The Newburyport Bridge: The First Long-Span Wooden Bridge in the United States

Using the truss in a way foreseen by Palladio, Timothy Palmer ushered in an age of long-span bridge building in the nation.

FRANCIS E. GRIGGS, JR.

The era of the long-span wooden truss bridge began with the construction of the Newburyport Bridge, also known as the Essex-Merrimack Bridge, across the Merrimack River between Salisbury and Newbury, Massachusetts, by Timothy Palmer in 1792. Using the lessons learned on this, his first bridge, Palmer went on to build three other bridges across the Merrimack and more over the Piscataqua River in Maine, the Potomac River near Georgetown, the Permanent Bridge over the Schuylkill River in Philadelphia and the Easton Bridge over the Delaware River. His construction methods and use of naturally curved timber set the stage for explosive growth in long-span bridge building in the United States.

Timothy Palmer

Timothy Palmer was born in Rowley, Massachusetts, on August 22, 1751, the first of eight children of John and Mary (Cressey) Palmer (see Figure 1). The Palmer and Cressey families had their roots in the Rowley area since the early days of the Massachusetts Bay Colony. His family moved to nearby Boxford in 1767, when he was sixteen years old. He marched as a Minuteman towards the Battle of Concord but turned back when the British retreated to Boston. He also fought in what was called the Battle of Bunker Hill before returning to Newburyport to apprentice under Moody Spofford as a millwright and architect, designing churches and meeting houses. He married Anna Wyatt on December 16, 1776, in Newburyport. She died in 1786 at the age of thirty-two before Palmer began his bridge-building career. He later married Hannah Downer on March 9, 1795. He had no

FIGURE 1. Timothy Palmer.

children by either of these marriages and died in 1821.

Little is known of Palmer and the life he led before, during and after his career as bridge builder. It is best to bear in mind the words of Christopher Wren, the famous English architect who designed and built St. Paul's Cathedral and much of London after the Great Fire. He said that, "If you want to see my monuments, look around." Palmer's works were truly his monuments. While no bridges have survived, their impact on bridge building and transportation in a young country was significant in earning him the title "The Nestor of American Bridge Builders." Many of his bridges were not well documented, but several were, including the Newburyport Bridge.

Bridge Location

Palmer's involvement with bridges was minimal when he began his bridge-building career at the age of forty-one. He would have been familiar with the bridge in Newbury over the Parker River, a tributary of the Merrimack River and the Thorlay Bridge over the Parker River, which was initially built in 1654 as a toll bridge. The only other bridges he might have known were the Charles River bridges and the other bridges located between Newburyport and Boston — all of which were short-span beam bridges.

In 1790, the federal census indicated that the town of Newbury had 3,972 inhabitants and 538 homes, while Newburyport, much smaller in area, had grown to a population of 4,837 inhabitants and 616 homes. The town of Salisbury, directly across the Merrimack River from Newburyport, had a population of 1,780. Newburyport was a major port city, ranking thirteenth in population in the country at that time, and was the home port to a large number of ships, brigantines, schooners and sloops. It was a very prosperous community due to its involvement in shipbuilding. In addition, it was situated on the main road from Boston north to New Hampshire. In 1790, several ferries crossed the river at Newbury and Newburyport.

The ferries across the Merrimack River were dangerous at times; however, they met the needs of the traveling public at a cost most could afford. In 1791, a group of local leaders proposed that a bridge be built across the river at a point just upstream from the town (see Figure 2). A bridge near the proposed site had actually been built across the river at what was called Carr's Ferry as early as 1650. George Carr was authorized to build this floating bridge 5 feet wide from an island he owned that was located in the channel of the Merrimack over the north branch of the river. When completed, this bridge was one of the earliest in the New World. Over time, Carr's Ferry was discontinued as the traffic shifted westerly, closer to Newburyport.

Initiating the Project

In the eighteenth, nineteenth and even into, but to a lesser degree, the early twentieth centuries, bridges were mainly built by private corporations that were issued charters by state legislatures to build and operate them. The stockholders were generally given a monopoly on river crossings for a certain distance upstream and downstream and were authorized to charge tolls that were approved by the legislatures. A charter typically was granted for a specified period of time and generally had a clause where the state could purchase the bridge at a fair price in the future. It was in this environment that a petition was prepared for approval by the legislature. The first step

in this process was the distribution of a subscription on May 30, 1791, stating:

> Whereas a bridge over the Merrimack River from the land of Hon. Jonathan Greenleaf in Newbury to Deer Island, and from said Island to Salisbury, would be of very extensive utility by affording a safe conveyance to Carriages, Teams, and Travellers at all Seasons of the year at all times of the Tide. We, the subscribers, do agree that as soon as a convenient Number of Persons have subscribed to this, or a similar writing, we will present a petition to the Hon'ble General Court of Massachusetts praying for an act incorporating into a body politic of the subscribers to said Writing with liberty to build such bridge and a right to demand a toll equal to that received at Malden Bridge and on like terms; and if such an Act shall be obtained, then we severally agree with each of the others that we will hold in the said bridge the several shares set against our respective names, the whole of two hundred shares being divided, and that we will pay such sums of money at such times and in such manners as, by the said proposed Corporation shall be directed and required.[1]

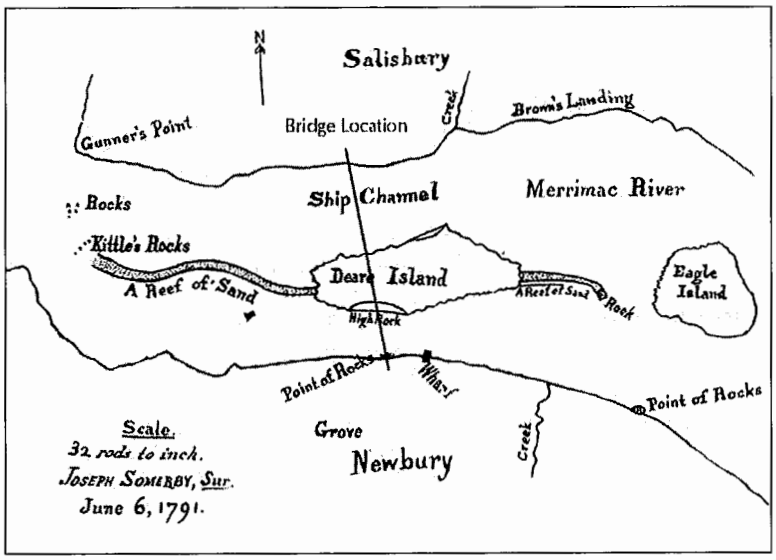

FIGURE 2. A map showing the location of the bridge.

The subscription was signed by forty individuals pledging between one and twenty shares. To meet the preliminary expenses of obtaining the approval of the legislature, surveying the site and preparing conceptual plans, each subscriber was required to pay an assessment of six shillings per share.

The formal petition to the legislature dated June 1, 1791, stated:

> To the honorable the Senate and to the honorable House of Representatives of the Commonwealth of Massachusetts in General Court assembled
>
> The petition of the subscribers, Citizens of the said Commonwealth shews
>
> That a bridge across Merrimack River from a place called the pines in Newbury in the county of Essex to Deer Island, so called, and from the said Island to Salisbury in said County would in the opinion of your petitioners very greatly subserve the public interest and convenience by affording a safe, prompt and agreeable conveyance to carriages, teams and travellers at all seasons of the year, and at all times of tide, whereas great dangers are incurred and great delays often suffered by the present mode of passing in Boats.
>
> Your petitioners further represent that they with others have associated for the purpose of erecting a bridge at the aforementioned place provided the countenance of the honorable Legislature can be so far obtained as to authorize the measure.
>
> Your petitioners therefore humbly pray your honors to take this subject into your wise consideration & that an act may pass incorporating our petitioners with such others as are or hereafter may be associated with them into a body politic, with permission to erect the said bridge with power to demand such reasonable toll as to your honor shall appear an adequate indemnification to them for the risk and expense

attending this undertaking, and with such further corporate power as to your honors shall seem necessary or proper for carrying the said under taking into effect. And your petitioners as in duty bound shall ever pray.[2]

Nine gentlemen, including the leading citizens of the town, signed this petition. As a part of the process, the legislature on June 13 required them to make public their petition in "three weeks successively in the month of September next in Adam's independent *Chronicle* printed in Boston and in Mycall's *Essex Gazette* printed in Newburyport, to the intent that any person may appear on the second Wednesday of the next session of the General Court and shew cause if any he may have why the prayer of the said petition should not be granted."[3]

Since the construction of such a structure would have been a great advantage to people using the ferries, the subscribers thought there would be universal support from the citizens, with the exception of those who made a living from the ferry business. Such was not the case since Newbury on three occasions at their town meeting voted to instruct its representatives to the legislature to vote against the act of incorporation. They sent a "long remonstrance to the General Court objecting to the proposed obstruction of the navigation of the river."[4] The town of Salisbury also voted against the bridge, as did the town of Haverhill upstream from the bridge. Haverhill had as its reason "that the piers would lessen the tide up the river" and that "the committee of this town say that there was not more than nine feet of water over the shoals in common tides, and they feared it would be greatly lessened if the proposed bridge should be built."[5]

The same opposition to any bridge over a navigable river was made for the next eighty years as shipping interests were against any pier being built that would inhibit free navigation of the river. It must be understood that this opposition occurred before the introduction of steamships, starting in 1807 with Fulton's steamship on the Hudson River. The first steamship on the Merrimack River did not appear until 1828. Shipping interests were properly concerned since bridge building at this time required many wood or stone piers in the waterway because it was not possible to span distances of much over 30 to 40 feet with beam-type structures. A bridge of this type across the Merrimack River would have put a stop to shipping as far as Andover at Bodwell's Falls. The people against the bridge, however, did not know what type of bridge that Palmer and the subscribers had in mind — one with spans upward to 160 feet, thus keeping the navigable waterway fairly clear.

