HISTORIC BRIDGES OF PENNSYLVANIA

2025

Commonwealth of Pennsylvania
Pennsylvania Department of Transportation

Market Street Bridge in Harrisburg

On the cover: Smithfield Street Bridge in Pittsburgh

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INTRODUCTION

The Pennsylvania Department of Transportation (PennDOT) plays a key role in the maintenance, repair, rehabilitation, or replacement of historic bridges across the Commonwealth. PennDOT's responsibilities, pursuant to state and federal regulation, include seeking to avoid effects to bridges that are listed in, or eligible for listing in, the National Register of Historic Places. Therefore, PennDOT needs a reliable list of such properties; evaluating these structures collectively, and in advance of projects, fosters a better understanding of which bridges are historically significant by enabling a comparison of other similar structures through a regional, statewide and national context. Such a collective evaluation is also required by Title 23 of the United States Code as part of requirements for states to receive federal highway funding. Beginning in 1982, PennDOT, with the support of the Pennsylvania Historical and Museum Commission (PHMC), the state's historic preservation office (SHPO), undertook a project to survey and evaluate PennDOT owned bridges; the effort resulted in a list of 180 bridges determined to be significant in the development of Pennsylvania's highway system and bridge engineering history. These bridges were collectively listed in the National Register of Historic Places in 1986. That same year, PennDOT and PHMC, with the assistance of the consulting engineering firm of McCormick Taylor, Inc., published the Historic Highway Bridges in Pennsylvania to present the results of the statewide survey. The publication included a brief history of the state's transportation system and bridge building in Pennsylvania. The publication included a presentation of the bridges identified through the survey organized by an overview of the major bridge types and designs in place prior to the 1950s: stone arch bridges, covered bridges, suspension bridges, metal arch bridges, metal truss bridges, and concrete arch bridges, along with examples of these bridge types and designs.

Beginning in 1996, PennDOT and the SHPO, with the assistance of the engineering firm A.G. Lichtenstein (now Transystems), undertook a statewide inventory and evaluation of all bridges over 20 feet in length found in PennDOT's Bridge Management System (BMS), including county and municipally owned bridges. In the last several years the SHPO, in conjunction with PennDOT, has conducted inventories and evaluations according to bridge type and design, the purpose of which is to account for loss in the intervening years, as well as current thinking regarding the evaluation of bridges for listing in the National Register of Historic Places. These evaluations utilize a point-based scoring system which enables an immediate understanding of bridge rarity, as well as bridges with uncommon details.

This publication updates the 1986 publication, starting with an overview of Pennsylvania's transportation and bridge building history, followed by photographs and descriptions of some of the many historically significant bridges that dot the landscape, from rural countryside to major city, from east to west, and everywhere in between. In addition to accounting for previously featured historic bridges that have been lost in the intervening years, this publication features a number of historically significant county and municipally owned structures and several of the many historically significant railroad bridges.

The featured bridges are but a portion of the diverse and significant population of historic bridges in Pennsylvania. They serve as examples and vestiges of Pennsylvania's dynamic transportation and bridge building history. A complete list of historic bridges, as evaluated by the PA SHPO and PennDOT, is available online on PennDOT's Cultural Resources website[1]. Additional information on historic bridges within Pennsylvania, including bridges outside PennDOT's BMS, can be found in Pennsylvania's Historic & Archaeological Resource Exchange (PA-SHARE), the SHPO's online GIS and project management system.

This publication has been funded by the following projects which necessitated the replacement of historic bridges: Pike Street Bridge in Washington County, and the State Route (S.R.) 4013, Section A03 Bridge in Potter County.

Rockville Stone Arch Bridge in Dauphin and Perry County

The "S" Bridge in Buffalo Township, Washington County, built in 1818 over Buffalo Creek, was once part of the National Road.

GROWTH OF THE STATE HIGHWAY SYSTEM

Pennsylvania's modern highway system is a product of over 300 years of evolution, beginning with early post roads and turnpikes, heavily influenced by canal and railroad agency advances, expanded by local automobile roads in the twentieth century and culminating with the interstate highway program. Physical remnants of each major period, bridges remain as reflections of Pennsylvania's growth and development.

EARLY HIGHWAYS

Pennsylvania's earliest travelers depended on rivers and Native American paths for movement across the state. Roads, as defined by modern travelers, were nonexistent. Early roads, even primitive ones by today's standards, were rare in the Commonwealth. It was the English settlers in the Philadelphia region who began to build them. Pennsylvania's network of roadways had its earliest beginnings in the "King's highways" which radiated out from Philadelphia. By a 1699 act of the General Assembly, all "King's highways or public roads" were to be laid out upon orders from the Governor and Provincial Council. These roads were cleared of brush and trees and could be as wide as fifty feet. Slowly, a system of King's highways grew in southeastern Pennsylvania. By the later seventeenth century, a road carried traffic from Philadelphia to Morrisville and Bristol. Among other early roads were a Queen's Road to Chester in 1706, the Old York Road from Jenkintown to New Hope in 1711, and a road from Philadelphia to Doylestown and Easton in 1722. In 1733, construction of the King's Highway connecting Philadelphia with Lancaster begun. These roads were constructed chiefly to facilitate trade and communication within and between the colonies.

Until the mid-eighteenth century, the focus of road building activity was in southeastern Pennsylvania. Although a network of roads had grown to facilitate trade in the east, travel to the west was difficult. The incentive for better roads to the west was produced by the French and Indian War. In 1752 a wagon road was opened from what is now Cumberland, Maryland to the Youghiogheny River. In 1755 it was improved and extended to the Monongahela River by General Edward Braddock's troops. This road became known as Braddock's Road. It carried traffic from Cumberland, Maryland through present Somerset, Fayette, and Westmoreland Counties and ended at Braddock, south of Fort Duquesne. It roughly followed the course of the present US-40. Another well-traveled route was the Forbes Road, constructed by order of General John Forbes in 1758 to allow British and Colonial troops to attack the French at Fort Duquesne, now Pittsburgh. Forbes' Road began at Raystown (Bedford) and went west to a point about ten miles west of Ligonier; much of the present US-30 between Bedford and Pittsburgh follows this route.

Braddock's and Forbes' Roads remained principal routes west until well after the American Revolution. From 1811 to 1818, parts of Braddock's Road were used for the National, or Cumberland Road built by the United States government to provide a connection between the Atlantic seaboard and the Ohio River.

After the Revolution, on September 21, 1785, the first highway legislation passed by the Pennsylvania General Assembly provided for the laying out of a state highway from western Cumberland County to Pittsburgh. Legislation continued to be enacted which created more roads in Pennsylvania, establishing the precursors of many current highways.

