technical leaflet

JACK E. BOUCHER

BRIDGE TRUSS TYPES:

a guide to dating and identifying

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Many of the bridges, canals, and factories once crucial to America's industry and economy have been forgotten and ignored. Fortunately, within the last decade, a new movement within historic preservation, called industrial archeology, has brought attention to these parts of our visual landscape. This movement reminds Americans that technological sites are vital parts of our historic development and our contemporary landscape.

Bridges, especially the iron and steel bridges of the late nineteenth and early twentieth centuries, are one example of both previous neglect and current interest. Deriving their structural form from earlier wooden covered bridges, they were built with materials that did not require extensive protection from the elements and that provided a strong, safe structure at a cost within the financial capabilities of many communities. These bridges were often prefabricated by specialized bridge companies and then erected throughout the country in both rural and urban settings. As a result, their presence provides a unifying structural and visual element within the American landscape.

Although there are many more metal truss bridges in America than there are wooden bridges, appreciation of their design, development, and importance is a recent phenomenon. This leaflet is intended to increase understanding of these bridges by introducing a variety of their forms and presenting a way to distinguish and identify specific forms of truss bridges.

There are many kinds of bridges in America. Some are essentially nothing more than a single beam of concrete or steel, the modern equivalent of a log placed across a stream. Others are arched bridges built of brick or stone, most often by railroads which required a structure capable of carrying their heavy loads. Many of our longest bridges are suspension structures in which the roadway is held up by huge cables hung from tall towers or by smaller cables attached to a great steel arch. But by far the most common bridge built between 1850 and 1925 was the metal truss bridge, a design that used many small pieces or members to make a long truss that provided the length and strength necessary for the bridge. There were dozens of ways these small members could be arranged, and it is the arrangement of these members within the bridge structure that determines the specific truss form.

Recognizing the differences between various truss forms requires some understanding of what a truss is and how it works. In a metal truss, many comparatively small pieces of iron or steel are joined together in a series of triangles. These structural triangles interconnect with one another to form the complete bridge. In resisting the loads placed by gravity upon a truss bridge, each of these pieces, or members, within the structure is put in either tension or compression. If a member is in compression, then the forces acting on it tend to push it together. If it is in tension, then these forces tend to pull it apart. The main members of a truss are either stiff, heavy struts or posts, or thin flexible rods or bars. Stiff struts or posts are capable of withstanding both tension and compression, however, thin rods or bars are only capable of withstanding tension, and this difference provides a major clue in truss identification. On the diagrams representing the separate truss forms, the main compression members are delineated with a thick, heavy line and the main tension members with a thin, light line. In determining the form of a specific truss bridge, match the structural outline of the truss with the diagram it most resembles and then make sure the arrangement of heavy compression and light tension members is compatible. If there is agreement, then the basic truss form is identified. The dotted lines in the diagrams indicate secondary counter-ties included in some trusses as tension members to help stiffen the structure.

Though the length of a truss may provide a clue to its type, the number of panels within the truss is not important. For example, the Pratt truss in diagram 12 consists of six panel lengths, however, the Pratt truss in photo 3 has a length of seven panels. Because they both have the same configuration of tension and compression members, they are both Pratts.

All the different forms of bridge trusses are one of three basic types. See diagrams 1,2,3. If a bridge carries its traffic load level with the bottom chords, it is a *through* truss. A *pony* truss is a through truss with no lateral bracing between the top chords. A *deck* truss carries its traffic load level with the top chords. See photos 1,2.

Diagram 4 shows a representative truss with its various components labeled. Diagrams 5,6 present the two basic types of structural connections.

Wooden Trusses

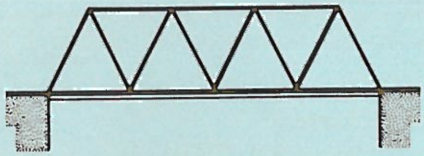
The earliest bridge trusses date to ancient times and were constructed of wood. The king post (diagram 7) and the queen post (diagram 8) represent the basic forms of these trusses, and their modern-day descendants can still be seen in very short bridges on some back country roads.

In 1803-04, Theodore Burr of Pennsylvania first constructed a bridge which combined several king post trusses with a wooden arch (diagram 9). The result was a stronger bridge, and many of these still exist today, though in the last several years their number has greatly diminished. Following Burr's patent, other bridge builders modified his design and utilized a wooden arch with truss configurations other than the multiple king-post. Trusses utilizing such modifications are usually known by the name of the later designer, but, in America, the initial use of an arch to strengthen the truss is attributed to Theodore Burr.