The subscribers submitted their plans to the legislature at the time of the petition. These plans included a description of the spans and width of the bridge. The act of incorporation was approved by the legislature on February 24, 1792, and was signed by Governor John Hancock. The five-page, handwritten document set up the corporation, stating:

And be it further enacted by the authority aforesaid that the said proprietors be and they are hereby permitted and allowed to erect a bridge over the Merrimack River, from the place called the pines in Newbury aforesaid to Deer Island so called and from the said island to Salisbury aforesaid.[6]

The toll was set up in part as follows:

For each foot passenger two thirds of a penny.

For each horse and rider two pence.

For each horse and chaise chair and Sulkey seven pence.[6]

The right to charge tolls was good for fifty years, but at the expiration of thirty years the legislature could regulate and determine the toll rate. From an engineering view, the legislation probably contained at least a preliminary design by Palmer since the act stated:

And be it further enacted by the authority aforesaid that the said bridge shall be at least thirty feet wide; that between Newbury & Deer Island there be an arch one hundred and sixty feet wide — that between Deer Island and Salisbury there be an arch one hundred & forty feet wide, a

convenient draw or passage way for the passing & repassing of vessels at all times fifty feet wide with well constructed substantial and convenient piers on each side of the bridge & adjoining said draw sufficient for vessels to lie at securely; and also another arch fifty feet in width; and that the crown of the arch between Newbury & Deer Island be at the least forty feet high, and that each of the abutments thereof be twenty eight feet six inches high in the clear above common high water mark; and that all the abutments and piers be built of wood below high water; and laid in the crib work manner, so called; and that the bridge be covered on the top with plank or timbers and the sides be boarded up two feet high & be railed for the security of passengers four feet high at the least, and the same shall be kept in good safe and passable repair, and that said draw shall be lifted for all ships and vessels without toll or pay by night and day: And all ships and vessels intending to pass the said draw shall be free of charge at the wharf or pier until a suitable time shall be offered for passing the same; And said proprietors shall constantly keep some suitable person or persons at said draw for lifting up the same for the purpose aforesaid, and also an anchor placed in the bed of the river at a proper distance on each side of the bridge with a buoy and such other accommodations as shall be necessary for the safe passing and repassing of vessels, through the said draw, & shall keep said bridge furnished with at least five good lamps on each side of the same which shall be well supplied with oil and kept burning through the night.[6]

The spans listed in the legislation were similar to those of the bridge as built. When the legislation referred to the bridge as being "covered on the top," it was referring to the decking. Railings were common, but normally they were not boarded up 2 feet high. The legislature was very careful to protect the rights of ships and vessels moving up and down the Merrimack River and required that no toll be charged for any such vessel passing through the draw. Even with opposition from the Haverhill, Salisbury and Newbury town boards the act was passed.

Records at the Newburyport Historical Society contain letters from Joshua Davis and Thomas Sumner in response to an announcement that the directors of the bridge placed in a local newspaper regarding the submission of plans for the bridge. Keep in mind that the directors already had preliminary plans they submitted to the legislature from someone who could have been Palmer or Moody Spofford. Davis wrote that "having four days hence observed your Publication concerning a Bridge over Merrimack River & having had some experience in superintending work of that kind in times past I loath to present to you a very rough sketch of a model that kind altho my expectations are very small of being the one expected."[7] His three-page letter talks about member sizes, connections and foundations, but without the rough sketch he mentioned it is difficult to understand most of it. Sumner's letter was much in the form of an apology for even offering a proposal since he wrote that "perhaps you will think it presumption in a young man to presume to write to a gentlemen he never saw, But Sir encouraged by the fairness of your character & the intent you take in erecting a bridge over Merrimack River & knowing that all are invited & many will try. Consequently if refused I shall not be alone, then I with the more readyness offer my product to your patronage. As the hope of gain inspires everyman with the spirit of ambition, I selected my scattered ideas upon the subject & put them together upon paper. But knowing that a plan is not so soon understood by every person, I determined to make a compleat model. Which I now send you."[8] Sumner went on to talk about connections and choice of wood for his various parts and concluded in his charming manner that "sir, if my plans do not answer the purpose & you will be kind enough to convey them back in the same channel, you will lay under a great obligation."[8]

By early April, the directors evidently had many proposals, consisting of drawings, models and extensive descriptions of bridge styles. It is still not known if Spofford and Palmer's bridge plan had been submitted by that time.

The directors, having no one on the board competent to make engineering judgments, sent out a letter on April 10, 1792, to eleven men, who apparently were bridge builders or individuals with some standing in the area asking:

> The Directors of the Essex-Merrimack Bridge request the favour of you to take an early opportunity to take a deliberate view of the several Models proposed for the Arch, and give us the result of your Examination, to which of the said Models you give the preference, and if neither of them appear to you on the whole proper to be executed, we request you further to take into your consideration whether new plans cannot be formed from those already exhibited, and if you shall be of that opinion, we further request that you would with all convenient speed furnish us with such a one.[9]

Apparently, eleven men voted on the proposals since, according to the Newburyport Historical Society, the final vote was as follows:

> Numbers that give the preference to:
> 6 — for Number 20 with some amendments
> 3 — for Number 3 with some amendments
> 1 — for Number 8 with some amendments
> 1 — for a well constructed deck bridge beams to [word illegible] one inch to a foot or more is necessary.[10]

Unfortunately, no record survives that indicates exactly what proposal Numbers 20, 3, and 8 referred to. It is probable, however, that Number 20 was Palmer's proposal, and it is also likely that his plan was the basis of the original proposal to the legislature. The level of interest in building the bridge was, however, clear. If proposals were numbered sequentially, there were at least twenty, and possibly more, submitted. It is also unfortunate that the models and drawings are lost. If they could be reviewed, they would show the state of bridge building in the latter part of the eighteenth century in the United States.

With a new, or enhanced, plan in hand, the directors evidently decided that the original legislation was not acceptable and proposed changes to be submitted to the legislature. In May 1792, Samuel Cutler received a sketch for the 160-foot span showing heights of abutments above high water and showing the rise in an arch and thickness of an arch. This arrangement gave the structure a height above water of 36 feet (in contrast to the 40 feet called for in the legislation). The directors requested a change in the law to permit a lowering of the arch and an alteration in the braces of the bridge. The bill was submitted to the legislature on June 9, 1792, and representatives from the towns of Haverhill and Amesbury, among others, saw a chance to kill the project on the second reading of the bill the following Wednesday (June 13). State Senator John Mycall wrote a letter to the directors on June 9, noting that "more opposition, I believe, had seldom been made, and there is every reason to suppose that it will recommence with increased fury at the second reading — during the interval, it stands re-committed, — and the members from Haverhill and Amesbury have this day taken their departure for home in order to stir up their constituents, that some means may be devised to frustrate the design of the proprietors — they have also engaged Mr. Blodget in their services who is now in town, and to tarry until the final issue of the bill."[11] Samuel Blodget was a well-known builder in the area, having placed improvements on the Merrimack River farther upstream at Manchester, New Hampshire. He may have submitted a proposal for the bridge that was one of those turned down in favor of Palmer's. Enoch Titcomb, a member of the House, wrote to Captain Coombs, saying that the House had "in order for Mr. Carr & Mr. Wingate time to go home & consult their constituents, — they are both very much opposed to any braces or any alteration which they think will in least obstruct the passage of boats & it was said in court that Mr. Blodget was in town, & could remove all the difficulties without having any braces — if either of the concerns in the bridge desire to be heard, further before the second meeting of the Bill, they will have [opportunity] — I mentioned to Mr.

