consequence of the sliding movement of the suspension plate under the chord.

The use of the vertical plate, *R*, to both stiffen the lower plate and add cross section to the arch was a good attempt at a design that would provide stiffness at the same time it minimized buckling of the arch. The use of saddle plates *s-s* was necessary to provide better bearing between the stirrups (which were strap iron) and the arch. Being loose, however, the stirrups would create erection problems and, quite probably, maintenance problems since they were not mechanically attached to the arch. The suspended straps were riveted to the stirrups and the lower chord was a single bar with screw adjustment capability at its ends.

In 1858, after being issued his patent, Moseley set up a factory in Cincinnati at 57 West Third Street to build his bridges. An advertisement his firm placed in the *Railroad Record* (see Figure 6) stated that:[8]

> "We are prepared to construct and erect our bridges in every part of the US., the Canadas, &c. with single spans up to 2000 feet (though in long bridges with single spans the increase in cost is very great). . . A

TABLE 1.
Moseley's Price List

Span Length (ft)	Cost/Foot
Railroad Bridges	
50	$31.50-$34.00
100	$45.00-$48.00
200	$76.00-$78.00
Highway Bridges	
50	$11.00-$14.00
100	$18.50-$21.00
200	$36.00-$38.00

bridge of 50 feet or less in span, we can construct in three days time, and when it is on the ground and ready for placing in position, we require but a few hours to remove the old one and place the new one complete in its stead. . ."

Prior to the Civil War he built over sixty bridges in Ohio, Illinois, Indiana, Virginia and Kentucky. One of these bridges was a 59-foot long aqueduct on the Ohio and Erie Canal built near Akron, Ohio, in 1859. This structure was sized to carry a trough of water 22 feet wide and 4 feet deep. He built two swing bridges between 1856 and 1857. One was in Chicago with a span of 162 feet and the other in Galena, Illinois, with a span of 209 feet. It is probable that the Chicago bridge was at Rush Street over the Chicago River. Otis Hovey in his book on *Movable Bridges* indicates that this bowstring bridge of cast and wrought iron was "the earliest all-iron bridge that was built in the Middle West."[9] His source wrote that "in 1856 a fine iron bridge (the first in the west), was built across the river at Rush Street and cost $48,000."[9] The Galena and Illinois Central Railroads paid for both bridges, making it all the more likely that it was Moseley's bridge. The bridge was destroyed in 1863 when a drove of cattle were on the bridge and it was mysteriously opened.

He built three bridges over the James and Kanawaha Canal near Richmond, Virginia. In 1861, he was planning to move his operations to Richmond since he had been offered the contract to build all of the bridges over the canal. The Civil War broke out, canceling this plan as well as "prostrating business in the West" which resulted in his closing his Cincinnati operation.[2] He received and accepted an invitation — with a promise of financing — to move his operation to Boston, Massachusetts, in early 1861. He moved his business to 31 (and later 53) Washington Street. His office was located a few blocks east of the Boston Common and just south of Faneuil Hall in the heart of downtown Boston. His plant was on Norfolk Street in Roxbury.

Moseley in New England

His new plant, housing all his specially designed equipment to cut and roll boiler plate to the shapes required, was completed in October 1861, six months after the start of the Civil War. He began successfully building iron bridges and buildings throughout New England, quoting his prices for bridges by the foot — much like the wooden bridge-building companies did. His price list is shown in Table 1.

In a prospectus issued in 1863 he indicated that he was looking for someone to set up a rolling mill near his bridge manufactory so that he would have a more reliable source of plate stock in the sizes he needed for his bridge and roof structures. He stated that "no one business, well attended to, pays any better than this; while in vitality and variety it excels almost any other."[2] He also indicated that he had received requests for his bridges from the British Provinces, the West Indies and South America and was convinced that "the field is almost limitless for energy and enterprise."[2] The person building this rolling mill would share in the limitless profits that Moseley saw on the horizon.

In 1864, his rolling mill was built at Readville "chiefly for the purpose of supplying the manufactory, light plate, sheet iron, shapes and merchant bar."[10] Readville was a part of Hyde Park and was located in the southwesterly suburbs of Boston.

After a slow start, the mill (which contained "three double puddling furnaces, three heating and annealing furnaces, two trains of rolls — one 20 inches for sheet and plates and one 17 inches for bar"[10]) became very active. It was powered by four steam engines, with the larg-

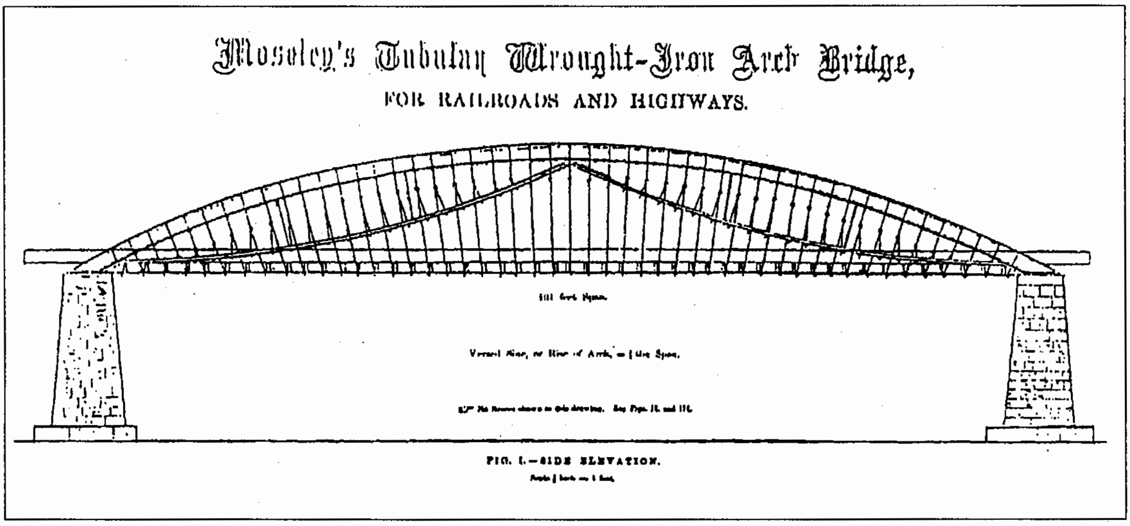

FIGURE 7. The Moseley arch as modified in 1859.

est being 200 horsepower. Its superintendent was David Buck, and Moseley was also listed as superintendent as well as agent.