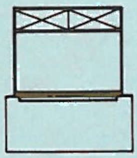
A major competitor to Burr's design was the Town lattice truss (diagram 10), patented by Ithiel Town in 1820. This design employs closely spaced diagonal timbers to create a stiff web of considerable strength. Though almost all bridges of this patent were built of wood, there were a few constructed of wrought iron in the latter part of the nineteenth century.

These wooden trusses were extremely susceptible to deterioration from the constant battering of wind and rain, and, consequently, they were covered to provide protection for the main structural members. Fire was also a constant hazard, especially for railroad bridges. As a result, wooden bridges gradually faded from the mainstream of bridge construction, although some were built until the early part of the twentieth century. Though not all-inclusive, the truss types shown here for wooden bridges do represent the forms found in most of those that still survive.

In 1840, William Howe patented a truss which utilized both wood and wrought iron, and his design was employed by a number of early railroad enterprises. Wood is difficult to use as a tension member, and it was as tension members that iron found its first use in bridge trusses. The essential feature of the Howe truss (diagram 11) was its use of metal verticals functioning as tension members and wooden diagonals functioning as compression members. Although this design was an improvement on



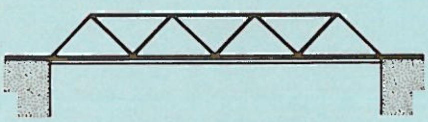
LONGITUDINAL SECTION / ELEVATION



TRANSVERSE SECTION

THROUGH TRUSS

Diagram 1



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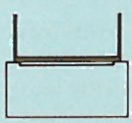
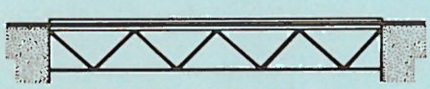


TRANSVERSE SECTION

PONY TRUSS

Diagram 2



LONGITUDNAL SECTION/ELEVATION

TRANSVERSE SECTION

DECK TRUSS

Diagram 3

the all-wood bridge, a number of infamous railroad bridge disasters of the mid-nineteenth century were caused by structural failures in Howe trusses. Railroads soon learned that an all-metal truss bridge was the only way to achieve the strength and permanence they needed.

Pratt & Warren Trusses

Most metal trusses in America are of two basic forms, the Pratt and the Warren. The basic outline of these forms is shown in diagram 12 and diagram 21.

Both forms date back to the 1840s, but many of the bridges employing these trusses that still survive were built since the turn of the century. The economic nature of the American construction industry is such that there is a natural tendency for uniformity and standardization. During the last half of the nineteenth century, many different trusses were developed, but, in the ensuing competition, the Pratt and Warren forms gradually demonstrated their versatility, durability, and economic desirability to such an extent that by the early twentieth century, almost all bridge trusses were constructed using variations of one of these forms.

Pratt

The basic Pratt truss was patented in 1844 by Thomas and Caleb Pratt and is distinguished by vertical members acting in compression and diagonals acting in tension (diagram 12). This design feature reduced the length of the compression members to help prevent them from bending or buckling. Photo 3 shows the 1907 Middle River Bridge in the vicinity of Meyers Cave, Virginia. A pin-connected through Pratt, it is representative of perhaps the most common type of early twentieth century truss bridge. Visually, the compression and tension members are clearly different: the thin diagonal eyebars are in tension and the posts (two heavy channel beams joined by riveted bracing) take the compressive loads. Diagram 13 presents a basic variation of the Pratt configuration, the Pratt half-hip, a design used only for short spans. It is often found in the form of a pony truss and, as such, is designed for light vehicular traffic.

Many trusses retain the Pratt configuration of compression and tension members, while altering the shape of the top and bottom chords. The Parker truss (diagram 14) is clearly a Pratt with a polygonal top chord. Because of its arched top chord, the bridge is stronger than a regular Pratt truss while it uses the same amount of material. However, the sizes of members in a Parker truss are not as uniform as they are in a Pratt, and, consequently, they were often more