March last evening that it might be of advantage to have Mr. Palmer here, to explain in one of the lobbys to the members the proportions of the model, distance, &c — it was much admired by many members, & some encomiums made on it. I am much inclined to think the Court will lower the arch & also the braces — be assured the Representatives of Newburyport will do all in their power honorably to serve the proposition of the bridge, & the Public Interest."[12]

The act was passed on June 22, 1792, and it modified the restrictions and limitations of the first act with regard to the height above high water mark, braces, etc. The change evidently came about after Palmer was selected as chief bridge engineer, as noted by a comment from Titcomb.

The revised act stated:

> Whereas the Directors of *Essex Merrimack Bridge* have petitioned this Court, setting forth, that in the execution of the said undertaking, sundry inconveniences have arisen to them from the particular restriction of the said Act respecting the form of the said bridge, and praying the interposition of this Court for the removal of the same:
>
> Sect.1 *Be it therefore enacted by the Senate and House of Representatives, in General court assembled, and by the authority of the same,* That in the building and completing of the said bridge, any alterations from the limitation and restrictions of the said Act, so far as the same respect that part of the said bridge which lies between Deer Island and Salisbury, be and hereby are authorized as allowed; anything in the said act to the contrary notwithstanding.
>
> Sect. 2 *Provided nevertheless,* That there shall be one arch, at least one hundred and ten feet wide, and a convenient draw for the passage of vessels, at least forty feet wide; and they provided also that there shall not be in the whole less vacancy for the passage of the water, that in and by the said Act is required.
>
> Sect. 3 *And be it further enacted by the authority aforesaid,* That the crown of the arch to be erected between Newbury and Deer Island may not be less than thirty-six feet high, and that each of the abutments thereof may not be less than twenty-four feet and a half high, above common high water mark; and that braces or shores may be placed from the abutments of the said arch, at four feet and a half from common high water mark, to pass up to the said arch, at not more than forty-eight feet distance, from the top of the said abutments; any thing in the said Act to the contrary notwithstanding.[13]

The directors got what they and Palmer requested, namely a lowering of the arch on the Newburyport side from 40 to 36 feet and a reduction of abutment height from 28.5 to 24.5 feet. They also got permission to place braces under the arch off the abutments. This alteration was extremely important, since Palmer's truss would have received significant support from these braces or struts. The span of 160 feet would not have been buildable without the braces due to the limitations on timber sizes available at the time. In addition, if Palmer used the full distance out to the lowest brace of 48.5 feet, the clear span through which vessels could pass would be only 64 feet. From a shipping standpoint, these specifications made the Newbury to Deer Island opening very restrictive and almost forced ships to pass through the Deer Island to Salisbury draw span. On the Salisbury side of the bridge, they reduced the draw span from 50 to 40 feet, and added the unenforceable clause that there "shall not be in the whole less vacancy for the passage of the water." In other words, they did not want the bridge to block the waterway to any significant degree so they could say that they had addressed the concerns of upstream cities like Haverhill. This consequence may be why Palmer increased the span length of the Salisbury arch to 113 feet from the required 110 feet.

It is not known how Palmer secured the contract to build his first bridge over the Merrimack River, but apparently his association with Moody Spofford was helpful. *The Massachusetts Magazine,* in May 1793, reported that "this bridge was built, under the prospect of advantages much less encouraging, than

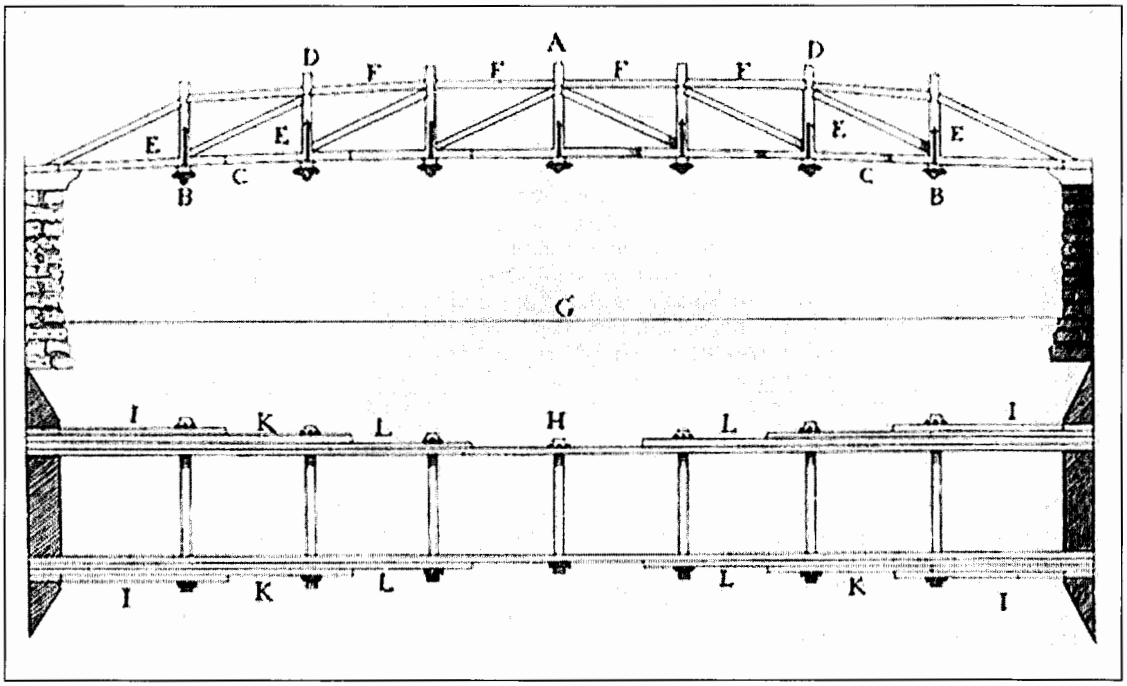

FIGURE 3. Palladio's truss bridge.

any which have been granted by the legislature to undertakings of a similar kind."[14] The site was a good fit since the meandering river narrowed there on a sharp bend. In addition, the existence of Deer Island (comprising over one-third of the width of the river bank to bank) cut down on the bridge spans needed to cross it. The bridge location on the Merrimack River at this spot was only a few miles from the Atlantic Ocean and on the main road north from Boston to points north to New Hampshire and what was to become Maine. It was also only less than 3 miles from Palmer's home.

The Breakthrough

Where did Palmer get his inspiration to do what no one else in the United States had done before? What made him think he could design and build a bridge over 1,030 feet long, with one span of 160 feet over water that averaged 34 feet deep?

A genius has been defined as someone who sees what everyone else sees but thinks what no one else has thought. This definition applies to Timothy Palmer. It has been written that he was the first American to utilize the truss in a way that was proposed by Palladio, in the sixteenth century in Italy (see Figures 3 through 5). It can be seen in Figure 3 that Palladio had his top chord and bottom parallel with a single compression strut in each panel. In another design, shown in Figure 4, he used twin parallel arches. It can also be seen that Palladio had two braces in each panel and the line of action of his braces did not go through the intersection of his chords and verticals (radials).

This truss pattern is similar to James Eads' St. Louis Bridge that was constructed in steel much later in the nineteenth century. Palmer did not have either of his chords acting in compression on his abutments, relying instead on trussing action to take out any horizontal loading on his piers or abutments.

Palladio's third truss was a trapezoidal truss with very flat diagonals (see Figure 5). This truss was a pure truss and it bears resemblance to Palmer's truss (see Figure 6). No plans or engineering drawings of the bridge are available, except for the representations of the bridge shown in Figures 6 and 7. Based on Figures 3 and 6, the following conclusions can drawn:

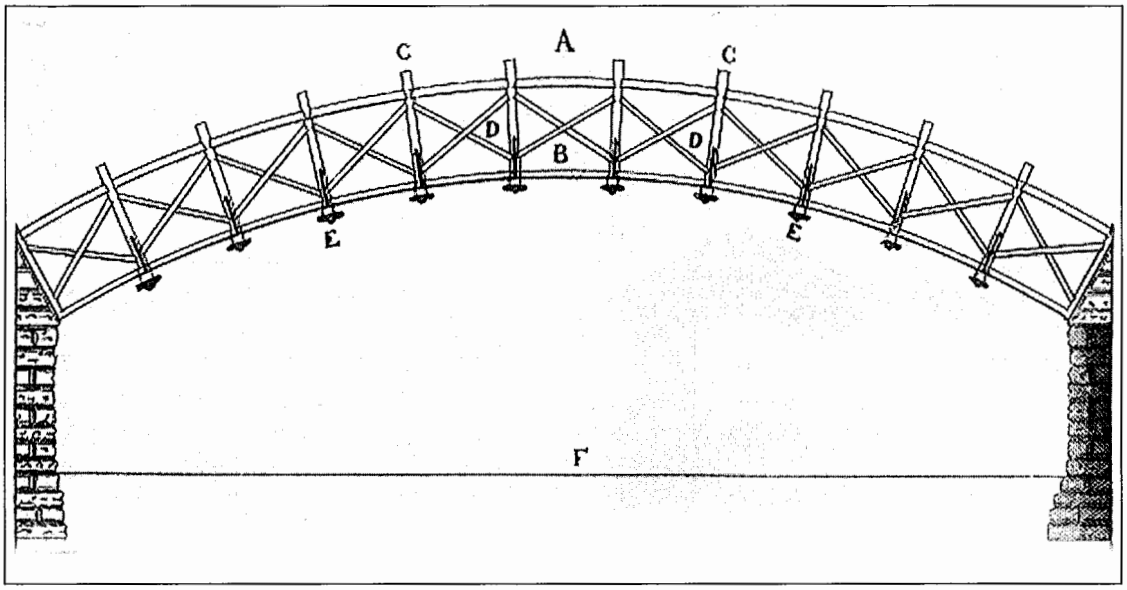

FIGURE 4. Palladio's arch bridge.