Moseley's iron arch evolved over time from the arch shown in Figure 5. His revised arch can be seen in an 1859 illustration (see Figure 7) and in his 1863 prospectus (see Figure 8), titled *Iron: New Enterprise in its Manufacture and Applications to Building*.[2] This version is an improved bridge since Moseley used his experience and addressed some of the problems that must have arisen with his earlier bridges. He stated in another advertisement that "in 1859, a radical improvement was made in the bridge, greatly increasing it strength and stiffness."[11]

This improvement consisted of the addition of counterarches, which are evident, as well as additional short pieces of iron running from the bottom of the loop over the top chord to the counterarch. These short bars evidently kept the stirrups from sliding down the arch under the action of the suspenders. The saddles, *s-s*, are gone and the stirrups were now round bar stock. His suspension straps were made of 5/8-inch wrought iron bar stock and were hooked by a loop to the saddles.

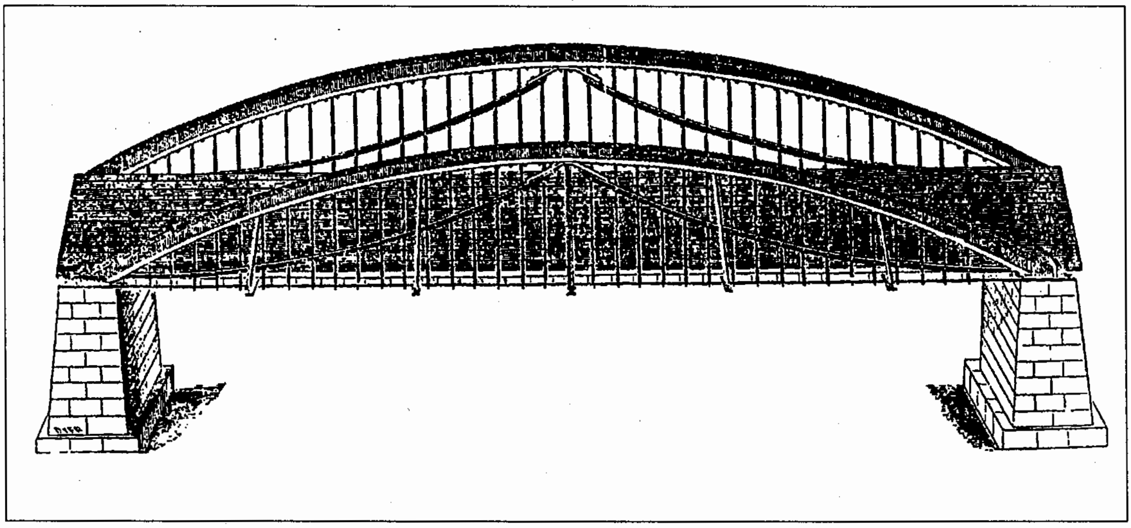

FIGURE 8. Moseley's arch as modified in 1863.

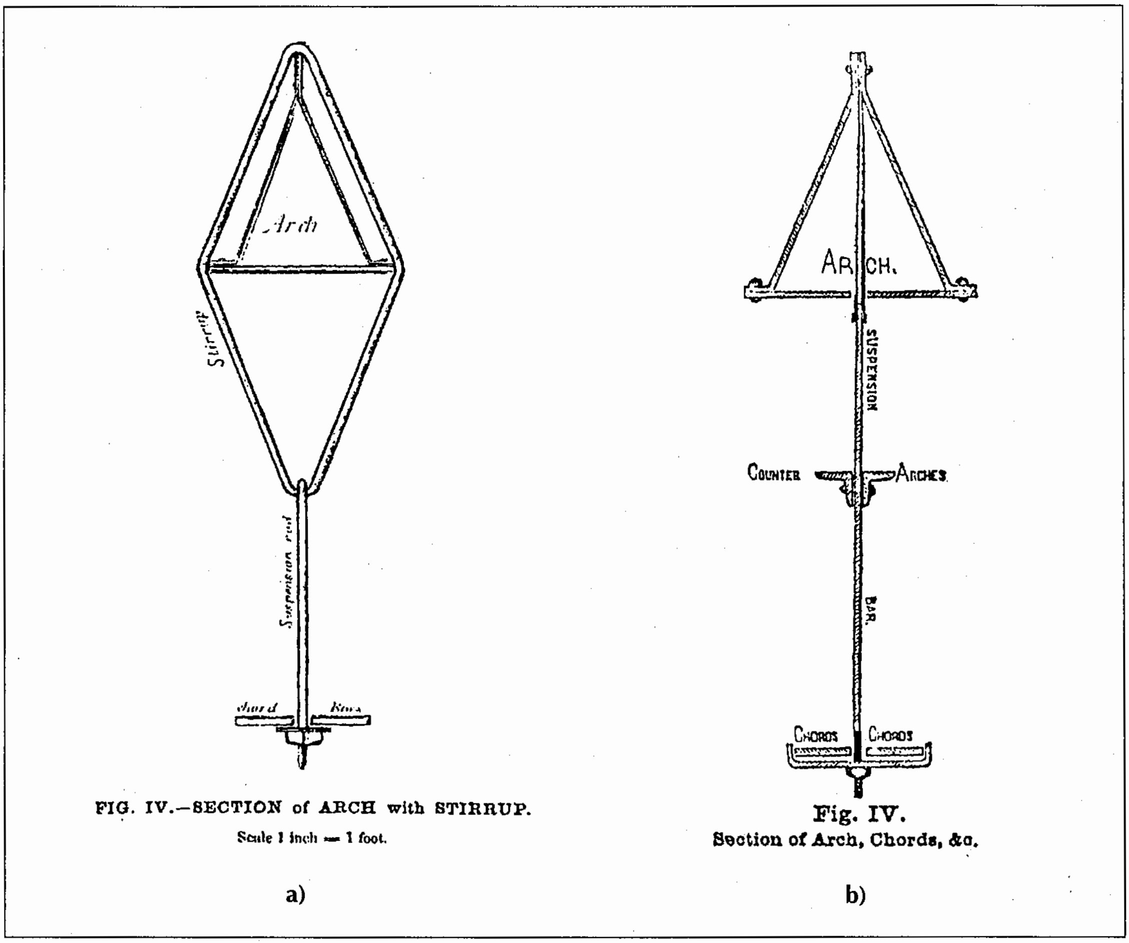

FIGURE 9. Evolution of the suspension system a) pre-1863 and b) post-1863.

He built several of these new improved bridges in Ohio and in Boston in the late 1850s and early 1860s. His most prominent early Boston bridge was of four arches built over the Boston and Worcester Railroad (later the Boston and Albany) at its intersection with Berkeley Street. It was located between Columbus Avenue and Chandler Streets and each arch was 66 feet long, making the entire bridge 264 feet in length.