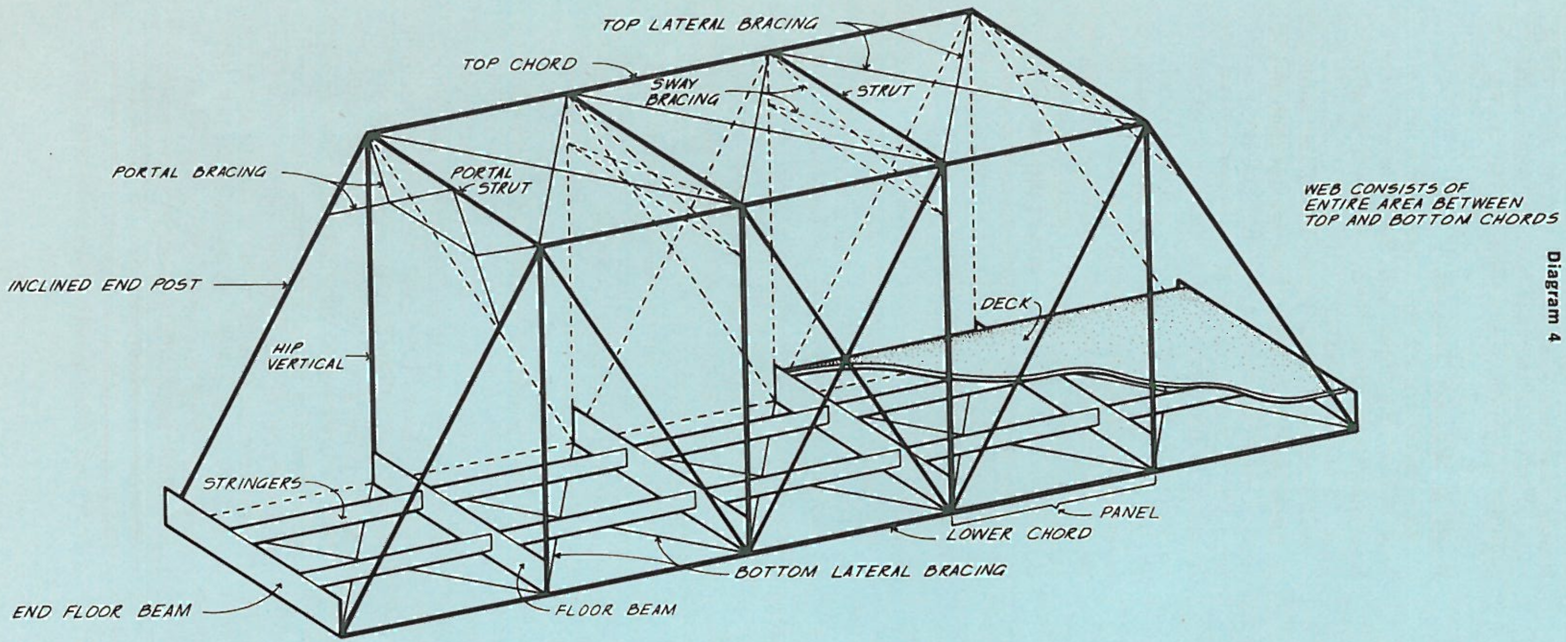


Diagram 4

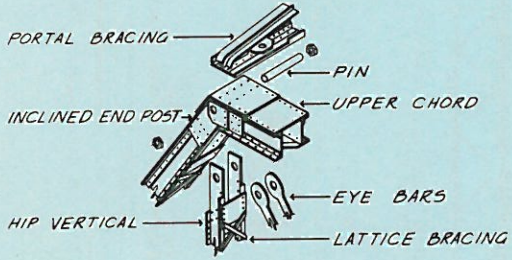


Diagram 6

PINNED CONNECTION

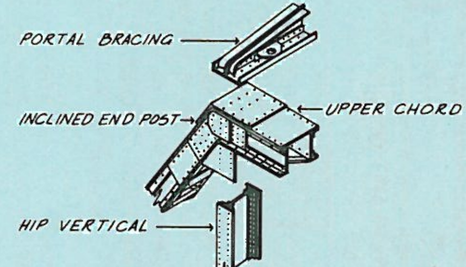
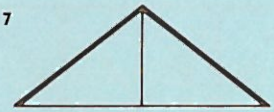


Diagram 5

RIVETED CONNECTION

Diagram 7



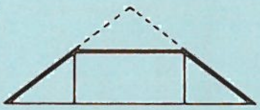
KING POST

(WOOD)

A TRADITIONAL TRUSS TYPE WITH ITS ORIGINS IN THE MIDDLE AGES.

LENGTH: 20-60 FEET
6-18 METERS

Diagram 8



QUEEN POST

(WOOD)

A LENGTHENED VERSION OF THE KING POST.