- Palladio's panel lengths were about twice the truss height, compared to Palmer's 1:1 ratio.
- Palladio's verticals ran through both the top and bottom chords. Palmer's verticals were tied to his top chord by straps and/or a mortise and tenon joint. It appears that Palladio connected his verticals to his lower chord with iron straps. Palmer notched members and connected them with bolts or treenails.
- Palladio had the size of his bottom chords widen as he approached the ends of his truss. It almost looks like he was cantilevering the bottom chords out from the abutments and using the overhead truss-

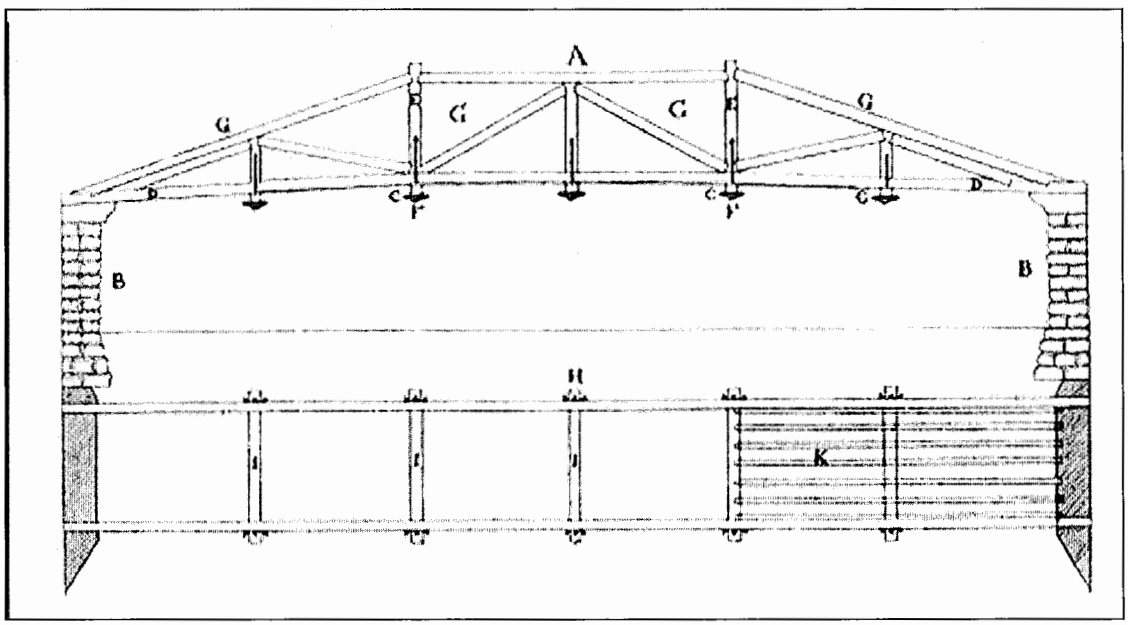

FIGURE 5. Palladio's truss.

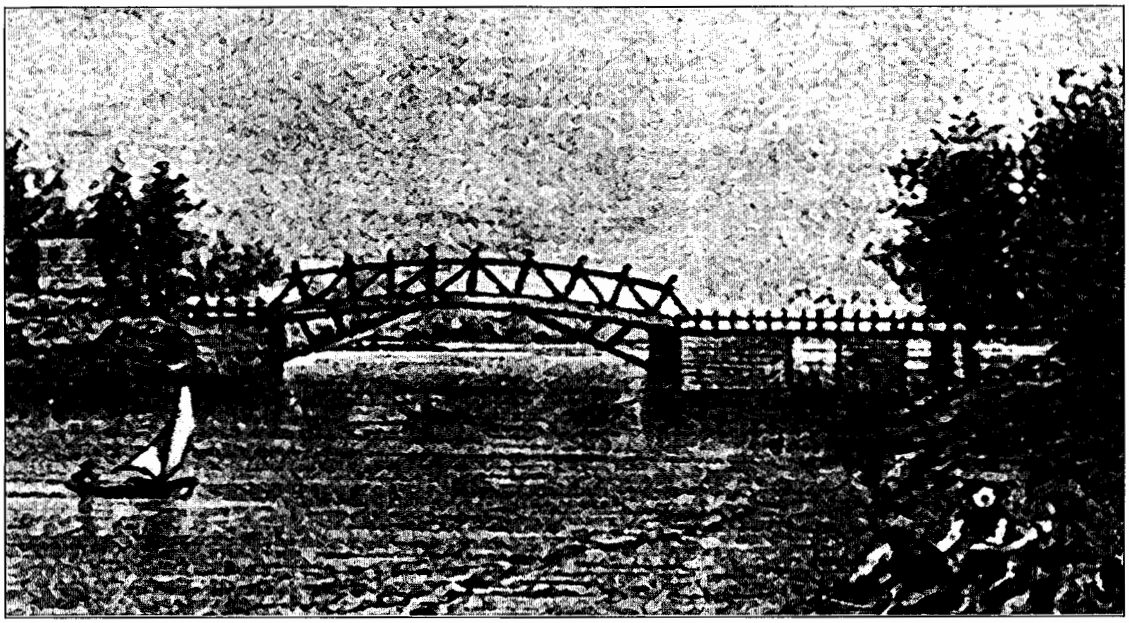

FIGURE 6. Palmer's truss with a 160-foot span.

ing to stiffen the cantilever. There is no illustration, however, of how he anchored his lower chord (cantilever arm) to the abutment. If he visualized his structure as a cantilever, he would have been correct in showing the member as he did. Palmer enlarged his bottom chords a small amount as he moved to the ends of his truss. Later knowledge showed that the bottom chord could actually get smaller as the ends of the truss were approached.

- Palladio had a small camber in his bridge, while Palmer had a large one. This large camber is what caused many to call Palmer's bridge an arch.
- Palladio had no apparent way to resist the lateral thrust coming from his diagonals to the upper and lower chords. Palmer attached a horizontal member to the top of his lower chord and the bottom of his upper chord to resist this lateral force.
- Palladio apparently broke his top chord at each vertical. Palmer's top chord was, through splicing, continuous throughout its length.
- It appears that Palladio hung his floor beams from his verticals with the same strap that connected his lower chord with his vertical. Palmer usually set his floor beams on top of his lower chord at the panel points.

It is very probable that Palmer knew of Palladio's designs since he was an architect and Palladio's work was common knowledge in architects' offices around the world. It is also very probable, given these significant differences, that Palmer did not base his design on Palladio's bridges but may have been inspired by Palladio's writings to expand on his ideas and design a bridge of his own.

Early illustrations of the longest span of his Newburyport Bridge show it with ten panels of approximately 16 feet, with a panel height equal to the panel length yielding compression diagonals on approximately a 45-degree angle, later shown by Squire Whipple a half century in the future to be the most efficient orientation for a diagonal.