His next improvement is shown in his 1867 catalog entitled *Iron Bridges — Roofs, Buildings, &c.*[12] The main difference between the 1863 and post-1863 design is in the suspension system. As shown in Figure 9, the suspension straps are riveted into what Moseley termed the "comb" of the arch. In addition, the suspender straps are vertical.

The base plate at the end of the arches did not change much but prior to his construction of the Lawrence bridge he made the changes that are indicated in Figure 10.

He described his tubular wrought iron arch bridge (see Figure 8) as follows:[12]

"The supporting parts of the bridge are two arches, one on each side of the highway. These arches are hollow, and are triangular or three sided made of wrought plate or boiler iron, by riveting three plates together at their edges. [See Figure 9, which shows the hollow arch, with suspension bar passing through it.]

"In no other form can iron be arranged to bear a greater burden than in this. By actual tests, every inch of iron in the cross section of the Arches will bear 15,000 lbs.; but in practice we provide for a weight of not less than four times the required burden, calculated, moreover, at a pressure of 7,000 lbs. per square inch of section.

"From foot to foot of each Arch goes the Chord [see Figure 10]. This is double, and binds securely the feet of the arch to each other, so that there is no thrust or outward pressure of the arches to require heavy abutments. The only pressure upon the masonry is vertical. In Highway Bridges, the cross-section of the chords has one-third the number of inches in that of the Arches; and in Railroad Bridges, one-half the number of inches in cross-section. The tensile strength of an inch of iron averages 60,000 lbs.: but, as will be seen, our calculations are based upon a tensile strain of 21,000 lbs. per square inch (in Railroad Bridges 14,000 lbs.), for four times the actual burthen (Burden).

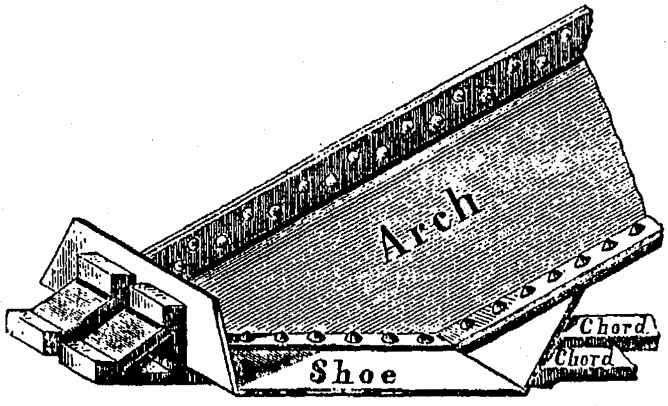

Fig. V. Part of Arch, with Shoe and Chords.

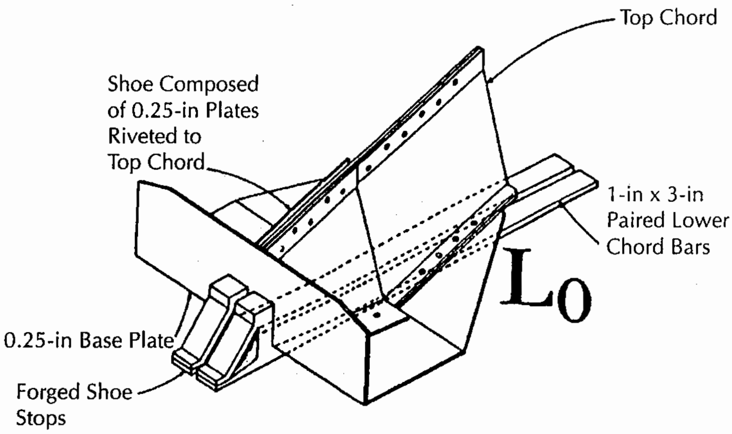

FIGURE 10. Base plate details.

"The Chords are held level, or in line, by Suspension Bars [see Figure 9]. These pass through the Arches; thence downward between the Counter-Arches (to which they are riveted), and support the Chord. They are placed at intervals of about 23 inches, giving 54 Bars in a fifty-feet [sic] Bridge. The same calculation governs the dimensions of these, as of the other parts of the structure, — *viz.*: to provide for eight or ten times the actual burden.

"The Counter-Arches are of angle Bar, doubled; and, varying with the span, correspond to the dimensions of the Main Arches and Chords [see Figure 8].

"The Floor rests upon the chords — a floor beam at every Suspension Bar. In common Highway Bridges of 16 to 20 feet wide, the floor beams may be of 3- by 14-inch lumber, covered with 2.5- or 3-inch plank.

"The adjustment of the various parts is such that no severe constant strain comes upon any bolt or other part of the structure; and thus all injury to the Bridge from jars, or impinging forces, is avoided. Hence there is no necessity for restriction as to rapidity of driving over it; and no injury has ever resulted from such cause. Contraction and expansion are fully provided for.

"These Bridges were first introduced in 1855. They have been from time to time modified and improved in the details of construction, until they now challenge comparison with all others.

"The earlier Bridges lacked the Counter Arches which, as now constructed, correct all undue elasticity.

"Later still, the present Suspension bars, which enter the Arch, and are riveted into its comb, were adopted, in lieu of the former Rods, which were connected with the Arch by means of a stirrup passing over it; and which failed to give the compact union of the parts now secured.

"While, for all purposes of a Bridge, the tubular-Arch principle is unsurpassed, we claim that, for certain uses, it cannot be approached in economy and security by any other."

Since it may be understood that Moseley was selling bridges in this catalog, some of his statements can not stand close scrutiny, especially the last paragraph. However, he is correct in stating that this new method of connecting the suspension straps to the top chord creates a more compact union of the parts.

In this same pamphlet, he stated he had built over 200 bridges in the six years that he had been in Boston including three bridges in Lawrence, Massachusetts. Photographic evidence, however, shows that at one time eight Moseley bridges crossed the North and South Canals of Lawrence — all of which were built between 1864 and 1868.

Moseley was granted three additional bridge patents — nos. 59,054 (in 1866) and 103,765 and 106,855 (both in 1870). These patents were all for wrought iron structures and had limited success.

In late 1867 or early 1868 he set up offices in New York City at 116 William Street and in Philadelphia at 147 South Street to promote the sale of his bridges in those areas. All fabrication, however, appears to have occurred at the Boston plant.[13]

His bridges had been built as far south as Houston and San Antonio, Texas, and as far west as Indiana. One of his more prominent, at least in terms of location, was a four-span structure in the Bronx. It had two long and two short spans, and crossed Pelham Bay at Rodman Neck, connecting Hunters Island with City Island at the west end of Long Island Sound. This area was, and still is, a major recreation area serving the city of New York.