Although public roads continued to be built after the Revolution, the lack of adequate funds for the continued construction and maintenance of its growing transportation network led to the beginning of Pennsylvania's turnpike or toll road era. These early toll roads and the military roads relied on ferries and fords for crossing rivers.

On April 9, 1792, the Pennsylvania legislature chartered the Philadelphia and Lancaster Turnpike Road Company, a venture which combined a partial public subsidy with private capital. The Lancaster Pike, a hard-surfaced road of macadam was completed in 1794 at the cost of approximately $450,000. An Act of 1806 authorized establishment of a turnpike road along what became known as the "Pittsburgh Pike" between Harrisburg and Pittsburgh; much of this followed the old Forbes Road which became US-30. This road was to be an important thoroughfare leading westward and its success spurred the formation of a large number of turnpike companies in the early 1800's. By 1831, Pennsylvania led the country in turnpike road mileage, having a total of about 3,000 miles divided among some 220 local companies.

These numerous privately owned - state chartered turnpikes carried so much traffic that ferries, which had originally crossed all major rivers, were incapable of handling the volume. Often, the turnpike companies built their own bridges. At major river crossings like the Delaware, Susquehanna, Juniata and Allegheny Rivers, separate, private companies formed to construct toll bridges. Because of the size of the bridges that needed to be built at these crossings, master bridge builders tested new construction techniques, exceeded previous span lengths successfully and became prominent. By the end of 1821, documents indicate that authority had been granted for the construction of forty-nine privately owned toll bridges across the state.

CANALS

The principal period of turnpike construction ended around 1830 with the successful completion of a statewide canal system. Travelers returned again to the water and the emphasis in bridge building changed from highway bridges to canal aqueducts. Between 1791 and 1819 fifteen private companies were charted in Pennsylvania to build canals. The network of turnpikes built in Pennsylvania was largely funded with private capital until the Commonwealth began to suffer a loss of trade as a result of the completion of New York's Erie Canal in 1825. In 1826 Pennsylvania legislation was passed which established the State Works, a state transportation system whose principal component was a statewide canal system. By 1834 travel by the canal was possible across the state from Philadelphia to Pittsburgh on the Main Line of the Pennsylvania Canal. The Allegheny Mountains were crossed by means of the Allegheny Portage Railroad, a unique system of inclines and planes. The thirty-seven-mile-long Allegheny Portage Railroad included several stone arch bridges which remain in service today as vehicular bridges. Numerous other private and Commonwealth sponsored canals were built throughout the state during the first half of the nineteenth century.

Construction of the system of canals required solutions for crossing obstacles just as other modes of transportation did. Bridges were built to accommodate intersecting roads, and aqueducts were built to carry the canals and towpaths across streams, large rivers, or ravines. Among the aqueducts built for Pennsylvania canals were several designed and built by John A. Roebling, of Brooklyn Bridge fame. Roebling's first aqueduct was a replacement bridge built in 1845 on the Pennsylvania Canal in Pittsburgh. Between 1847 and 1850 he built four aqueducts on the Delaware and Hudson Canal in northeastern Pennsylvania. One of these, the aqueduct at Lackawaxen, is still standing.

Innovations in bridge technology and engineering advances developed for canals eventually led to more sophisticated applications in railroad and highway bridge design. It was with the building of America's early canals that a group of field-trained engineers emerged in the United States.

RAILROADS

No sooner had the canals become fully operational than major railroad lines began to be built, further expanding the demand for advances in engineering technology. A systematic approach to bridge design developed which would influence highway bridge design. By 1860, with 2,600 miles of trackage, railroads had superseded the highways and canals as the preferred means of transportation. Pennsylvania pioneered in railroad development, with the largest, the Pennsylvania Railroad, traversing the state. Other railroads included the Reading, Delaware and Hudson, and the Pittsburgh and Lake Erie. The rapid growth of the railroad industry influenced the art of bridge building and resulted in the development of new bridge types, new construction techniques, and the shift to new building materials. Because of the relative economy and superiority of railroads, most canal and turnpike systems were abandoned during this period and fell into disrepair. While a few canals and several turnpikes continued to be used for local traffic, the railroad became the primary means of long-distance transportation.

Many canal beds were used for railroad rights-of-ways because they were flat, long, and linear. Parts of the Pennsylvania Main Line were taken over for railroad use. In 1857 the Commonwealth sold the Main Line Canal, and two railroads which linked the canal system, the Allegheny Portage Railroad and the Philadelphia and Columbia Railroad, to the Pennsylvania Railroad Company for $7,500,000. Other canals were sold to subsidiaries of the Pennsylvania Railroad and to other railroads.

RISE OF THE AUTOMOBILE

In the late nineteenth century, the development of the automobile and the popular use of the bicycle spurred a national movement for the re-establishment of good roads. Many of the old turnpike roads were in use again, even though they had been maintained poorly for years. In 1895 Pennsylvania enacted legislation which furnished procedures for any county to take over local roads and improve them.

During the early 1900s, the increasing volume of automobile traffic gradually re-established the highway as the principal facility by which people and goods were moved. As traffic increased, communities and counties were unable to cope with the maintenance, construction, and improvement of roads. The need for state intervention became clear.

With the backing of Governor Pennypacker, an act was passed on April 15, 1903, organizing the State Highway Department (later the Pennsylvania Department of Highways), one of the first such departments in the country. The Department provided a means to handle state assistance to townships and counties for road improvements. On May 31, 1911, the Sproul Act, signed by Governor Tenor, provided for a state highway system. The Sproul Act made provisions for the Commonwealth to take over a system of 8,835 miles of roads on 296 different routes, linking county seats and other important places. These roads included county, township, and private turnpike company roads.

The focus of highway work in the 1920's was to complete the paving of a network of primary highways. Some of these, like the Lincoln Highway, were intended for national travel and were the beginning of a transcontinental system of U.S.-numbered highways. In the 1930's the focus shifted to the paving of the farm-to-market roads. The greatest growth in the state highway system occurred in 1931 when 20,156 miles of rural roads were taken over by the Commonwealth. This growth in the state highway system included the state assuming responsibility for all the bridges on these roadways, which had been built by county and local authorities through the nineteenth century. In this manner, many old highway bridges became the property and responsibility of the state.