Palmer used what has been called by some a trussed, or braced, arch as his supporting system. In reality, it was more like a truss that was later called a Long, or Howe, Truss since it had a single compression diagonal in each panel with verticals (radials) in tension. Howe made use of iron verticals and usually had a vertical end post. The idea of having a compression diagonal was common in both Long's

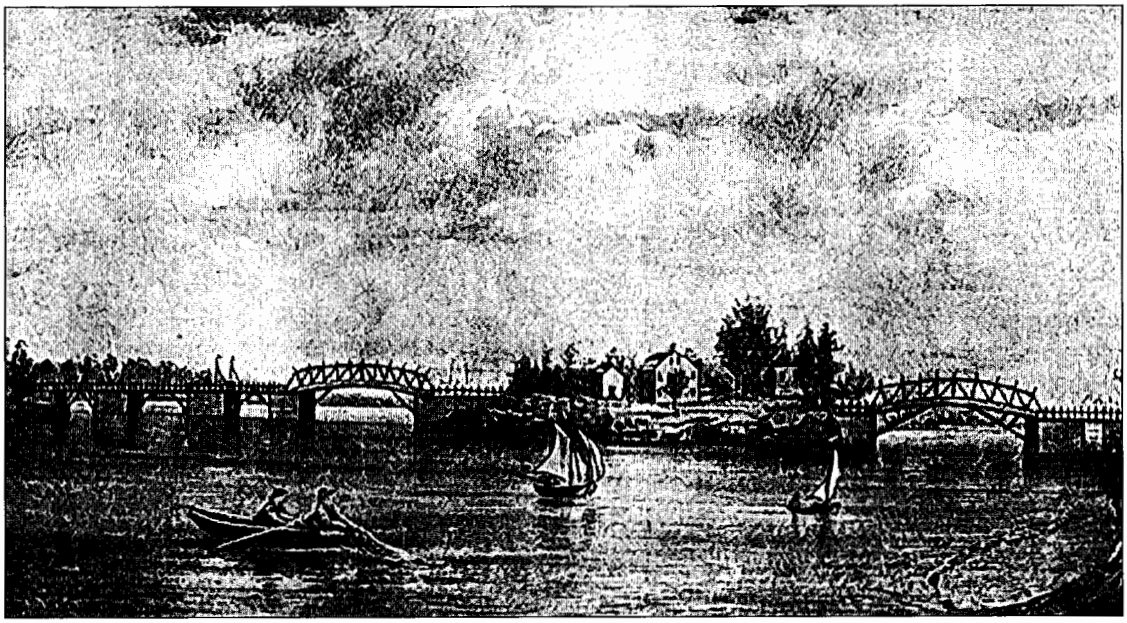

FIGURE 7. A rendition of the Newburyport Bridge (from Ref. 14).

and Howe's trusses as well as Palladio's. It was also the first "trapezoidal" truss since the end top chord member was inclined upwards from the abutment or pier. How the truss/arch worked depended greatly on how the members were connected at the upper and lower chords as well as the stiffness of the lower chord. If the lower chords were very stiff, then the structure would act more like a braced arch if it were built into the abutments that prevent longitudinal movement at the ends of the member. Evidence on his later bridges indicated that he used large wedges at the ends of his lower chords braced off the abutments or wood work on his piers to counteract any shrinkage of wood, or possibly to preload (prestress) his truss. If the lower chords were less stiff and not anchored to the abutment, then the whole structure would act more like a cambered truss with radial tension posts and compression diagonals. In the arch the lower member would be in compression and bending, and in the truss it would be in tension so that if there were any splicing required, it would have to be significantly different. Due to a lack of detailed sizes of members and types of connections, it is not clear how the structure acted, but it appears that it behaved more like a truss, possibly with both ends pinned and preloaded, and less like Palladio's trussed arch.

Bridge Design

Assuming that Palmer saw his structure acting like a truss, how would he have sized the members, and, equally as important, how would he have connected the members? It is likely that having built relatively long-span roof structures in his church buildings, at least two of which still exist in and around Newburyport, he would have used trusses and developed methods of connecting his large wooden members. Christopher Wren, the seventeenth-century architect, used trusses in several of his buildings and published his drawings and truss patterns. With that background, it is known that Palmer used models to illustrate bridges that he planned on building and later evidence indicated that he test loaded his models in demonstrations for the bridge companies that were buying his bridge designs. While it is difficult to project the load-carrying capacity of a long-span truss from tests made on models, it is possible to get an idea of how a trussed assemblage of wooden members would act under load. With a trial and error process, it would be possible to gain a better understanding of truss action, mem-

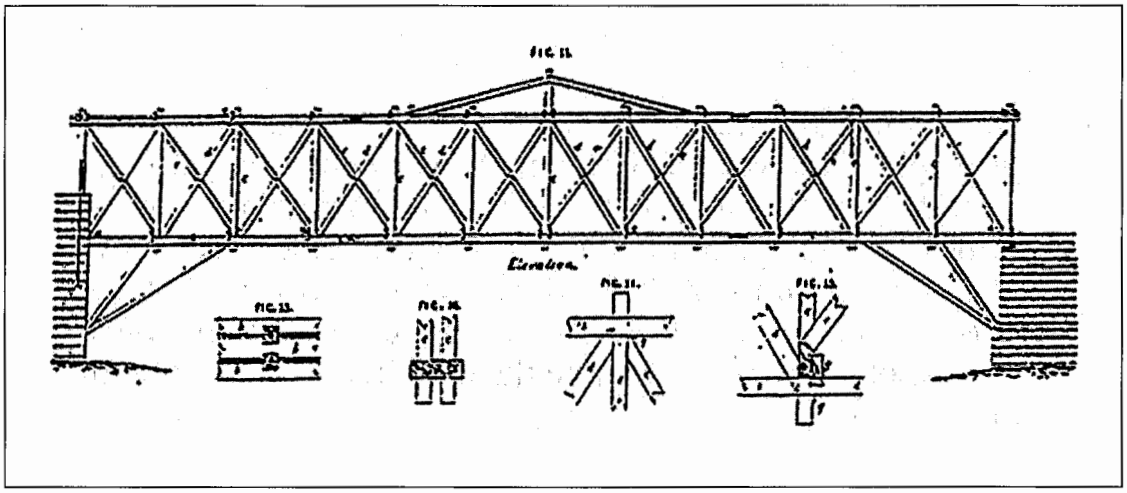

FIGURE 8. Long's 1830 Jackson Bridge with struts.

ber connections and relative sizes. Iron was very expensive in the United States at that time so Palmer made very little use of it except for bolts, washers and plates. This method of test-loading models continued through the iron bridge building era until 1847 when Squire Whipple developed the analysis technique that permitted the designer to actually size his members by calculation. Without a full understanding of truss action, it is understandable why Palmer built in such a large camber since he was apparently hoping for some arch action as well. Without a record of how Palmer understood his structure to act, it can be only assumed, based on later developments, how the bridge was designed.

The foundations for the superstructures were probably supported by wood pilings or by stone-filled wooden cribs (which were Palmer's standard foundation methods), sometimes with piling and sometimes without. In the language of the day, they were called "huge log piers which extended far below the water line to a firm foundation of either stone, hardpan or gravel."[15] On most of his bridges, Palmer did not design or build the foundations and only did so when the piers and abutments were in place. With the foundations in place, he would construct wooden falsework on which to build his deck structures and his arches/trusses.

For the curved lower and upper chords, he used what Theodore Cooper in his fine work on railroad bridges called "crooked pieces of timber, so that the fibre might run in the direction of the curves."[16] Palmer actually specified timber with a given amount of curvature so that it almost amounted to little more than crooked timber. In the engraving of the bridge, it can be seen that he used trussed struts off the piers extending out several panel points to help support his arches as permitted by the modified Act of the Legislature (see Figures 6 and 7). These braces would, of course, have changed the manner in which vertical and horizontal loadings would have been transferred to the abutments.

Lengths working from the northerly shore (the Salisbury shore) were: 124 feet abutment, 50 feet water, 45-foot pier, 50 feet water, a 40-foot draw structure, 50-foot feet, his arch of 113 feet and a 60-foot abutment to the northerly shore of the island. The bridge then ran from Deer Island 93 feet, with an arch of 160 feet, and then 185 feet to the Newburyport shore. The struts off the piers may have been based on Enoch Hale's Bellow's Falls Bridge or the European bridges of the Grubenmanns. S. H. Long, in a patent for his 1830 Jackson Bridge, also adopted the use of struts (see Figure 8).

Shortly after the opening of the bridge, *The Massachusetts Magazine* in 1793 noted:

> The two large arches, one of which is superior to anything on the continent, were both invented by Mr. Timothy Palmer, an

ingenious house wright of Newburyport, and appear to unite elegance, strength and firmness beyond the sanguine expectation.[15]

An article by Fletcher and Snow entitled, "A History of the Development of Wooden Bridges," published in the *ASCE Transactions* included a statement that Palmer "may well be called the Nestor of American Bridge builders" for this bridge and the others he built over the next fifteen years.[17] In the book, *Ould Newbury*, Currier stated:

> The principles upon which it was constructed were novel and hitherto untested; but the beauty and strength of the structure, when completed, demonstrated their practical value and utility.[1]

The bridge opened in December 1793, but apparently the official opening came on July 4, 1794, when Timothy Dexter gave an address that was published in several of the local newspapers.