Moseley sold his interest in the Boston plant, apparently under financial pressure, in 1871 to the New England Iron Company. The family history indicates that he and the company "met with reverses due principally to lack of capital and much of his property was used to liquidate heavy indebtedness, his patents taken over, appropriated, and even stolen."[1] He moved to 1433 Fawn Street in Philadelphia and became an agent for that company in the eastern Pennsylvania area. He later moved to Scranton, Pennsylvania, in 1875 and according to his obituary "lived in style" there until his death on March 10, 1880, of pneumonia.[14,15]

The Lawrence, Massachusetts, Moseley Bridges

By the early nineteenth century, the Industrial Revolution was in full swing in Northeastern Massachusetts. Dams and mills were seemingly being built everywhere to use the water power of the region's rivers and streams to power looms, spinning machines and forges, as well as saw and grist mills. Samuel Slater's water-powered cotton spinning equipment built in Rhode Island in 1795 slowly spread throughout that state and Massachusetts. The first of the large mills were built in Waltham, Massachusetts, and the revolution in cotton manufacture had begun. Lowell, Massachusetts, took the Waltham methods to new levels when huge mills were built to tap the water power of the Merrimack River.

As the Lowell mills expanded some enterprising businessmen just downstream began the development of a new city, which was to be called Lawrence. The Essex Company had been formed to build this new city around a core consisting of a dam, water-power canal system and manufacturing plants. The 5-foot drop at Bodwell's Falls in Lawrence required a high dam to provide water at the elevation needed to power the proposed mills. This "Great Stone Dam" across the Merrimack River was built under the supervision of Charles Storrow, the Chief Engineer for the Essex Company, and was completed in 1848. The dam's height was

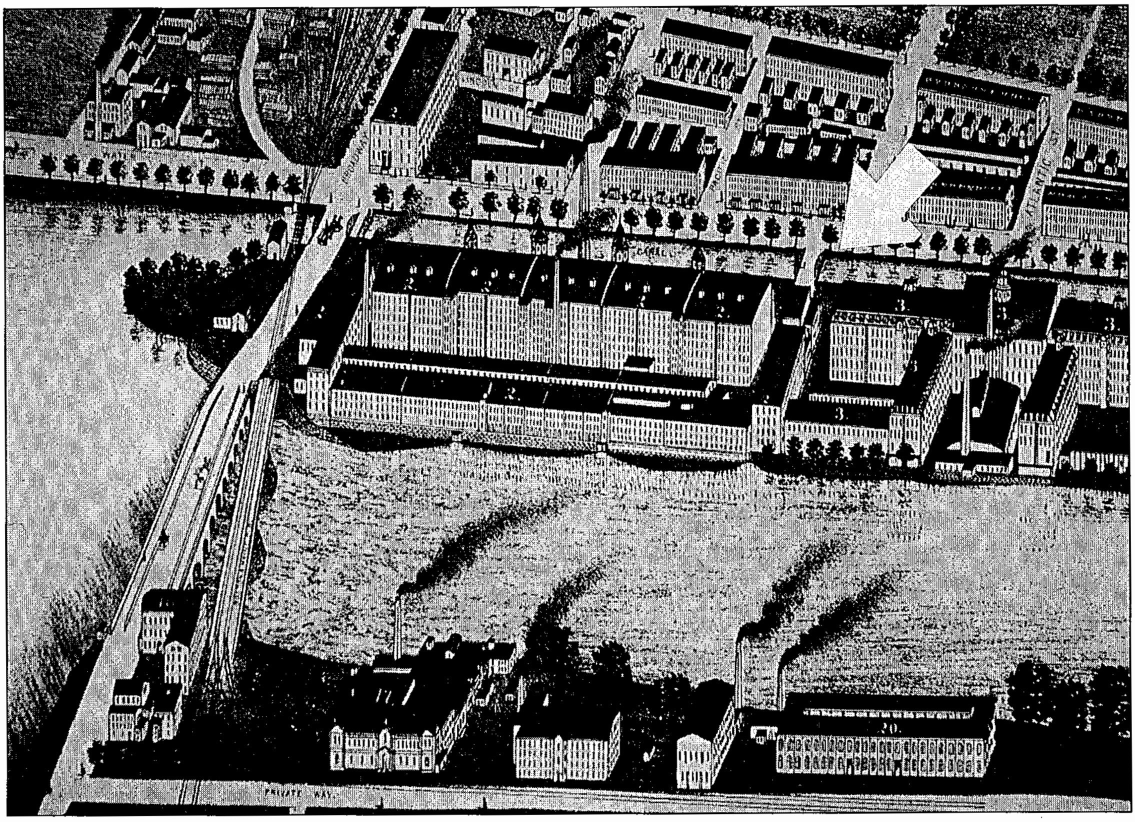

FIGURE 11. The Lawrence Great Dam and the North Canal. The arrow (at the upper right) marks the location of the Upper Pacific Mills Bridge.

33 feet with a length well over 1,600 feet. The North Canal (see Figure 11, near the top of the photo) was over 1 mile long. It was constructed to supply water to the mills that would be built between the canal and the river below the dam. The Upper and Lower Pacific Mills, incorporated in 1853, were built on this newly created island in the mid-1850s. Water from the canal would flow through penstocks turning a turbine which would distribute the power throughout the mill by means of flat belting and iron shafts. By 1860, Pacific Mills would be one of the largest producers of worsted and cotton goods in the country.

At the same time the mills were being built, housing for the work force was also constructed nearby and the rest of the city grew around this manufacturing core. It was necessary to build bridges to access the island across the North Canal so that the workers — and materials as well — could reach the mills. Most of these early bridges were of wood because iron bridge construction in the 1840s and early 1850s was limited to Squire Whipple's bridges in New York State over the Erie Canal.