The late 1930's saw the construction of Pennsylvania highway and bridge projects under the work-relief program of the Works Progress Administration (WPA) and the creation of the Pennsylvania Turnpike Commission. On October 1, 1940, 160 miles of the Pennsylvania Turnpike were opened from Middlesex to Irwin. The road was heralded as America's first long-distance superhighway and featured four lanes, no at-grade intersections, and very low roadway grades. This progress was dampened by World War II when wartime controls were imposed on travel and funding was channeled to military needs. After the war, a growing population and increased mobility created new needs. Urban bypasses were built to alleviate urban traffic congestion. At the same time, turnpike extensions were completed which joined the Pennsylvania Turnpike with the Ohio and New Jersey turnpikes, forming a part of a four-lane road connecting New York with Chicago. In 1956 the Federal Highway Act established a new 41,000-mile Interstate Highway System, stretching across the country. By the late 1970's, 1,576 miles of Federal-aid Interstate Highways were built in Pennsylvania.

In 1970, the Department of Highways became the nucleus of the Pennsylvania Department of Transportation, created by Act 120. The intent of the legislation passed in May 1970 was to consolidate transportation-related functions formerly performed in the Departments of Commerce, Revenue, Community Affairs, Forest and Waters, Military Affairs, and other state agencies.

Narrows Bridge in Snake Spring Township, Bedford County

Germantown Pike over Skippack Creek in Montgomery County. Courtesy of HDR.

PENNSYLVANIA'S BRIDGES: EVOLVING TECHNOLOGY

All travel routes, whether they were turnpikes, canals, railroads, or highways, eventually reached waters which were difficult to cross. For pedestrians, horse drawn vehicles, and automobiles, the earliest crossing solutions were either to ford the stream or to be carried across by ferry. In cases where there was sufficient demand, bridges were built.

TRADITIONAL MATERIALS AND EARLY BRIDGE BUILDERS

The earliest bridges built were elemental structures of timber or stone, and most likely consisted of simple beams resting on supports. For long-span timber bridges, a series of beams were carried on these supports, called pilings. In the case of stone, the beam was actually a slab, but the structural principle was the same. Although timber lent itself to use as a beam, which can bend and is subject to stresses, stone could not be used efficiently as a beam since stone was very brittle in tension. Thus, primitive applications gave way to designs which allowed for efficient use of the material and longer spans. For longer spans, the simple timber beam was expanded to a truss by joining vertical and diagonal members, and stone was used to build arches, compression structures which use the natural strength of stone as a building material.

STONE ARCH

The oldest extant highway bridges in the Commonwealth are stone arch bridges. Many early examples remain throughout Pennsylvania, illustrating not only variations typical in stone arch bridge construction, but also illustrating evolutionary types. Two early examples of stone arch bridges include the Frankford Avenue Bridge, built in 1697 to cross Pennypack Creek in Philadelphia, and the Skippack Bridge, constructed in 1792 over Skippack Creek in Montgomery County. These bridges are among the ten oldest bridges in the United States.

A large number of early stone arch bridges in Pennsylvania still remain. The tradition for building stone arch bridges may not have been widespread in other states, but Pennsylvania's reputation for stone construction was recorded in 1808 by then U.S. Secretary of the Treasury, Albert Gallatin, in his report on transportation in America:

> "In the lower counties of Pennsylvania, stone bridges are generally found across all the small streams. Both in that state and at some distance eastwardly, bridges with superstructures are common over the wide rivers."

This early recognized tradition continued into the twentieth century with the construction of many fine stone arch bridges. Today, there are extant stone arch bridges which were built for King's highways, turnpikes, canals, railroads, and modern highways. Many of them still carry traffic.

COVERED BRIDGES

While no eighteenth-century timber bridges remain, there are many extant examples of nineteenth century timber bridges all across Pennsylvania.

Bridge historian Henry Tyrell wrote in his 1911 book History of Bridge Engineering that the majority of bridges built prior to 1860 in the United States were made of timber. The timber bridges which remain are the well-known covered bridges. These bridges are wood trusses, sheathed and roofed to protect and prolong the life of the framing and deck.

Historical records abound in descriptions of timber bridges built in Pennsylvania by America's most famous wood bridge builders, Timothy Palmer, Theodore Burr, and Lewis Wernwag. The earliest recorded timber covered bridge built in Pennsylvania was Timothy Palmer's three-span Permanent Bridge constructed across the Schuylkill River at Philadelphia in 1805. Theodore Burr built many of his patented "arch-trusses" in Pennsylvania, among them multiple span bridges crossing the Susquehanna and Delaware Rivers. Lewis Wernwag's most famous Pennsylvania bridge was named the Colossus and spanned the Schuylkill River at Fairmount, a neighborhood near the historic waterworks in Philadelphia. It was a single span arch truss of 340 feet. None of these bridges remain.

The tradition of building long and short span timber bridges continued through the nineteenth century and into the twentieth century, with local craftsmen erecting their own handiwork at various locations. Many nineteenth century covered timber truss bridges remain in Pennsylvania, more than any other state.

CRAFTSMEN AS BRIDGE BUILDERS

As Gallatin noted elsewhere in his 1808 report, streams in Pennsylvania were crossed by both stone and timber bridges. Thus, through the earliest years of Pennsylvania's growing transportation network, stone arch bridges and timber bridges were built simultaneously. Of course, the inherent durability of stone, when properly used, contrasts with the relatively short life of uncovered timber structures. Thus, there are no extant timber bridges built in the seventeenth or eighteenth centuries, but there are stone bridges from this period.

The early builders of stone arch bridges were highly skilled craftsmen who continued an ancient established tradition of masonry construction. Some of their names are carved in datestones or noted in public records. Among these were Silas Harry and D.S. Stoner, who built many nineteenth century bridges on the National Road in both Maryland and Pennsylvania. A later stone arch bridge builder was P.J. McCormick, active in the early 1900's in Chester County. Skilled craftsmen, their names often unknown, built handsome stone bridges across Pennsylvania between the eighteenth and twentieth centuries that still continue to carry traffic.

The builders of the early nineteenth century long-span timber bridges, like Palmer, Burr and Wernwag, were not only highly skilled craftsmen in heavy timber construction, but they were also innovative designers. Though none had formal training in engineering, they relied on their previous experience in timber building to devise and patent their own designs. Their work remains only through illustrations and descriptions in historical records.

THE INTRODUCTION OF MODERN MATERIALS

While stone and timber bridges continued to be built in Pennsylvania into the twentieth century, improvements in metallurgy, manufacturing, and field riveting techniques beginning in the mid-nineteenth century made metal and concrete the material of choice for bridge design and construction in the United States. Over time, bridge forms and components became increasingly standardized, decreasing costs and making analysis of stresses simpler and more precise.

The transition to composite truss bridges with wood and iron members began in the 1840s. By the 1860s, bridges were being constructed of a combination of cast and wrought iron. Wrought iron, however, is brittle in tension and the mid and late nineteenth century witnessed a number of spectacular failures of iron bridges. Seeking a better material for truss bridges, manufacturers turned to steel, which is stronger than iron, more malleable, and strong in both compression and tension. By the 1890s, steel had replaced iron as the structural system in truss bridges.