LENGTH: 20-80 FEET
6-24 METERS

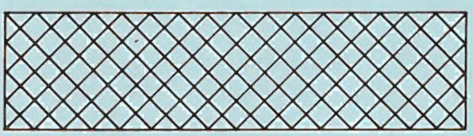
BURR ARCH TRUSS

1804-LATE 19TH CENTURY
(WOOD)

COMBINATION OF A WOODEN ARCH WITH A MULTIPLE KING POST. (ARCH ALSO COMBINED WITH LATER WOODEN TRUSSES).

LENGTH: 50-175 FEET
15-50 METERS

Diagram 9



TOWN LATTICE

1820- LATE 19TH CENTURY
(WOOD)

A SYSTEM OF CROSS-HATCHED WOODEN DIAGONALS WITH NO VERTICALS.

LENGTH: 50-220 FEET
15-66 METERS

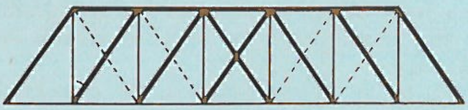
Diagram 10

expensive to construct. Photo 4 shows a 1907 Parker truss bridge that carries highway traffic over the Grand River in South Portlandville, Michigan.

A particular type of Parker is the camelback truss (diagram 15) in which the arched top chord is formed with five slopes. The camelback design allowed both greater standardization of its members and better stress distribution, and it was often the most economical truss for many railroad and highway spans. Photo 5 shows such a highway bridge in Michigan, and even a quick check in any area will show that the camelback is a form well represented in the modern American landscape.

Another form of the Pratt truss, perhaps the most visually striking of all truss bridges, is the lenticular truss shown in diagram 16. Distinguished by curved upper *and* lower chords, the lenticular truss derived its name from its particular lens shape. First developed in Europe in the 1850s, it was introduced in American bridge construction in 1878. Originally an economically attractive design because it required less material, its dramatic shape did entail high fabrication cost, and this expense soon ended its popularity. There are presently only about fifteen to twenty of these bridges remaining in the northeastern United States. The largest lenticular truss built in America was the Smithfield Street Bridge in Pittsburgh, Pennsylvania, designed by Gustav Lindenthal (photo 6). Now a national historic landmark, the 1883 structure still carries traffic across its 720-foot span, while it adds a distinctive visual element to Pittsburgh's historic riverfront.

As railroads increased the size and weight of their locomotives and rolling stock during the latter part of the nineteenth century, bridge engineers were forced to develop trusses capable of safely carrying greater loads. A major advance in strengthening the standard Pratt truss came in the 1870s with the implementation of sub-struts and sub-ties. As shown in diagrams 17 and 18, these sub-struts and sub-ties stiffened the truss under heavy moving loads. The Baltimore truss, another modification of the basic Pratt form, was used extensively by the Baltimore and Ohio Railroad. Later, other lines adopted it, as shown in photo 7 of the 1910 Raisin River Bridge in Monroe, Michigan. The Pennsylvania truss utilized sub-struts and sub-ties with an arched top chord. It derived its name from extensive use on the Pennsylvania Railroad. Another design which sub-divided the Pratt configuration is the Kellogg truss shown in diagram 19. Widely advertised in railroad journals during the 1870s and 1880s, it



HOWE

1840 - 20TH CENTURY

(WOOD, VERTICALS OF METAL)

DIAGONALS IN COMPRESSION, VERTICALS IN TENSION.

LENGTH: 30-150 FEET
9-45 METERS

Diagram 11

PRATT

1844 - 20TH CENTURY

DIAGONALS IN TENSION, VERTICALS IN COMPRESSION (EXCEPT FOR HIP VERTICALS ADJACENT TO INCLINED END POSTS).

LENGTH: 25-150 FEET
8-45 METERS

Diagram 12

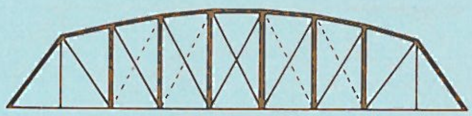
PRATT HALF-HIP

LATE 19TH-EARLY 20TH CENTURY

A PRATT WITH INCLINED END POSTS THAT DO NOT HORIZONTALLY EXTEND THE LENGTH OF A FULL PANEL.