The eight Moseley bridges built in Lawrence between 1864 and 1868 were as follows (see Figure 12):

- Union Street over the North Canal — moved to Parker Street over the South Canal in 1888; removed in 1923; approximately 72-foot span.
- Atlantic Mills Bridge — built in 1868 over the North Canal; removed some time after 1926; 92.25-foot span.
- Washington Mills Bridge (Office Bridge at the easterly end of the mill) — built over the North Canal in 1868; removed some time after 1923; span approximately 80 feet.
- Turnpike Bridge (South Broadway, Route 28) — built over the South Canal in 1867; span clear 63 feet 10 inches; a new higher

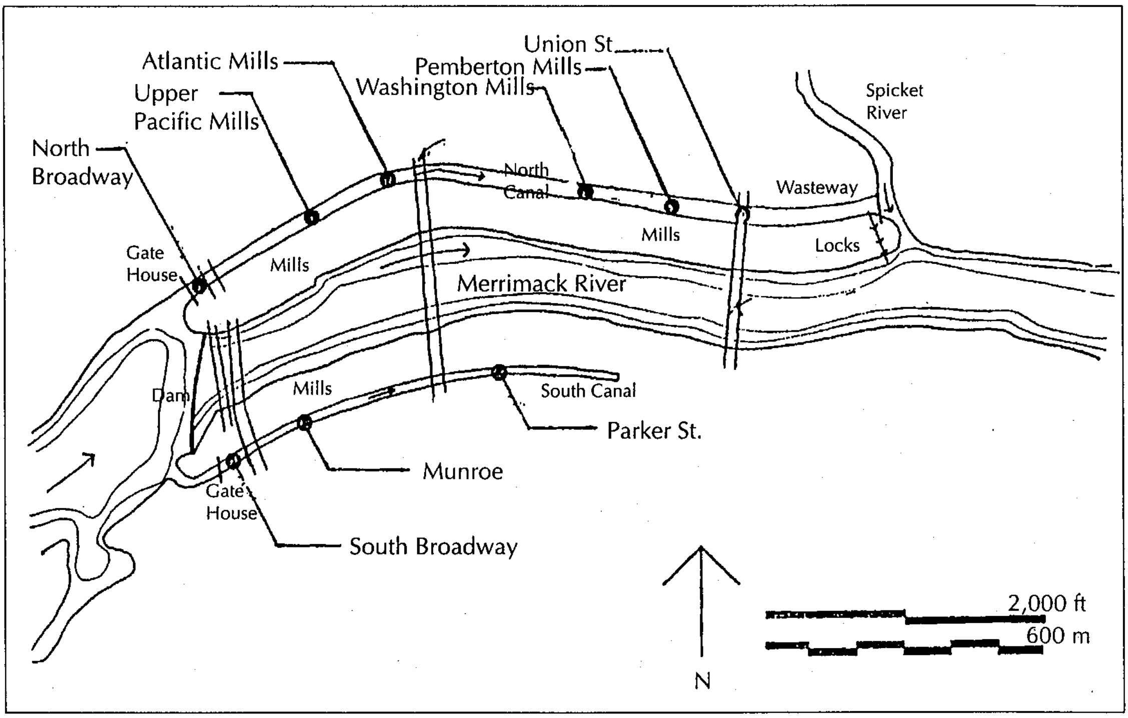

FIGURE 12. The location of the eight Moseley bridges in Lawrence.

capacity bridge was proposed as early as 1878 but no record exists as to the actual date of replacement.

- Turnpike Bridge (North Broadway, Route 28) — built over the North Canal in 1867 (probable the same date as for the South Canal); photographic evidence only exists; a higher capacity bridge was proposed as early as 1878 but no record exists as to the actual date of replacement; span would have to have been about 100 feet.
- Munroe Mill Bridge — built over the South Canal 1867; span clear 60.67 feet; removed after 1951.
- Pemberton Mill Bridge — adjacent to the railroad bridge; no data available other than a photograph that a Moseley bridge did exist at this location.
- Upper Pacific Mills Bridge — built over the North Canal in 1864; span 96.25 feet, removed 1989 and reconstructed on the campus of Merrimack College.

The Upper Pacific Mills Bridge

This Moseley iron arch bridge was built across the North Canal in 1864 to service the Upper Pacific Mills and to replace a wooden bridge that had outlived its usefulness. It is shown by the large arrow in Figure 11.

The Upper Pacific Mills Bridge is the oldest extant iron bridge in the Commonwealth of Massachusetts and one of the oldest riveted wrought iron bridges in the United States. It is one of only four known bridges built by Moseley still in existence. One Moseley bridge located in Claremont, New Hampshire, was built in 1870 and is a 103-foot span bowstring with web members in a diagonal pattern (see Figure 13). It served as a foot bridge across the Sugar River and is in danger of imminent collapse. Another Moseley bridge carried Murphy Road over the Walloomsac River near Bennington, Vermont. It was removed from service in 1958 and is stored behind the Bennington Museum. The last bridge is the Hares Hill Road Bridge over French Creek in Chester County, Pennsylvania, which was built in 1869 (see Figure 14).

The Historic American Engineering Record (HAER) visited the site of the Upper Pacific Mills Bridge in 1976 and recorded the condition and situation of the bridge as follows (see Figure 15):[16]

FIGURE 13. The Moseley bridge in Claremont, New Hampshire.

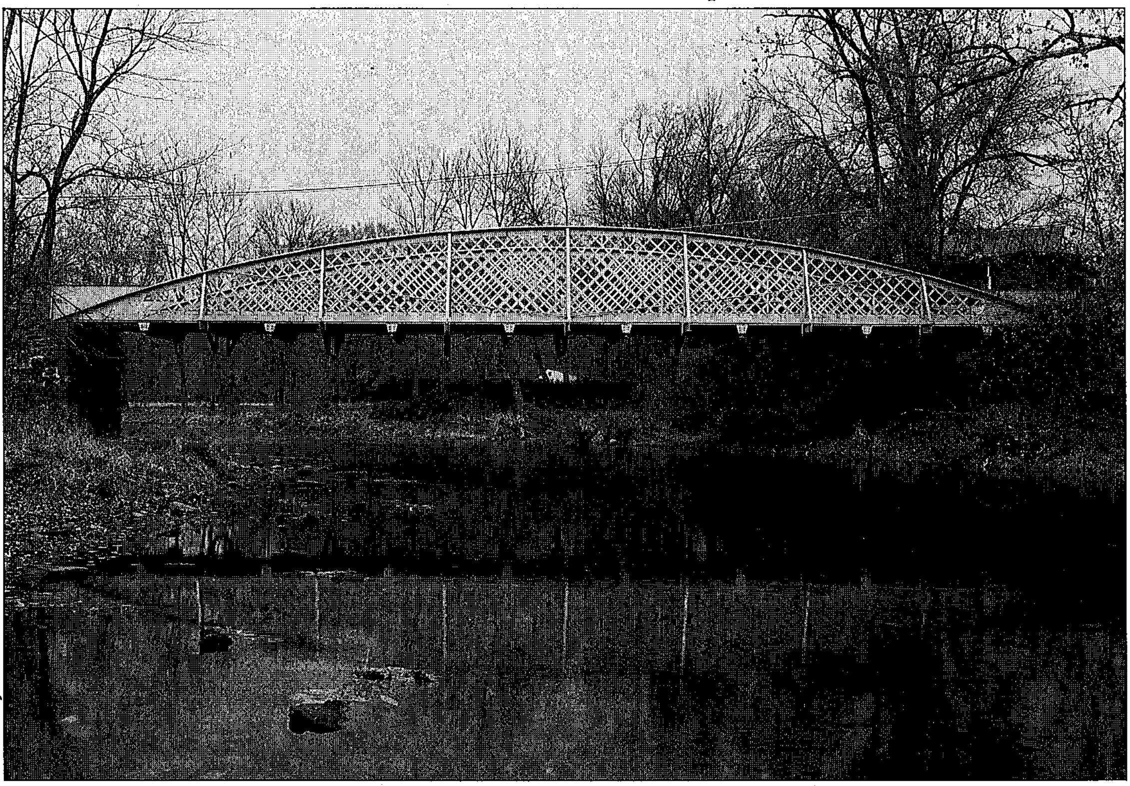

Photo by Steven Schwartz © 1991

FIGURE 14. Moseley's Hares Hill Road Bridge in Chester County, Pennsylvania.