Travelers' Impressions

Timothy Dwight, President of Yale University, traveled through much of New England in 1794 and 1795, and later in 1812. An associate published a record of his travels in 1821 after Dwight's death. Dwight described two other Palmer bridges in greater detail, but he did write this about the Newburyport Bridge:

> Between Salisbury and Newbury the Merrimack is crossed on Essex Bridge. . . It consists of two divisions, separated by an island at a small distance from the southern shore. The division between the island and this shore consists principally of an arch, whose chord is one hundred and sixty feet, and whose vertex is forty feet about the high water mark. In appearance and construction, it resembles Piscataqua Bridge; the whole length of Essex Bridge is one thousand and thirty feet, and its breadth thirty-four. I have already mentioned that Mr. Timothy Palmer, of Newburyport, was the inventor of arched bridges in this country. As Mr. Palmer was educated to house building only and had never seen a structure of this nature, he certainly deserves not a little credit for the invention. . . The workmanship of the Essex Bridge is a handsome exhibition of neatness and strength.[18]

John Drayton, another traveler through New England in the 1790s, also wrote about the Newburyport Bridge. He listed all the individuals who subscribed to the publication and included three sketches. It was the only bridge he took time to describe:

> Two or three miles beyond Newburyport is a beautiful wooden bridge of one arch, thrown across the Merrimac River: whose length is one hundred and sixty feet; and whose height is forty feet above the level of high water. For beauty and strength, it has certainly no equal in America: and I doubt whether as a wooden bridge there be any to compare with it elsewhere. The strength of the bridge is much encreased above the common mode in use, by pieces of timber placed upon it, and shouldered into each other. They run upon the bridge in three lines; parallel with the length of the bridge, and with each other; so as to make two distinct passageways for carriages. These braces, are some feet in height, and are connected on the top by cross pieces, affording sufficient room for carriages to pass underneath without inconvenience. It is said, that the upper work has as great a tendency to support the weight of the bridge; as the sleepers upon which it is built.[19]

Drayton included a sketch (see Figure 9) of the bridge that he prepared later from memory, stating:

> I had not time to stay here longer than five minutes; so must be excused in a sketch which I have taken of it: and that was not done upon the spot, but only by recollection. If in so doing, I should persuade others to enquire more particularly respecting it; and to adopt what may be good in its mechanism; my object will be gratified.[19]

It is clear that Drayton did not have a very good recollection of the bridge and that he

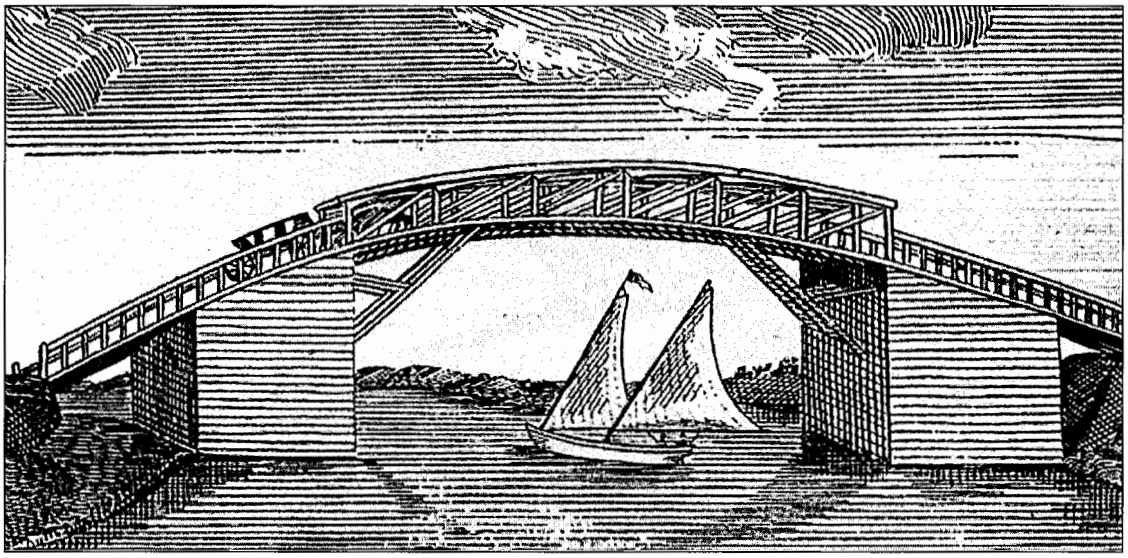

FIGURE 9. Drayton's sketch of the Newburyport Bridge.

exaggerated the arch, but he did know that it had large abutments in the river and that the bridge was a truss with the top chords tied together across the bridge. Drayton did have all Palmer's diagonals running the same way from the lower left of the panel to the upper right rather than having them running from the lower right to the upper left on the right half of the truss. He did show the under deck struts correctly.

In the years 1795, 1796 and 1797, the Duke de la Rochefoucault Liancourt, a French nobleman, traveled the country and wrote his treatise, *Travels Through the United States of North America the Country of the Iroquois and Upper Canada.* He visited the bridge and wrote:

> Before you arrive at Newbury Port, you have to cross the river Merrimack, by means of a bridge, which, prior to the building of that thrown over the Piscataqua, was considered as the most elegant in New England. It is at least shorter by one-third than the latter, and the arch, which measures only one hundred and thirty feet in width, is supported by a crooked piece of timber, measuring twenty feet, which gives the bridge, at first sight, a heavy appearance.[20]

Liancourt, like Drayton, did not have perfect recollection of the bridge and probably meant to say that the chords were made of crooked timber 20 feet in length that were spliced together and tied into the diagonals securely.

Robert Gilmor, from Baltimore, visited the bridge in 1797. While he did not give a written description of the bridge, he did make a sketch and included it in his *Memorandums Made in a Tour to the Eastern States in the Year 1797* (see Figure 10).[21] It is very similar to *The Massachusetts Magazine* sketch.

Thomas Pope wrote, in 1811, in his treatise on bridges (the first bridge book printed in the United States):

> Over the Merrimack River, in the County of Essex, near Newburyport, is a Bridge that was planned by Mr. Timothy Palmer, in the year one thousand seven hundred and ninety-two, constructed with two arcs; the one is one hundred and sicty and the other is one hundred and thirteen feet chord, and is erected forty feet above the level of high-water.[22]

Joseph Sanson, a well-known banker from Philadelphia, made a New England trip in 1795. In a letter dated August 27, he briefly described the Newburyport Bridge to his parents as follows:

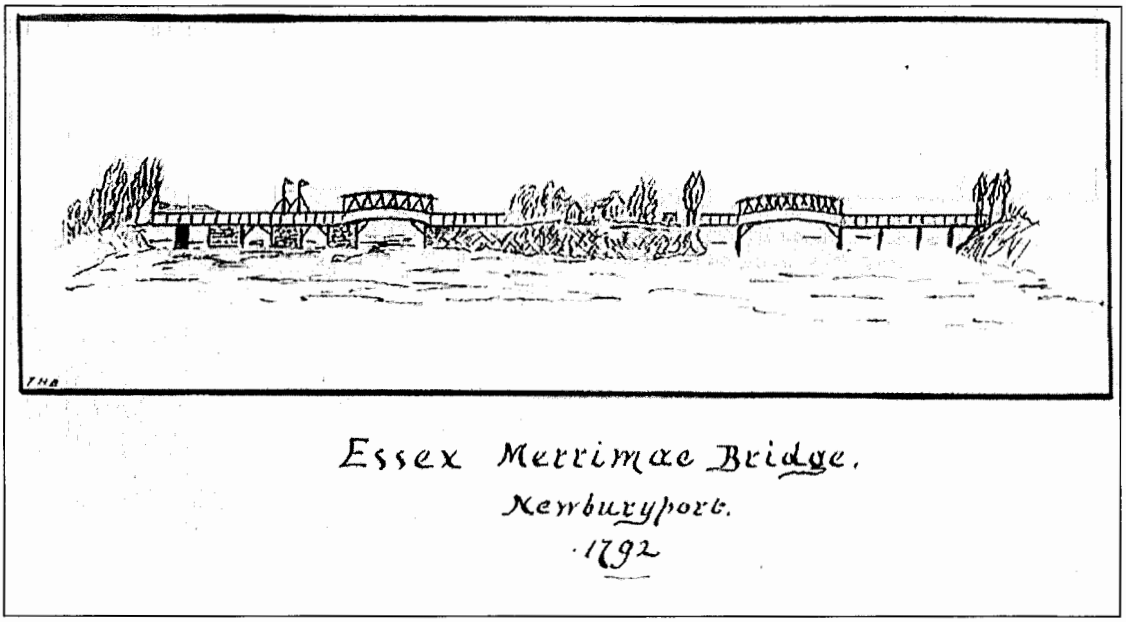

FIGURE 10. Gilmor's sketch of the Newburyport Bridge.