SUSPENSION

The first metal bridge built in the United States, also the first modern suspension bridge, was built in 1801 over Jacob's Creek in Fayette County. Designed by James Finley of Fayette County, it was one of many chain suspension bridges he built. Finley received a patent in June 1808, and through numerous historical accounts, his work is well known. However, none of his suspension bridges remain.

The design and construction of early and significant suspension bridges continued in Pennsylvania, with noteworthy designs by both Charles Ellet and John Roebling. Charles Ellet's first major bridge was a suspension bridge built in 1843 to replace Lewis Wernwag's Colossus Bridge across the Schuylkill River in Philadelphia. Ellet's wire cable suspension bridge extended 358 feet in a single span over the Schuylkill River. It carried vehicular traffic until 1874.

John A. Roebling, now recognized principally for New York's Brooklyn Bridge, developed his reputation for substantial suspension bridges in Pennsylvania. One of

Roebling's Delaware Aqueduct over the Delaware River in Pike County

Roebling's early bridges, the Delaware Aqueduct built in 1848, stands today as the earliest extant suspension bridge which retains its original structure. It was built for the Delaware and Hudson Canal, which served northeastern Pennsylvania's coal industry. This wire cable suspension bridge carried the Delaware and Hudson canal in a wooden flume across the Delaware River. John Roebling built several other suspension bridges in Pennsylvania for both canal and highway traffic, such as the Sixth Street Bridge crossing of the Allegheny River at Pittsburgh in 1860, which was replaced in 1892.

METAL ARCH

The first metal arch bridge in the United States was completed in 1839 and still spans Dunlap's Creek in Fayette County. It was built of cast iron by the U.S. Army Corps of Engineers for the National Road and replaced an earlier Finley suspension bridge. Unlike suspension bridges, which were built for Pennsylvania highways throughout the nineteenth century and into the twentieth century, few metal arch bridges were built after the remarkably early Dunlap's Creek Bridge until the late nineteenth century. Beginning at that time several noteworthy iron or steel arch bridges were built in Pittsburgh.

Dunlap's Creek in Fayette County. Photograph from HAER.

METAL TRUSS

The overwhelming majority of metal bridges built during the nineteenth and early twentieth centuries were metal truss bridges. As a structural form, the truss was first built with timber. In the 1840's, two truss types were patented as combination wood and iron structures. The truss members which acted in compression were made of wood, while the tension members were iron. The combination wood and iron truss proved to be short-lived, replaced by the more durable – and fireproof – all-iron truss, largely as a result of innovation in bridge engineering developed for the nation's fast-growing railroads. During the post-Civil War years, the American railroad system expanded to all parts of the country. As it did, railroad companies developed new metal truss types that could span greater distances and accommodate heavier and faster trains. Well-known truss types like the Baltimore and Pennsylvania truss were designed and patented by railroad companies.

Metal truss bridges also became a favored choice for many local highway bridges due to their ease of erection and suitability for various site conditions. The metal truss bridge had several characteristics prized by railroad companies and highway bridge designers. First, their structural behavior could be analyzed through systematic engineering calculations. Second, members became standardized in size and shape, making it possible to reduce fabrication costs and to physically test materials and members for their capacity and behavior under applied loads. Finally, standardized truss components could be easily manufactured and shipped, and the entire bridge could be erected quickly on a pre-built substructure with a minimum of skilled labor. Each railroad had its own preferred truss type and many railroad engineers patented the trusses they developed. Although the metal truss bridge has become identified with the nineteenth and early twentieth century American railroad network, many early highway truss bridges continue to carry traffic in Pennsylvania today. Others have been moved to parks or hiking-biking trails, where they serve pedestrians.

CONCRETE

The development of concrete as a primary construction material was roughly simultaneous with that of steel. By 1900, zealous proponents of both concrete and steel were developing and selling patented bridge types throughout the United States. Concrete became as popular as steel for highway bridges and short railroad spans, and the use of both concrete and steel in bridge building continues today.

The earliest concrete bridges were arched, and they could span much greater distances than stone masonry bridges. The first concrete bridge in the United States was constructed of unreinforced, or plain, concrete built in 1871 in Prospect Park, Brooklyn, New York. The first reinforced concrete bridge, reinforced with steel rods or bars, was built in 1889 in Golden Gate Park, San Francisco, California. Steel reinforcing provides tensile strength to concrete. Designed by a pioneer of concrete use, Ernest L. Ransome, this bridge was a solid barrel arch treated on the surface to imitate stone. The use of concrete in bridge building was seen as an extension of stone masonry and it was years before concrete bridges were built using an unembellished concrete finish.

As theoretical understanding of reinforced concrete progressed, changes in the shape and configuration of the arch bridge occurred. While the massive barrel arches continued to be built by more conservative designers, more progressive designers produced

Westinghouse Bridge in Pittsburgh

Old Columbia-Wrightsville Bridge in York and Lancaster County

arches which were flatter. less bulky, and more efficient in its use of concrete. This included the use of open, or arched, spandrel walls between the arches and the bridge deck, a bridge design that was very popular during the "City Beautiful" movement of civic improvements. The longest open spandrel arch bridge of its time was built between 1906 to 1908 to carry Walnut Lane across Wissahickon Creek in Philadelphia and has a span of 233 feet. This bridge span was exceeded in 1912 by the Larimer Avenue Bridge in Pittsburgh, which has a clear span of 312 feet, and contains parabolically shaped ribs.

Noteworthy concrete arch spans continued to be built in Pennsylvania into the 1930s. In 1930, the longest multiple span arch bridge of its time was built over the Susquehanna River between Columbia and Wrightsville, in Lancaster and York Counties. The Old Columbia-Wrightsville Bridge has forty-eight spans totaling 6,656 feet in length. Allegheny County's George Westinghouse Memorial Bridge was the longest and highest concrete arch highway bridge when it was completed in 1932. Its central span measures 460 feet.

Non-arch reinforced concrete bridge types also developed in the first two decades of the twentieth century. These included T-beam bridges, slabs, through girders, and rigid frame bridges. These types were used primarily for shorter span bridges.