Photo by Martin Stupich, courtesy of HAER

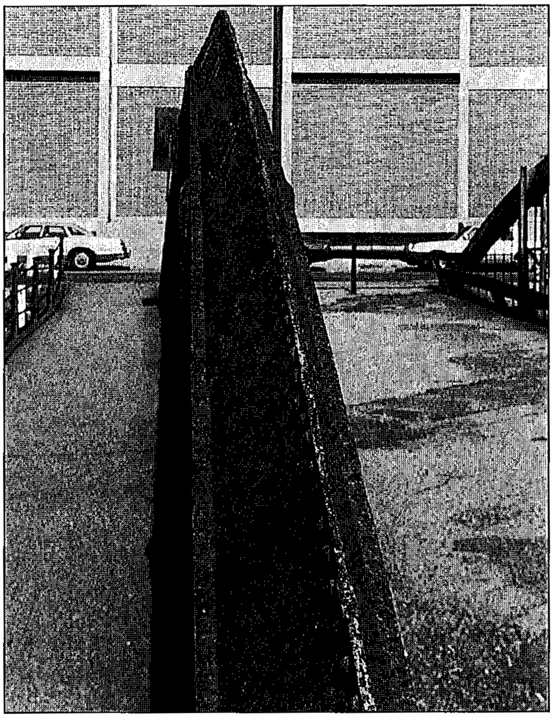

FIGURE 15. The Upper Pacific Mills Bridge in 1976.

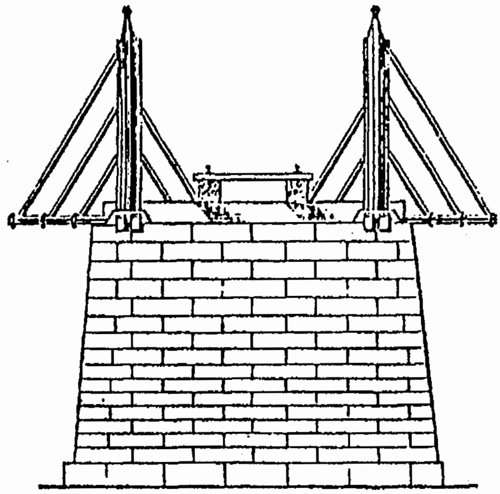

FIGURE 16. A Moseley bridge with outside lateral bracing.

"The bridge was built to span the North Canal and connect the Pacific Mill with Canal Street. It was built in 1864 by the Moseley Iron Building Works of Boston. The designer was Thomas W. H. Moseley of Cincinnati, Ohio, who held two patents on the upper chord design, dating from 1857 and 1858. The bridge is a bowstring truss, and contains five panels. There are no diagonal members. The vertical members are pairs of parallel 3-inch rod which are riveted to the upper chord and bolted to the lower chords. There is a curved member which is riveted to the upper chord and bolted to the intersection of the upper and lower chord. It is probably intended to stiffen the truss. The upper chord is a series of triangular iron sections riveted at 8-foot intervals. The lower chord is a system of parallel iron plates riveted in sections. There is no upper lateral system. The lower lateral system consists of girders similar in style to the upper chord, and wooden stringers. The bridge has been supplemented by a modern wooden system of piers and girders and stringers. Span is 100 feet, depth is 10 feet and width is 18 feet."

While there are many improper uses of terms in this description, the wooden structure referred to was carrying all pedestrian and vehicular traffic loads for some time. The arches were serving primarily as a railing.

This version was different from all other known Moseley arches in terms of his method of providing lateral support to the arches. Previously, with long spans, he used diagonal braces outside of the bridge as shown in Figure 16. In the Upper Pacific Mills Bridge he had sidewalks on the outside of the arches, thus prohibiting his standard method of providing lateral support. He overcame this difficulty by cantilevering twin vertical pipe members off of triangularly shaped, iron cross beams in six locations and tying these posts to the lower portion of the top arch members, thus stabilizing the arch (see Figure 17).

Wooden beams, which rested on the top of the tension straps, supported the deck and sidewalk surfaces. In addition, the vertical straps were not riveted to the counterarches as called for in most descriptions. The counterarches had drilled holes in them — apparently to connect with the suspenders but it appears that a fabrication error occured and the holes in the counterarches did not line up with those in the suspension straps.

Moseley had tinkered with this bridge design for over seven years before he built in Lawrence. What he had in mind, or what he had experienced over time with his other bridges, is not known, so it is difficult to reconstruct this evolution except by tracking his reports and observing the bridge as built in 1864. The exact date that the wooden understructure was placed is not known, but many other Moseley bridges that were owned and maintained by the Essex Company were replaced in the 1920s. The bridge had been closed to vehicular traffic for many years and served only as a pedestrian bridge until the summer of 1989.

The Collapse

In the summer of 1989 the wooden understructure of the bridge partially collapsed and caused the eastern arch to buckle at about the third point (see Figure 18). The owners of the bridge had begun the process of demolishing the bridge when the writer became aware of the situation. The owners were asked to donate the bridge since it was of great historic significance and should be preserved. They gave the author the bridge, but said that they could not assist in any way to move or preserve it. Also at that time the first of many small "miracles" occurred, since it so happened that the contractor who was demolishing the bridge was a former student of the author. The contractor helped move the bridge to the Merrimack College campus in short order.

When it arrived on campus it did not look much like a bridge (see Figure 19). Over the next two years — with the help of the BSCES section of ASCE, many friends, companies, family members and students — the bridge was fully restored (see Figures 20 and 21) and ready to be moved back, it was hoped, to some location in Lawrence.

After several attempts to persuade the city to help move the bridge back to North Canal, it was determined that while there was some interest there would be no support of any kind from the city. Working with civil engineering students, the author succeeded in getting permission of the Board of Trustees of Merrimack College to place the bridge on campus adjacent to the new Science and Engineering building. The bridge was moved across campus and placed on two new piers in April 1995.