> That over the Merrimack near Newbury in Massachusetts is a beautiful arch of one hundred and eighty feet span, and forty foot chord, which being painted white glitters, like a feary vision, through a tall grove of white pines as you approach it from one side.[23]

The Massachusetts Magazine carried this description in announcing the opening of the bridge:

> The bridge over the Merrimack River between the towns of Salisbury and Newbury is now opened for the use of the publick. The arch is deemed the largest on the continent. The whole work contains more than six thousand tons of timber. Mr. Timothy Palmer, an ingenious housewright of Newburyport, has received a medal for the best construction of an arch.[14]

Bridge Facts

The bridge was built for $36,397 and its first dividend was paid on February 25, 1794, to forty-three stockholders, many of whom were different from the group that petitioned the legislature for permission to incorporate and build the bridge. Dividends were paid quarterly up to May 1807 so the bridge, which averaged over $4,000 per year in tolls, was a good investment. The incorporating act was amended on February 15, 1793, shortly after the bridge opened, with the statement:

> Whereas the Proprietors of Essex Merrimack Bridge have represented to this court, that the said bridge has been much more expensive than upon calculation was expected; and it being reasonable to grant to the said Proprietors some further benefit that in said Act is contained: Be it therefore enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, that the toll in and by the said Act granted and established shall continue to be received by the said Proprietors for the term of fifty years from the day of the first opening of said bridge.[24]

The original act indicated that the legislature could change the toll after thirty years. *The Act Authorizing a Bridge Between Haverhill and Newbury* (Rock's Village Bridge), dated June 14, 1794, contained a clause that stated:

> Whereas the erection of said bridge may diminish the emoluments of The Proprietors

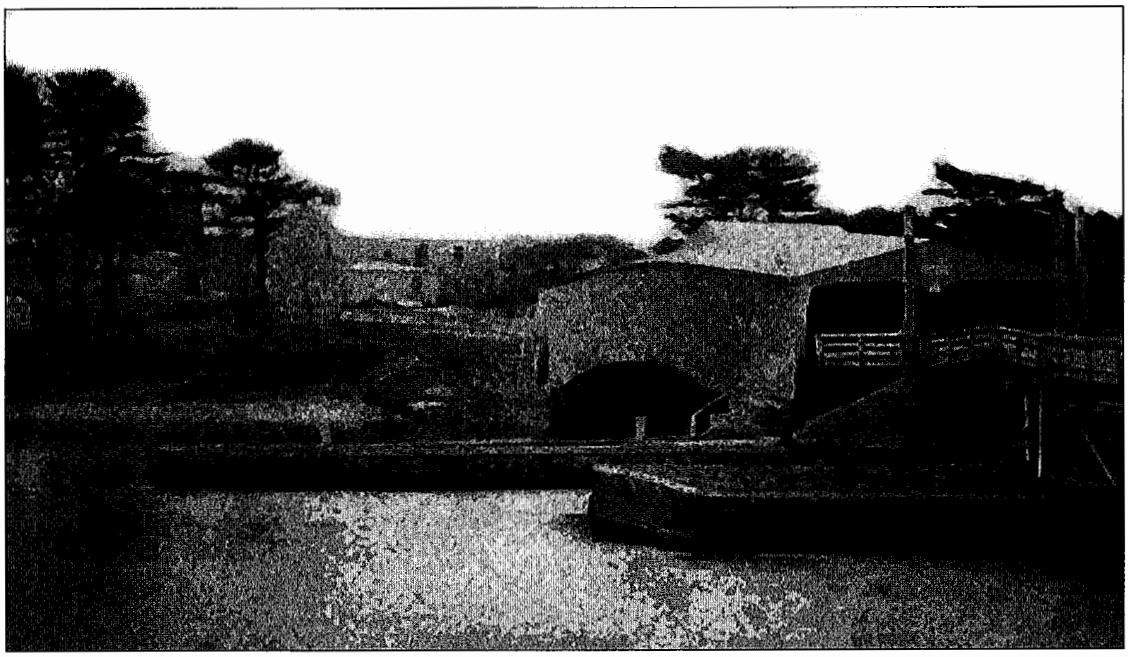

FIGURE 11. The Salisbury Truss, post-1808, with lift span, looking south.

> of the Essex Merrimack Bridge built at Deer-island, which was a work of hazard and public utility; be it enacted That the Proprietors of Essex Merrimack Bridge shall continue to be a corporation and body Politic for and during the term of seventy years.[25]

In other words, the legislature, in granting the charter for the Rock's Village Bridge, extended the corporate life of the Newburyport Bridge for another twenty years.

Usually, uncovered wooden bridges only have a life expectancy of 12 to 15 years. It is highly probable that the bridge had begun to exhibit signs of decay in the first decade of the nineteenth century. The bridge was rebuilt in 1807 (roughly thirteen years after it was opened). This rebuilt bridge was similar to the Permanent Bridge that Palmer built in Philadelphia in 1804. This rebuilt bridge had three tiers of longitudinal timbers. In a letter to Richard Peters, President of the Schuylkill River Bridge Company, for whom Palmer would build a bridge later on, dated July 11, 1808, Palmer wrote:

> Last summer, I rebuilt one of the Arches; the span of which is one hundred and thirteen Feet and is on the same principle with your Bridge. With much persuasion, I obtained liberty to cover it. There were many doubts in the minds of the Stockholders as to its stability against strong winds.[26]

This covered span survived until 1882. In the same letter, Palmer informed Peters that:

> [On] the 17th of June last there came on, one of the most tremendous gales of wind, ever known in this country. The wind blew down from the North West, for about thirty minutes — The most sturdy oaks and elms were torn up by the roots; some twisted off. One meeting house was blown down in the neighbourhood of this town; and a new dwelling house was slipped thirty inches off its base broke off the chimney and went no further — The reason of my being thus particular in this reason is — Essex-Merrimack bridge stands nearly in the centre of the direction of this tempest; and stood like mount Atlas amid the warring elements.[26]

Richard Allen in his book, *Covered Bridges of the Northeast*, presented an exaggerated sketch

FIGURE 12. A view of the Salisbury Truss, post-1812, from *Gleason's Magazine*.

from *Gleason's Magazine* of this truss and wrote "that from a distance it resembled a half squeezed accordion."[27] This covered truss can be seen in the historical photograph presented in Figure 11. Figure 12 shows the entire view of the bridge, post-1812, including the covered span that Allen was describing; however, Figure 11 puts the span in a different light.

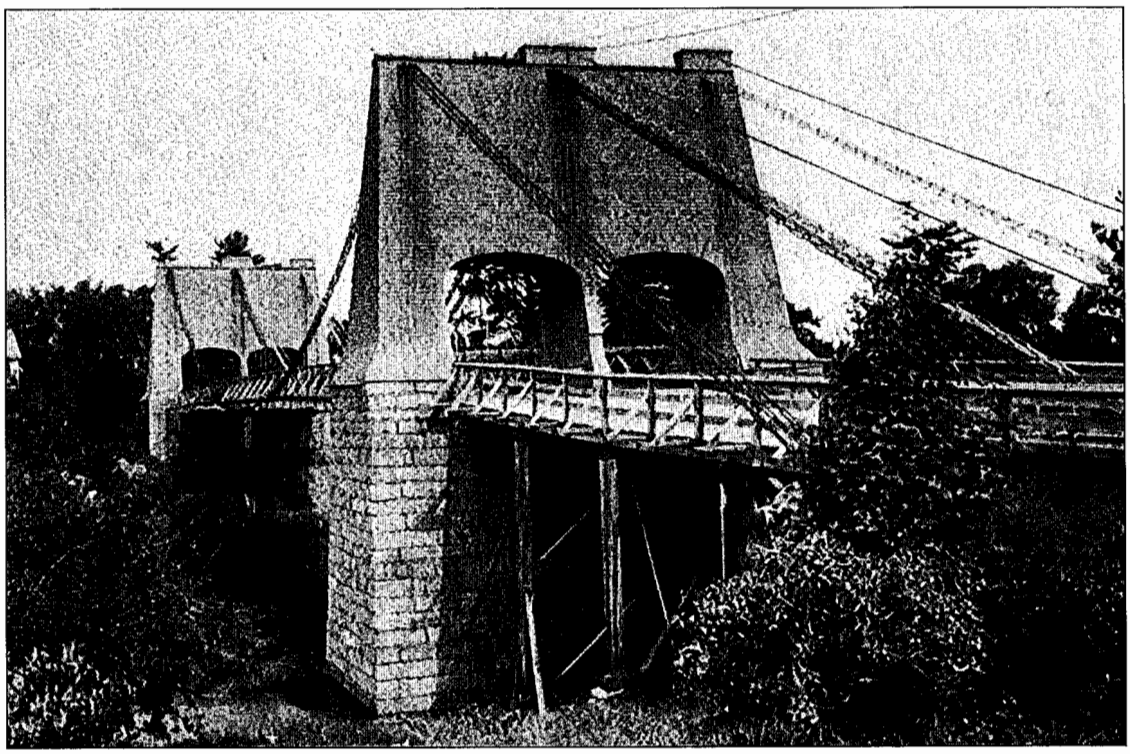

FIGURE 13. Templeman's bridge.