In 1950, the first major prestressed concrete beam bridge designed and built in the United States was completed. This three-span bridge carried Walnut Lane over Lincoln Drive and Monoshone Creek in Philadelphia. Gustav Magnel, a Belgian engineer acknowledged as an authority on concrete pre-stressing, designed the bridge as consultant to the City of Philadelphia. The form of the bridge was simple and appeared to be like many highway bridges carrying traffic on U.S. highways. The technological significance was hidden in the structure of the bridge. The bridge deck of the Walnut Lane Memorial Bridge was supported by thirteen concrete girders, each spanning 160 feet. These girders were prestressed by post-tensioning four wire cables imbedded in the concrete. Although this type of construction had been used in Europe for quite some time, the Walnut Lane Memorial Bridge was innovative in the United States and led to the successful application of this technology throughout the country. The Walnut Lane Memorial Bridge was replaced in 1990. For small and medium span prestressed concrete bridges, in the early 1950s Concrete Products of America, a corporation with manufacturing plants in Pottstown and Pittsburgh, developed box shaped beams that were pretensioned before the concrete was placed. The concrete was then poured around hollow cardboard tubes to create voids in the beams and reduce weight. The hollow box beams would become a hallmark of post-war American bridge technology.

ENGINEERS AND BRIDGE BUILDERS

The Rise of the Engineer

In the early years of the American Republic, public works projects were frequently supervised by European-trained engineers. Most of the formally educated engineers in early nineteenth century America graduated from European universities or from the U.S. Military Academy at West Point, established in 1802. The introduction of bridges built of easily fabricated manufactured metal components in the early nineteenth century began the transformation from the empirical design traditions of those early American stone and timber bridge builders.

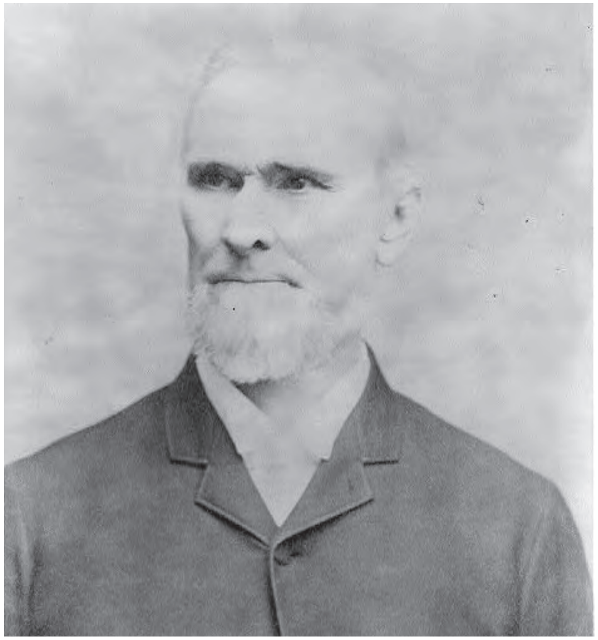
As noted previously, the first metal bridge in the United States was James Finley's 1801 wrought iron suspension bridge in Fayette County. Historical records document that Finley devised a graphical method of calculating member lengths for his suspension bridge which carried a horizontal roadway. Though Finley apparently had no formal engineering training, his invention was lauded even by the well-trained French engineers, the best in the world at that time. The other early all-metal bridge built in America was the cast iron arch built over Dunlap's Creek designed by Richard Delafield of the Army Corps of Engineers.

As late as the 1830's only a few colleges in the United States offered civil engineering training, including the U.S. Military Academy and Rensselaer Polytechnic Institute. The few engineers in charge of public works lamented the scarcity of formally trained engineers in the United States. The number of native engineers in the nineteenth century was small; the national census of 1850 numbered 512 civil engineers in the United States. The largest segment of mid-nineteenth century engineers had little or no formal education. They developed their engineering knowledge through self-study and apprenticeship, serving as axmen and rodmen in survey parties for the roads, canals, and railroads built during the time. Many of the bridge builders of this era were skilled craftsmen who relied on time-tested construction traditions; some of them developed their own innovative structures.

The building of canals provided field training for a few young civil engineers in America during the early and mid-nineteenth century. But it was the rapid growth of the American railroad, with their need for longer and stronger bridges, which demanded systematic rules of analysis and controlled, standardized material for bridge building.

As the transportation network grew and innovations in materials and manufacturing increased, those involved began exchanging ideas and codifying civil engineering practices and techniques. Two engineers with railroad experience developed books on bridge building in the mid-nineteenth century, Squire Whipple's A Work on Bridge Building, in 1847 and Herman Haupt's, General Theory of Bridge Construction, in 1851. Haupt had extensive experience on the Pennsylvania railroad and also taught engineering at Pennsylvania College in Gettysburg. Squire Whipple was a New York engineer with experience on the Erie Canal and several New York railroads. The patentee for several bridge designs, Whipple was called the "father of American bridge building" or the "father of iron bridges."

The availability of trained engineers for teaching and the resultant increase in programs which produced more engineers led to an established engineering profession in the United States by the 1860's. Professional associations, which still exist, were organized and an increasing supply of engineers was guaranteed. The growing number of engineers began the transformation of American bridge building from the empirical design traditions of early American stone and timber bridge builders to something more formal.



Squire Whipple, civil engineer - Library of Congress

THE ESTABLISHMENT OF BRIDGE COMPANIES

The last half of the nineteenth century saw the establishment of large, specialized bridge building companies, with manufacturing, erecting, and material testing capabilities. Some of these companies were formed by patentees to construct their particular truss types.

In 1889, Theodore Cooper, a well-known railroad engineer, listed approximately forty American bridge building companies and said of them, in a paper published in the American Society of Civil Engineers:

> *"Up to about 1874, the designing and the construction of bridges were, almost exclusively, in the hands of the several bridge companies. Each of these companies had its own peculiar style of bridge…each company also had its own special geographical field, or lines of railroad, giving it the preference. Even at points where they did meet as competitors, it was rather as advocates for their special trusses or forms of parts…"*

By the late nineteenth century, all the major bridge companies had the shop capacity to handle bridge manufacturing from receiving the iron to straightening, punching, fitting, riveting, finishing, painting, and shipping.

Roaring Run Stone Arch Bridge in Jenner Township, Somerset County

Many of these bridge building companies were located in Pennsylvania, close to the nation's leading steel companies and national railroad line. Among these were the Keystone Bridge Company in Pittsburgh and the Phoenix Bridge Company in Phoenixville, Chester County. The Keystone Bridge Company was organized in 1865 with J.H. Linville as President and steel-maker Andrew Carnegie as Vice President. Between 1891 and 1894, this company became the Keystone Bridge Works of the Carnegie Steel Company. Steel bridges throughout the United States, including the Eads Bridge built in 1874 over the Mississippi River, were fabricated by this company. The Phoenix Bridge Company was organized in 1864 as a division of the Phoenix Iron Works of Phoenixville. Its famous Phoenix Column, patented by Samuel Reeves in 1862, was a hollow cylinder composed of four, six, or eight wrought iron segments riveted together. The resulting

Market Street Bridge in Wilkes-Barre, Luzerne County

column was much lighter and stronger than the solid cast iron columns of the day and the chief component of its bridges.