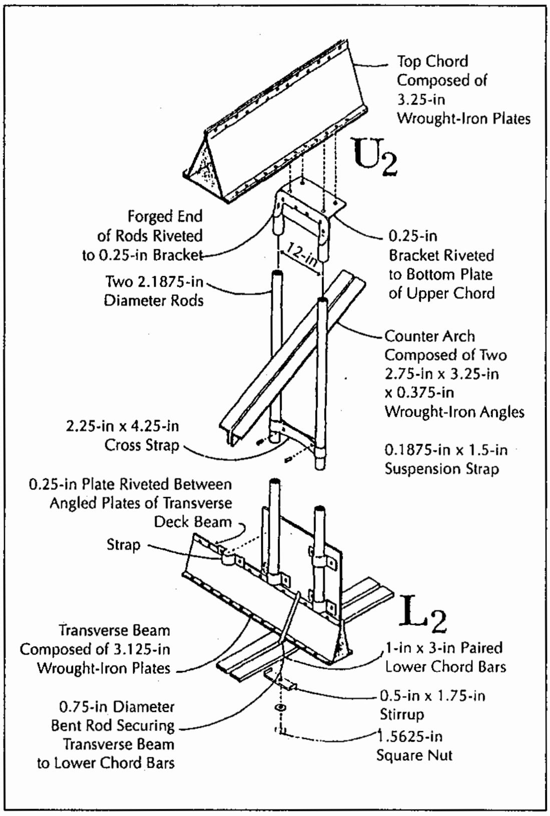

FIGURE 17. The lateral bracing system on the Upper Pacific Mills Bridge.

After the bridge was in place, a reflecting pond was constructed under it. The usual case is that bridges go over bodies of water, not bodies of water under bridges, but that turned out to be the best way to handle this particular problem. The pond was completed in early fall and the project was dedicated on December 1, 1995.

Moseley's bridge now carries pedestrian traffic across a beautiful pond (see Figure 22). Since it is located in a protected environment, it should last another 125 years serving the students and faculty of Merrimack College. This preservation and restoration project — that was accomplished with the help of many individuals, associations and companies — is an example of what can be done without government money to preserve our engineering heritage. Moseley would be proud!

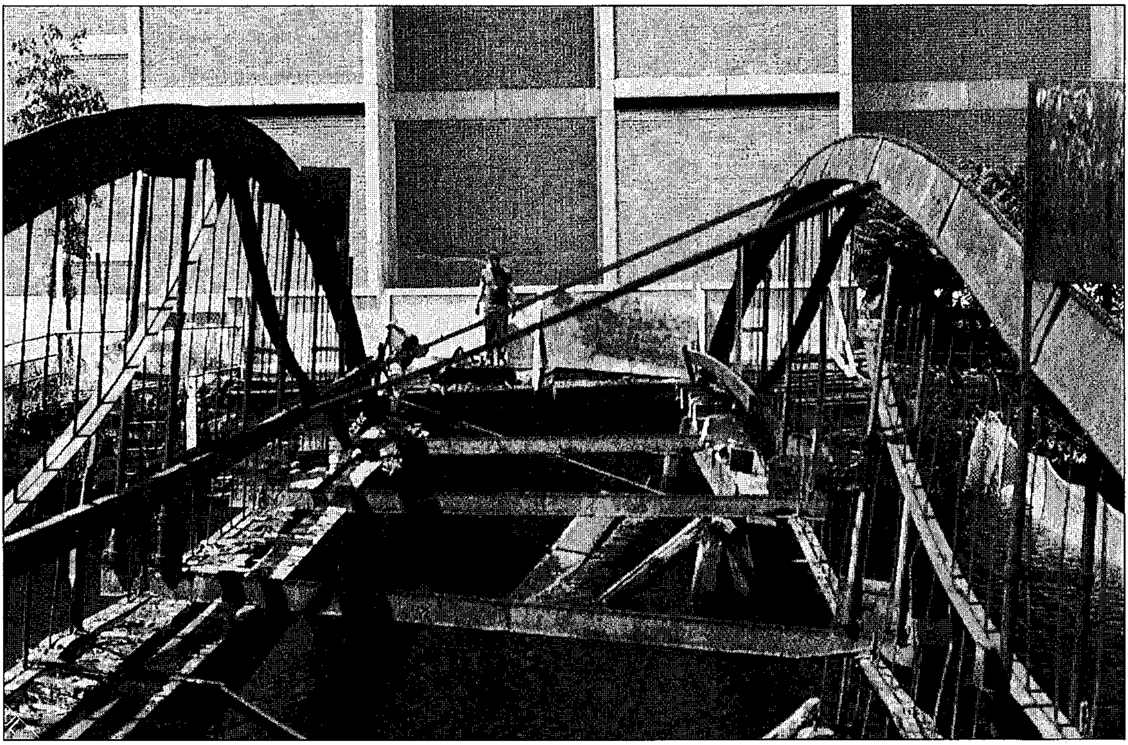

FIGURE 18. The Upper Pacific Mills Bridge after its collapse and during dismantling.

FIGURE 19. The Upper Pacific Mills Bridge during its rehabilitation.