LENGTH: 30-150 FEET
9-45 METERS

Diagram 13



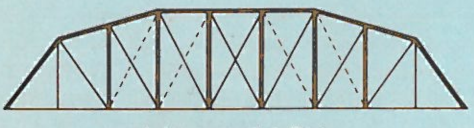
PARKER

MID-LATE 19TH-20 CENTURY

A PRATT WITH A POLYGONAL TOP CHORD

LENGTH: 40-200 FEET
12-60 METERS

Diagram 14



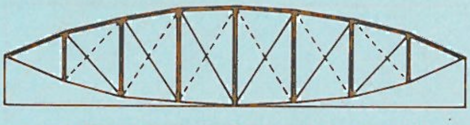
CAMELBACK

LATE 19TH-20TH CENTURY

A PARKER WITH A POLYGONAL TOP CHORD OF EXACTLY FIVE SLOPES

LENGTH: 100-300 FEET
30-90 METERS

Diagram 15



LENTICULAR (PARABOLIC)

1878 - EARLY 20TH CENTURY

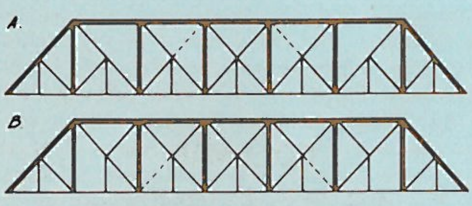
A PRATT WITH BOTH TOP AND BOTTOM CHORDS PARABOLICLY CURVED OVER THEIR ENTIRE LENGTH.

LENGTH: 150-400 FEET
45-120 METERS

Diagram 16

A.

B



BALTIMORE (PETIT)

1871- EARLY 20TH CENTURY

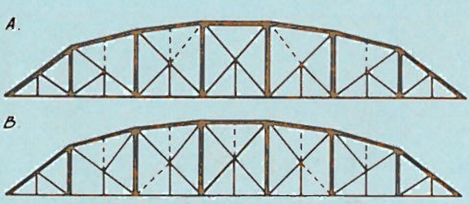
A. A PRATT WITH SUB-STRUTS
B. A PRATT WITH SUB-TIES

LENGTH: 250-600 FEET
75-180 METERS

Diagram 17

A.

B.



PENNSYLVANIA (PETIT)

1875- EARLY 20TH CENTURY

A. A PARKER WITH SUB-STRUTS.
B. A PARKER WITH SUB-TIES.

LENGTH: 250-600 FEET
75-180 METERS

Diagram 18

KELLOGG

LATE 19TH CENTURY

A VARIATION ON THE PRATT WITH ADDITIONAL DIAGONALS RUNNING FROM UPPER CHORD PANEL POINTS TO THE CENTER OF THE LOWER CHORDS.

LENGTH: 75-150 FEET
23-30 METERS

Diagram 19

DOUBLE INTERSECTION PRATT

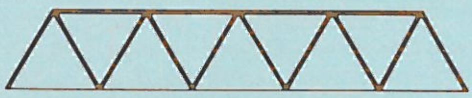
1847 - 20TH CENTURY

(WHIPPLE, WHIPPLE-MURPHY, LINVILLE)

AN INCLINED END POST PRATT WITH DIAGONALS THAT EXTEND ACROSS TWO PANELS.

LENGTH: 70-300 FEET
21-90 METERS

Diagram 20



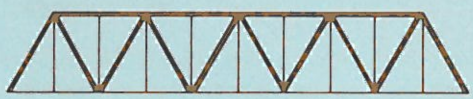
WARREN

1848 - 20TH CENTURY

TRIANGULAR IN OUTLINE, THE DIAGONALS CARRY BOTH COMPRESSIVE AND TENSILE FORCES. A "TRUE" WARREN TRUSS HAS EQUILATERAL TRIANGLES.

LENGTH: 50-400 FEET
15-120 METERS

Diagram 21



WARREN

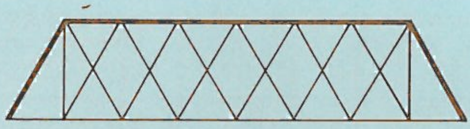
WITH VERTICALS

MID 19TH-20TH CENTURY

DIAGONALS CARRY BOTH COMPRESSIVE AND TENSILE FORCES. VERTICALS SERVE AS BRACING FOR TRIANGULAR WEB SYSTEM.

LENGTH: 50-400 FEET
15-120 METERS

Diagram 22



DOUBLE INTERSECTION WARREN

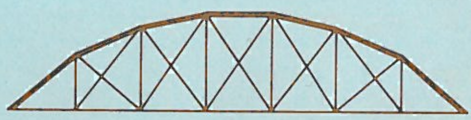
(LATTICE)

MID 19TH-20TH CENTURY

STRUCTURE IS INDETERMINANT. MEMBERS ACT IN BOTH COMPRESSION AND TENSION. TWO TRIANGULAR WEB SYSTEMS ARE SUPERIMPOSED UPON EACH OTHER WITH OR WITHOUT VERTICALS.