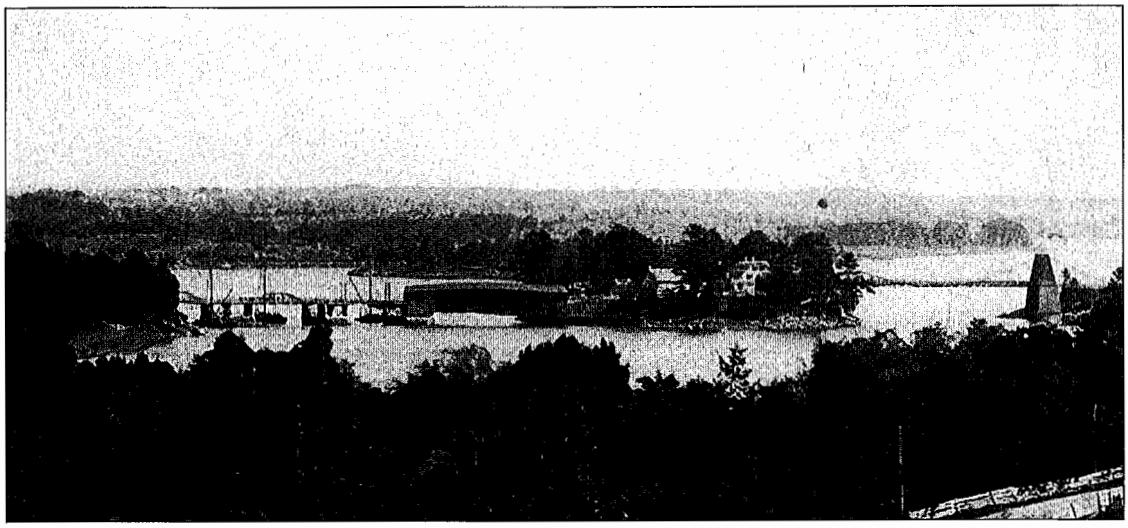

FIGURE 14. A view of the Newburyport Bridge, post-1812, with Templeman's chain suspension bridge.

FIGURE 15. A view of the concrete towers for the wire cable Newburyport Bridge built in 1909.

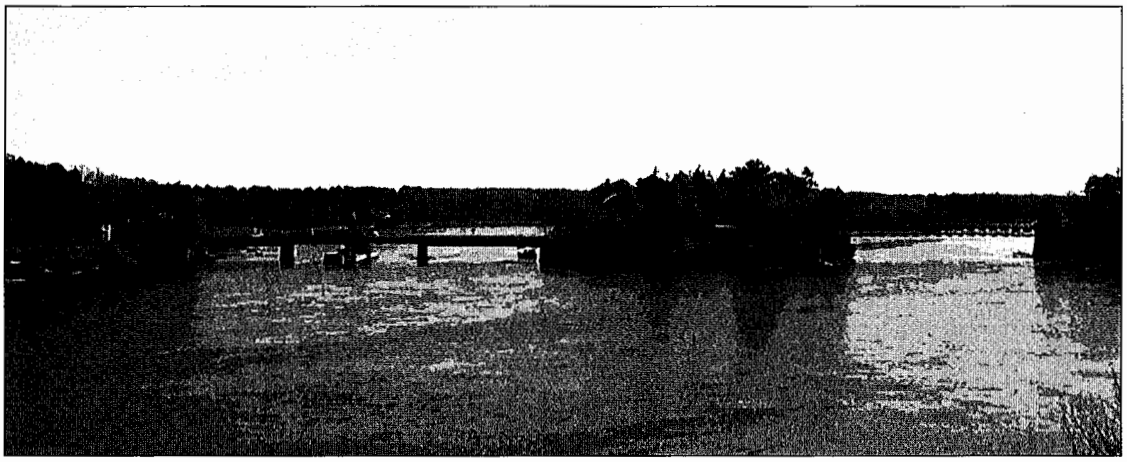

FIGURE 16. The bridge site in 2003.

In 1810, John Templeman, using James Finley's suspension bridge patent, built a chain suspension bridge to replace Palmer's 160-foot arch (see Figures 13 and 14). Palmer's span had been, in the words of boatmen, a "menace to navigation." By going with a 244-foot suspension span, as contrasted to a 160-foot truss with abutments extending greatly into the river, it was possible to open up the southerly passage around Deer Island. The northerly abutment had been 93 feet long and the southerly abutment 185 feet.

The bridge was a long-term financial success since the total toll receipts over its lifetime were $302,276. In 1868, it was purchased from the stockholders by the Commonwealth of Massachusetts for $30,000. In 1909, the bridge was replaced with a wire cable suspension bridge. This new bridge's concrete towers were meant to replicate Palmer's wooden towers (see Figure 15).

Conclusion

Palmer built the first successful long-span wooden truss in America near Newburyport, Massachusetts, in 1792. Drayton, with his sketch and description, did — along with descriptions of Dwight, Gilmor, Liancourt and Pope — "persuade others to inquire more particularly respecting it, and to adopt what may be good in its mechanism."[19] Palmer's reputation was made and the construction of long-span wooden truss bridges can be traced back to his work over the Merrimack.

Figure 16 presents a view of the bridge site in 2003, taken from the Interstate 95 bridge, showing the house still on the island. The lift span on the Salisbury side is now a swing bridge. At the time the photograph was taken, the Chain Bridge (from circa 1909) was in the process of being rehabilitated. Figure 15 shows the bridge after this rehabilitation. The rehabilitation cost $4,583 570.

FRANCIS E. GRIGGS, JR., *is Professor Emeritus of Civil Engineering at Merrimack College in North Andover, Mass. He holds the following degrees: B.S. in Civil Engineering, M.S. in Management, M.S. in Civil Engineering and Ph.D. in Engineering — all from Rensselear Polytechnic Insititute. He is interested in nineteenth-century civil engineering, particularly bridge engineering with special focus on iron bridges and their builders.*

REFERENCES

1. Currier, J.J., *Ould Newbury*, Damrell and Upham, Boston, 1896.

2. *Petition to [Commonwealth of Massachusetts] Senate and House*, 1791.

3. House action affixed to 1791 petition.

4. Coffin, J., *A Sketch of the History of Newbury, Newburyport and West Newbury*, Peter Randall, 1977.

5. Chase, G.W., *The History of Haverhill, Massachusetts, From Its First Settlement in 1640 to the Year 1860*, Clearfield, 1860.

6. *Act of General Court of the Commonwealth of Massachusetts*, Feb. 24, 1792.

7. Davis, letter to Bridge Company, Records Newburyport Historical Society.

8. Sumner, letter to Bridge Company, Records Newburyport Historical Society.

9. Letter, April 10, 1792, Newburyport Historical Society Papers.

10. Loose undated summary in the papers of the Newburyport Historical Society.

11. Mycall, letter to Bridge Company, Records Newburyport Historical Society.

12. Titcomb, letter to Bridge Company, Records Newburyport Historical Society.

13. *Act of General Court of the Commonwealth of Massachusetts*, June 22, 1792.

14. *The Massachusetts Magazine*, May 1793.

15. Pease, G.B., *Timothy Palmer, Bridge-Builder of the Eighteenth Century*, Essex Institute Historical Collections, Vol. XXXIII, April 1946.

16. Cooper, T., *General Specifications for Iron Railroad Bridges and Viaducts*, 1885.

17. Fletcher, R., & Snow, J.P., "A History of the Development of Wooden Bridges," *ASCE Transactions*, Vol. 99, 1934.

18. Dwight, T., *Travels in New England and New York*, New Haven, 1821.

19. Drayton, J., *Letters Written during a Tour Through the Northern and Eastern States of America*, 1794.

20. Liancourt, F.-A.-F., *Travels Through the United States of North America, the Country of the Iroquois, and Upper Canada, in the Years 1795, 1796, and 1797*, 1800.

21. Gilmor, R., *Memorandums Made in a Tour to the Eastern States in the Year 1797*, Bulletin of the Boston Public Library, April 1892.

22. Pope, T., *A Treatise on Bridge Architecture; in Which the Superior Advantages of the Flying Pendent Lever Bridge Are Fully Proved*, New York, A. Niven, 1811.

23. Sanson's letters to parents, Haverford College.

24. *Act of General Court of the Commonwealth of Massachusetts*, February 15, 1793

25. *Act of General Court of the Commonwealth of Massachusetts*, June 14, 1794

26. *U.S. Gazette*, July 19,1808, Palmer letter to Peters.

27. Allen, R.S., *Covered Bridges of the Northeast*, S. Greene Press, 1983.