Although the bridge manufacturing companies grew primarily out of railroad needs, they quickly saw the adaptability of their product to the highway bridge market. In a bid to gain an advantage over rivals, bridge companies increasingly turned to patented and standardized bridge designs, marketed through each company's bridge catalog.

The procedure by which a municipality would contract to have a truss bridge erected was detailed in the 1873 catalog of the Phoenixville Bridge Works, a predecessor to the Phoenix Bridge Company. There are fourteen plates in the back of their catalogs which illustrated various styles of available bridges. Prospective bridge buyers used the catalog much like a mail order catalog customer would. The bridge company instructed its customers to "follow directions" and provide information concerning the site conditions. When this data was furnished, the company promised to "quote prices, by return mail" and "construct the bridge in as short a time as any other bridge builders can do".

Their cash rates were uniformed to all, but prices were lower if a number of trusses were ordered. Although their system encouraged the customer to choose one of their standard designs, they claimed to be able to "make special plans and estimates to suit any required case" for a higher cost.

This marketing and sales procedure continued to be used into the early twentieth century for the construction of local highway bridges as vehicular traffic increased, and more highway bridges were needed. However, patented bridge design gradually gave way to standardized, most notably the Warren, Pratt, and Parker trusses and their variations because of its relative ease of fabrication and construction.

As concrete arch bridges for highway spans came into common use, bridge companies again led the trend towards both specialization and standardization. Bridge companies which specialized in reinforced concrete structures flourished in the early twentieth century. The Luten Bridge Company was one of the most prolific concrete arch bridge companies. Established by Daniel Luten of Indiana, the company produced catalogs of various arch styles, from monumental city bridges to ornamental park bridges. The catalogs also advertised the advantages of concrete bridges over steel bridges. Luten employed sales agents and built hundreds of his concrete arches throughout the east and Midwest. Its construction agent in Pennsylvania, Whitaker and Diehl of Harrisburg, built many Luten-designed spans across the eastern United States.

Although the majority of bridges constructed during this late nineteenth and early twentieth century flurry of standardized bridge building were of the catalog type, long span or complex structures still required the design skills of trained engineers. Then, as the states began to see the need for central control of highway and bridge design, highway departments were established, and today's method of bridge design was born. Beginning in the 1910s and 1920's, highway bridges in Pennsylvania were either designed by the State Highway Department, municipal departments of public works, or consulting firms. The construction of both substructure and superstructure was accomplished by contractors.

The following chapters provide an overview of the six bridge types previously mentioned. Each chapter includes details on the development of the bridge type, terminology, and key characteristics. Highlighted bridges are featured at the end of every chapter; however, this is not an exhausted list. Additional bridges and information is available online on PennDOT's Cultural Resources website[1].

Dunlap's Creek Bridge in Fayette County

Frankford Avenue Bridge over Pennypack Creek in Philadelphia.

The tradition of constructing stone arch bridges is long established in Pennsylvania. The oldest known stone arch bridge in the United States which still carries a modern highway is found in Pennsylvania. This bridge, the Frankford Avenue Bridge, mentioned previously, was constructed in 1697 as part of the King's Road and was designated a National Civil Engineering Landmark by the American Society of Civil Engineers. The King's Road, the earliest inner-city commerce route, was built at the behest of William Penn, founder, planner and developer of Pennsylvania's initial cities and roadways. The road led from Philadelphia to Wilmington and eventually north to New York. Stone arch bridges were built as part of the network of public roads and turnpikes which moved people and their products across the Commonwealth. The tradition for building stone highway bridges in Pennsylvania continued well into the twentieth century. The style of these later stone arch bridges often imitated that of the eighteenth and nineteenth century bridges.

Geographic concentrations of stone arch bridges exist. Sandstone, limestone, gneiss, and marble are all available in central and eastern Pennsylvania. The concentration of stone arch bridges responds to this distribution. Masonry bridges are located primarily in the southeastern and south-central portions of the state; a few are located in the western counties.

The components of a typical single span stone arch bridge are shown. The spandrel walls serve as the retaining walls for the fill material (usually stone, large rocks and soil) on either side. The arch barrel and roadway surround the fill material on the bottom and top, respectively.

The parapet is an extension of the spandrel wall and is the outermost edge of the roadway. On stone arch bridges, parapets are usually solid and unembellished, although some are designed with ornamental features.

Other decorative features which may be found on a stone arch bridge are a belt course, dressed voussoirs, keystone and date stone. The belt course is a horizontal band of masonry which usually extends across the spandrel wall and may be flushed with or projecting from the wall. The voussoirs are the wedge-shaped stones which create the arch ring. The central voussoir is called the keystone, and it is often embellished.

The date stone is usually found in the parapet on the cartway side and is inscribed with the date of construction and may contain other information such as the builder's name, the name of the bridge and any public officials involved.

Stone masonry can be differentiated by the type of material used, the method of finishing the stone surfaces, and the method of bridge construction. As previously discussed, the type of material used can be sandstone, limestone, gneiss, and marble, but could also include brick, granite and other building stone.

Three broad categories can be used to describe the method of finishing the stone surfaces. The first category is rubble masonry, consisting of rough stones which are unsquared and used as they come from the quarry. The second category, squared-stone masonry, consists of stones which are squared and dressed roughly. The third category, ashlar, consists of stones which are precisely squared and finely dressed. The facing of finely dressed stone can be worked to produce a variety of finishes, depending on the tools used. Commonly used hand tools for stone cutting were the pick, the peon hammer, the tooth ax, the bush hammer, the crandell and a wide variety of chisels and points. The surface treatment was often identified by the name of the tool used to produce the finish; e.g., crandelled, bush-hammered, etc.

Standard engineering specifications existed for ashlar (first class masonry), squared-stone masonry (second class masonry), and rubble construction (third class masonry). Rubble masonry could be constructed to approximate regular rows or courses (coursed rubble) or could be uncoursed (random rubble). Random rubble was the least expensive type of stone masonry construction but was considered strong and durable for small spans if well executed. Ashlar and squared stone could be laid randomly or in courses. Single span and multiple span stone arches were built of both rubble and ashlar construction in Pennsylvania, although most of the earliest stone arch is associated with highways were constructed of rubble masonry.

Two early examples of ashlar construction in Pennsylvania are the Lilly Bridge and the Bridge in Cassandra Borough over Ben's Creek. Both bridges were built in 1832 by the Allegheny Portage Railroad in Cambria County. They were built to carry Pennsylvania Canal boats over the mountains. Today they carry vehicular traffic on state highways.