LENGTH: 75-400 FEET
23-120 METERS

Diagram 23



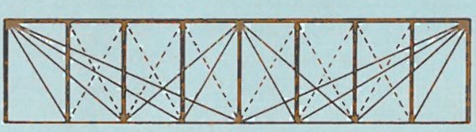
BOWSTRING ARCH-TRUSS

1840 - LATE 19TH CENTURY

A TIED ARCH WITH THE DIAGONALS SERVING AS BRACING AND THE VERTICALS SUPPORTING THE DECK.

LENGTH: 70-175 FEET
21-50 METERS

Diagram 24



FINK

1851 - MID-LATE 19TH CENTURY

(RARE)

VERTICALS IN COMPRESSION, DIAGONALS IN TENSION, LONGEST DIAGONALS RUN FROM END POSTS TO CENTER PANEL POINTS.

LENGTH: 75-100 FEET
23-45 METERS

Diagram 25

BOLLMAN

1852 - MID-LATE 19TH CENTURY

(RARE)

VERTICALS IN COMPRESSION, DIAGONALS IN TENSION. DIAGONALS RUN FROM END POSTS TO EVERY PANEL POINT.

LENGTH: 75-100 FEET
23-30 METERS

Diagram 26

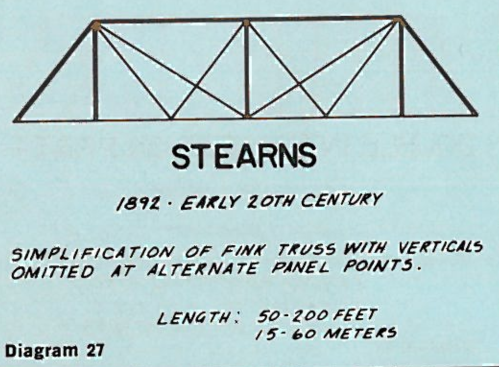


Diagram 27

has apparently disappeared from the American landscape.

In 1847, Squire Whipple, a famous bridge engineer, patented a truss which utilized the basic form of the Pratt, but lengthened the diagonals to extend across two panels, thus allowing longer spans. Now referred to as the double-intersection Pratt (diagram 20), it also has been called the Whipple, the Whipple-Murphy, or the Linville. A number of double-intersection Pratts may still be seen today. Photo 8 shows a rare triple intersection Pratt (1878) which crosses the Laughery Creek near Aurora, Indiana. Now listed in the National Register of Historic Places, it is apparently the only one of its kind remaining.

Warren

As mentioned previously, the other major truss form found in America is the Warren, patented in 1848 by two British engineers and quickly adopted by American bridge designers (diagram 21). Its simple, straightforward design proved so successful that it is still being used by present-day bridge engineers. The basic Warren truss has diagonals which are alternately placed in either tension or compression. As a result, the Warren is most easily recognized by its triangular outline. Most Warren trusses (diagram 22) are built with vertical members which stiffen the entire structure. Photo 9 illustrates the most common form of the Warren truss in which both diagonal and vertical members are rigid metal posts. Though most Warrens are constructed exclusively of stiff, diagonal members, some older bridges survive in which the diagonals serving as tension members are thin eyebars. An example of this is the 1910 Studley Bridge over the St. Joseph River in Sherwood, Michigan (photo 10). Though safe for controlled usage, this older form of Warren truss can be susceptible to failure under modern heavy loadings.

Another way to strengthen the basic Warren truss is to increase the number of diagonal members, and diagram 23 shows a double-intersection Warren formed by the super-position of two triangular web systems within the same truss. The bridge in the foreground of photo 1 is a triple intersection Warren. Both the double intersection Warren and triple intersection Warren are sometimes referred to as lattice trusses, and it is interesting to compare them with the early Town lattice truss (diagram 10).