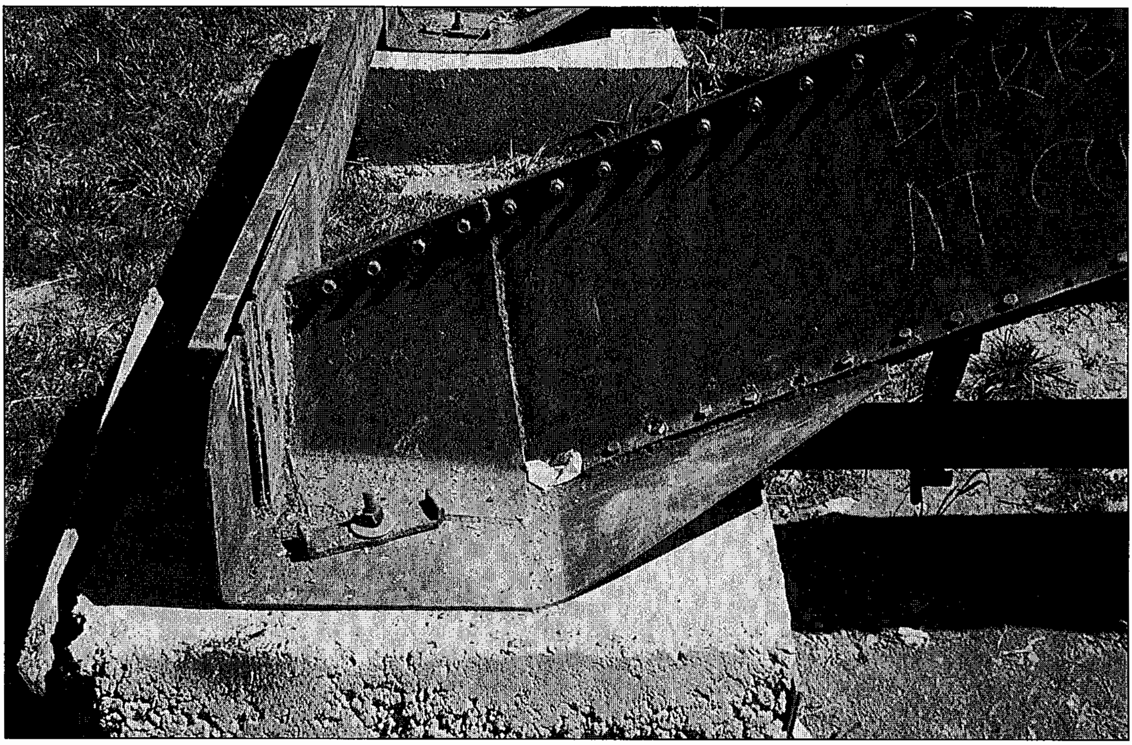

FIGURE 20. New end detail of steel for the bridge.

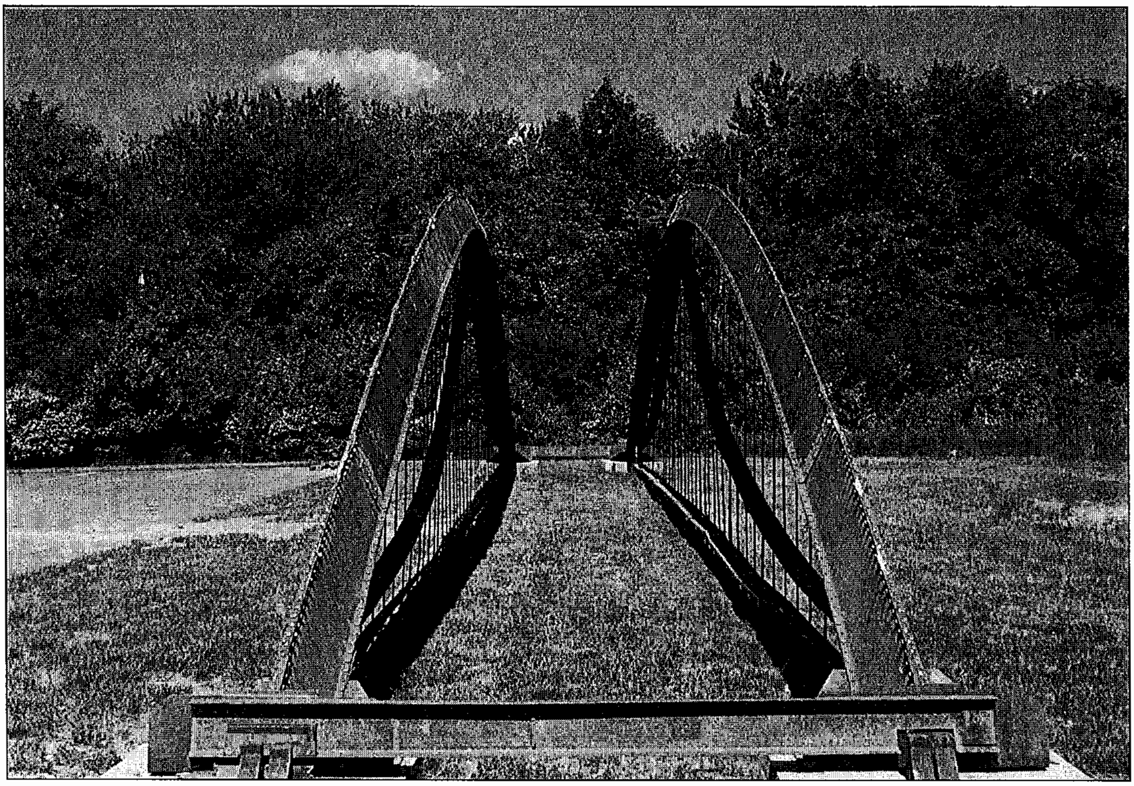

FIGURE 21. Both arches completed in the rehabilitation process in 1991.

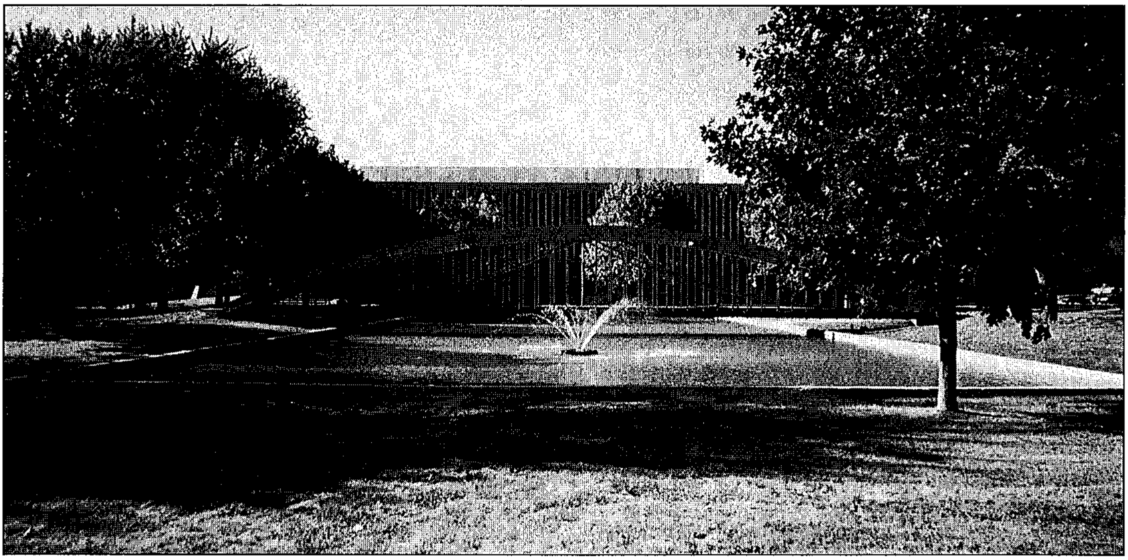

FIGURE 22. The bridge and pond at its new location at Merrimack College in 1995.

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