Lilly Bridge in Lilly Borough, Cambria County

Bridge in Cassandra Borough over Ben's Creek, Cassandra Borough, Cambria County

Stone arches also vary in their geometric shape. The arch could conform to numerous curves, the most common being semi-circular, and segmental. Other shapes were elliptical and multi-centered curves. The arch barrel could be built "right", so that the spandrel wall and longitudinal axis of the bridge are perpendicular; the barrel alternatively could be built "skew", such that the spandrel wall would be built at an angle oblique to the axis of the bridge.

The shapes represented by Pennsylvania stone arches are varied. Bridges are most commonly built "right", to minimize the span length and therefore the bridge costs. However, there are some skew arch bridges in Pennsylvania. One skew bridge, the Bridge in Shaler Township over Pine Creek in Allegheny County, was constructed of high-quality ashlar and features curved crowned parapets.

By the late 1800's theoretical knowledge abounded in the approach to arch design, standardized nomenclature was established, and design specifications were published. In 1877, recommended specifications were published in the Transactions of the American Society of Civil Engineers. Still, the design of masonry arches was always interpreted by the experience of the engineer, designer or contractor. Authorities noted the need for continued research and acknowledged that there could be no exact scientific approach to masonry arch analysis because of its inherent indeterminate nature. Many variations were possible in the material used, the workmanship in dressing and bedding the stone, the bond and strength of the mortar, the construction method used, and the effort of foundation settlement.

Thus, the success of masonry arch bridges depended equally on correct design and careful craftsmanship. Common precautions demanded laying the stone on its bedding plane to ensure durability, but there was little reliable scientific knowledge on the predictable performance of the durability of stone. That the material itself was subject to deterioration was understood. An 1896 text on masonry construction noted that stone deterioration was accomplished by mechanical means (frost, wind, fire, pressure, and friction), chemical means (atmospheric acids), and organic means (mineral decomposition of stone). However, it was not possible to predict the durability of a particular stone because variable climates produced a range of effects. The principal factors understood to control the durability of stone as a construction material were its proper seasoning prior to use, and the proper laying of the stone.

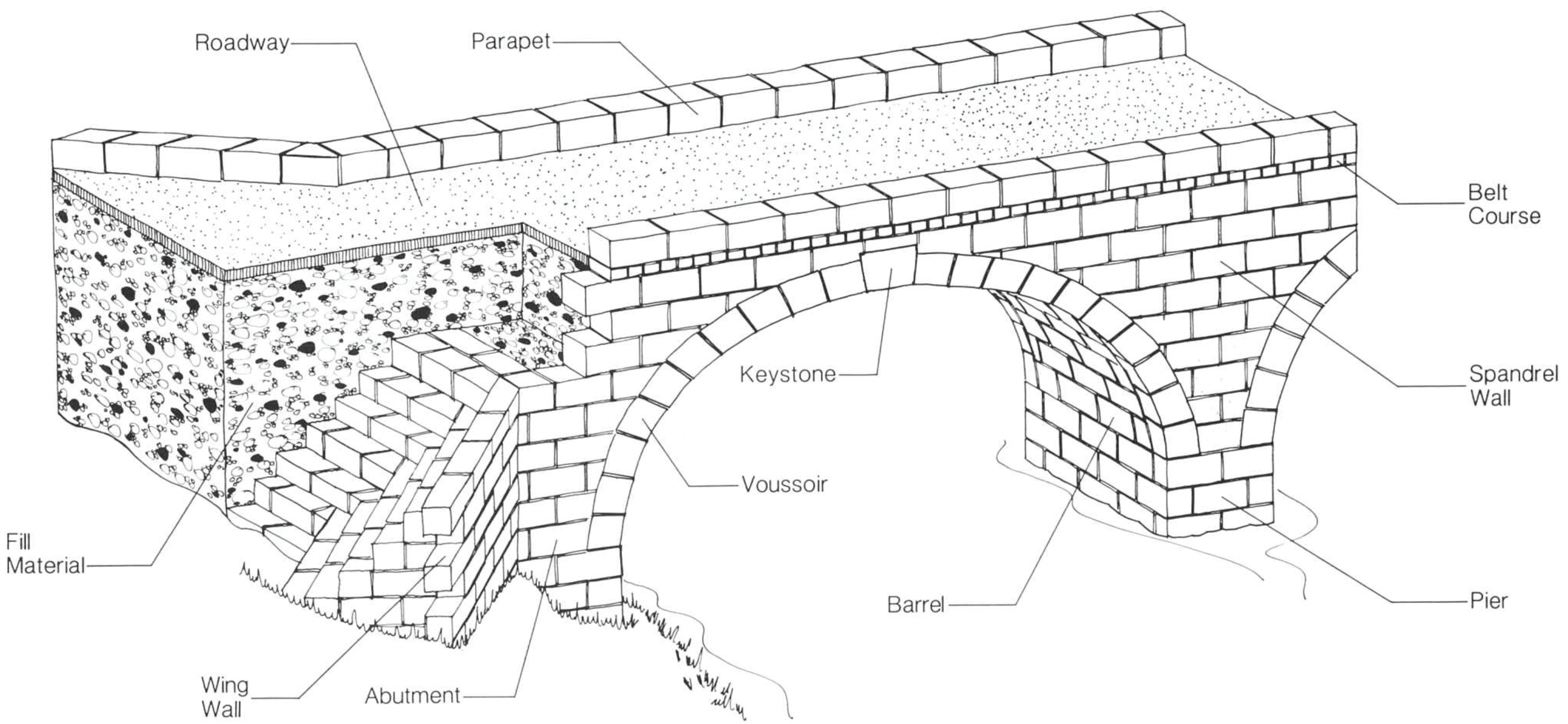
Three general rules were to be followed in stone masonry construction. First, the stones were to be laid so that the courses were perpendicular to the pressure exerted by the loads above. In addition, the mortar joints were to be staggered to avoid long continuous joints parallel to the pressure exerted by vehicles. Second, the largest stones were to be used in the foundation. Third, stratified stones were to be laid so that pressure was exerted perpendicular to the strata of the stone; this was termed "laying the stone on its natural bed".

Care was also taken to ensure good mortar bond and strength. Dry, porous stones needed to be moistened well to avoid drying the mortar and reducing it to powder. Joints were to be well packed and as small as possible. Ira O. Baker stressed, in his 1899 Treatise on Masonry Construction, that "the principal object of the mortar is to equalize the pressure" and "the rougher the stones, the better the mortar should be".