Other Types

In addition to introducing the double-intersection Pratt form, Squire Whipple was the first to patent the bowstring arch-truss bridge, a type further developed by many others for smaller roads. As shown in diagram 24, the bowstring arch-truss is essentially an arch bridge in which the deck is suspended from the top chord, thus placing all verticals in tension. The horizontal thrust exerted by the arch is resisted by the lower chord which is also placed in tension. Photo 11 is of the three-span 1875 bowstring arch-truss bridge over the North Platte River in Laramie, Wyoming. Built by the U. S. Army after a design developed by Zenas King of Cleveland, Ohio, it is the oldest iron bridge in Wyoming. A similar structure built according to King's patent, and now preserved by the State of Virginia as part of a roadside park, is shown in photo 2. Like the North Platte River bridge, it was originally fabricated in 1875. However, it was moved to its Roaring Run site in the early twentieth century. The two structures only differ in that the Roaring Run bridge has no lateral bracing.

Two of the most famous railroad bridge engineers of the mid-nineteenth century, Wendel Bollman and Albert Fink, both patented bridge designs which played important roles in early American development. Unfortunately, both the Fink (diagram 25) and Bollman (diagram 26) trusses were replaced and/or destroyed to such an extent during the early twentieth century that at present only one Bollman and two Fink trusses are known to exist. Photo 12 shows the 1869 Bollman truss which crosses the Little Patuxent River in Savage, Maryland. The oldest known Fink truss (1857) is located in Hamden, New Jersey (photo 13). Both designs came out of some of the earliest American engineering attempts to construct all-metal bridges, and they are mentioned because of the prominent positions these trusses have attained within literature concerned with America's technological development.

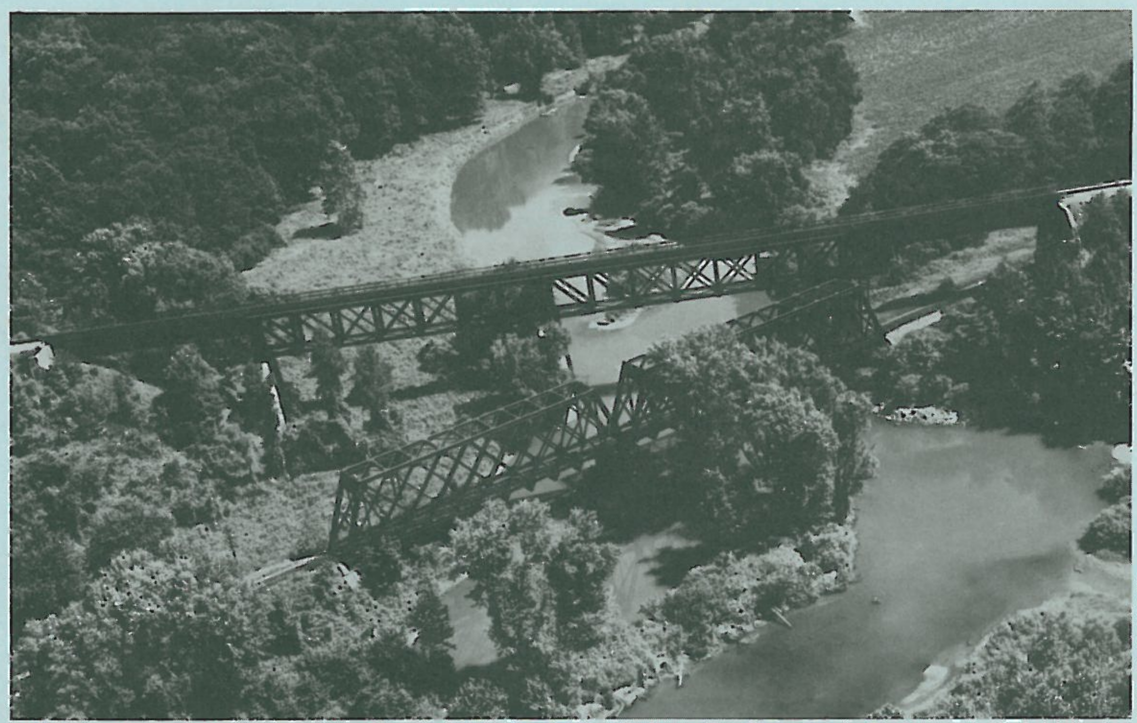


Photo 1. Erie Railroad Crossing over French Creek, Cambridge Springs, Pa. Foreground: Two-span riveted triple intersection Warren through truss, c. 1910. Background: Two-span riveted Pratt deck truss, c. 1900.

Photo 2. Roaring Run Bridge in Bedford, Va. Single-span pony bowstring arch-truss, 1875.

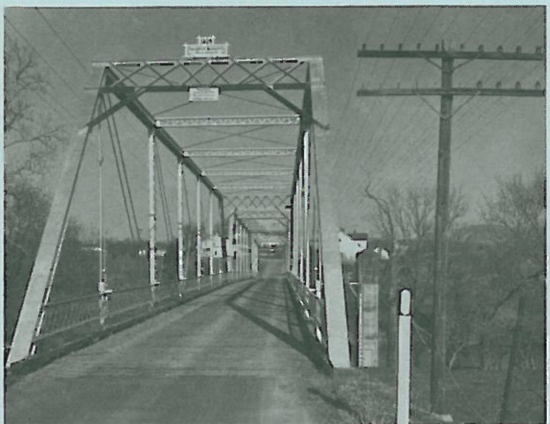


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Photo 3. Middle River Crossing, Mount Meridian, Va. Three-span pin-connected Pratt through truss, 1907.

CHARLES HYDE

Photo 4. Portland and Danby Bridge over the Grand River, South Portlandsville, Mich. Single-span pin-connected Parker through truss, 1907.

CHARLES HYDE

Photo 5. Washington Road Crossing over Fish Creek, Ionia, Mich. Single-span pin-connected camelback through truss, 1906.

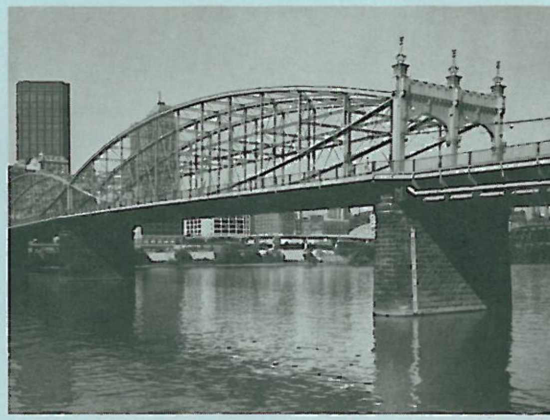

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Photo 6. Smithfield Street Bridge over the Monongahela River, Pittsburg, Pa. Two-span pin-connected lenticular through truss, 1883.

CHARLES HYDE

Photo 7. New York Central Railroad Crossing over Raisin River, Monroe, Mich. Three-span (only one is shown) pin-connected Baltimore through truss, 1910.

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Photo 8. Laughery Creek Bridge near Aurora, Ind. Single-span pin-connected triple intersection Pratt through truss, 1878.

JACK E. BOUCHER

Photo 9. Pere Marquette Railroad Crossing over Raisin River, Monroe, Mich. Two-span riveted Warren through truss with verticals, 1911.

JACK E. BOUCHER

Photo 10. Studley Bridge over the St. Joseph's River, Sherwood, Mich. Single-span pin-connected Warren through truss, 1910.

WILLIAM E. BARRETT

Photo 11. North Platte River Bridge, Fort Laramie, Wyo. Three-span bowstring arch-truss, 1875.

WILLIAM E. BARRETT

Photo 12. Baltimore and Ohio Railroad Crossing over the Little Patuxent River, Savage, Md. Two-span pin-connected Bollman through truss, 1869.

JACK E. BOUCHER

Photo 13. South Branch Raritan River Crossing over Hamden, N. J. Single-span pin-connected fink through truss, 1857.

DONALD C. JACKSON

Photo 14. Linville Creek Crossing near Broadway, Va. Single-span pin-connected "hybrid," Warren and double intersection Pratt through truss, 1898.

In 1892, the Kansas engineer, W. E. Stearns patented the Stearns truss (diagram 27), a simplified version of the Fink truss. *Engineering News*, an important source of information on bridge truss design, described it as particularly suited for short-span highway bridges. Photo 14 shows a 1898 bridge near Broadway, Virginia, built by the Wrought Iron Bridge Company of Canton, Ohio. Its outline is similar to the Stearns, but it appears to incorporate structural aspects of both the double-intersection Pratt and the Warren. An unusual design, it is a good example of a "hybrid" truss.

As illustrated by the many photographs of Michigan bridges included in this leaflet, a wide variety of truss bridges can be found within a specific locale. Unfortunately, this variety is endangered by many bridge demolition and replacement programs. These bridge replacement programs often times focus exclusively on replacement with little concern for repair; however, some progressive communities are learning that repair costs can often be lower than the cost of building a new bridge. Only after communities recognize the significance of these older bridges within America's contemporary landscape will some be retained as working, useful reminders of our nation's historical development.

A poster of the drawings in this technical leaflet is available for $4 plus $1 for postage and handling from MCMOC, c/o The Historic American Engineering Record, The National Park Service, Washington, D.C. 20240.

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