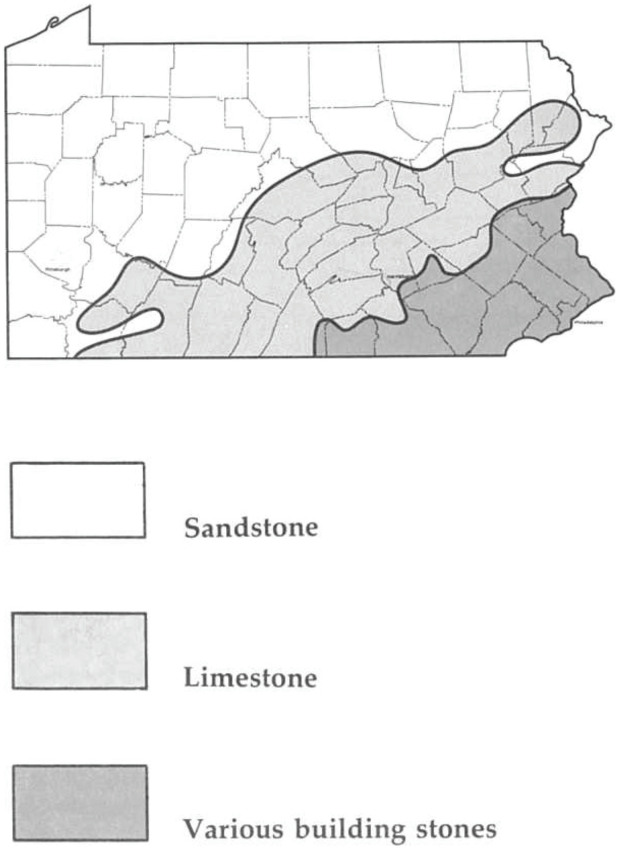
To ensure a solid structure, it was recommended that the stones be fitted into place dry so the stone cutter could correct the fit before the stone was laid in mortar. Recommended joint thickness varied with the quality of mortar: from one-eighth inch for the very best ashlar masonry to one-half inch for first class masonry used for railroad bridges.

The actual construction of the bridge began with excavation for the foundations. For single span bridges, foundation and abutments were built first, while multiple span bridges incorporated piers in the first phase of construction. Often, the foundations consisted of timber grillage on piling. Once the abutments and, in the case of multiple span bridges, the piers were constructed, the arch or arches could be built.

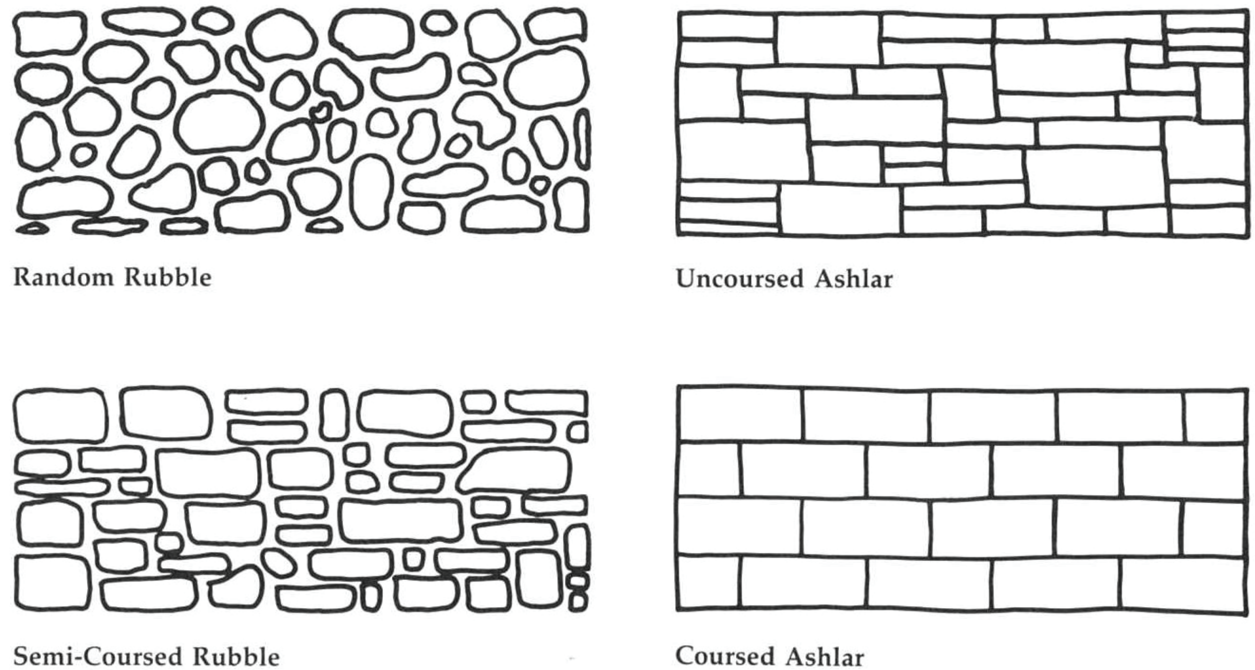
Constructing the arch from abutment to abutment required a temporary structure which would support the stones until complete. This temporary structure, called a center or centering, was usually built of wood but sometimes was made of rolled iron. Generally, the center was made of ribs spanned by narrow planks (laggings) which supported the arch stones. The end of the ribs could rest on the abutment, or they could be carried by timber trusses and struts. The exact



Typical Stone Arch Bridge



Distribution of Quarries in 1932



Stone Arch Masonry Styles

configuration of the center was determined by the span and shape of the arch. The framing and setup of the center was extremely important for the stability of the arch; a weak, shifting, or sagging center could change the shape of the arch and, if drastic, make the arch unsafe.

Once the center was in place, the arch was constructed, and the spandrel wall and filling were placed. The space from the arch itself to the roadway was ordinarily filled with earth and broken stones. Sometimes, to lighten the load, a series of longitudinal and transverse arches was built inside the filling space and the top few feet consisted of fill material. The interior of the arches was waterproof by application of a layer of cement mortar, coal tar or asphalt. A drainage system was sometimes constructed to discharge infiltrating water over the piers and abutments.

Finally, when the arch was completed, the temporary support was removed. The proper time and method for the removal, or striking, of the centers was crucial. After allowing the mortar appropriate time for hardening, the center could be safely removed, but often it was left in place for months for arch bridges. The construction of the center allowed for gradual uniform lowering.

Both brick and stone arches were constructed in this manner. Since brick arches had many more joints, they were likely to settle more than stone arches. A small brick arch bridge example is the Bryn Mawr Avenue Bridge over Meadowbrook Run in Delaware County. The bridge was built in 1905 as a gift to Radnor Township and features gothic-revival style parapets with ornate parapet caps.

Stone was preferred to brick as a building material of greater durability. However, brick voussoirs were sometimes used to delineate the arches of stone bridges.

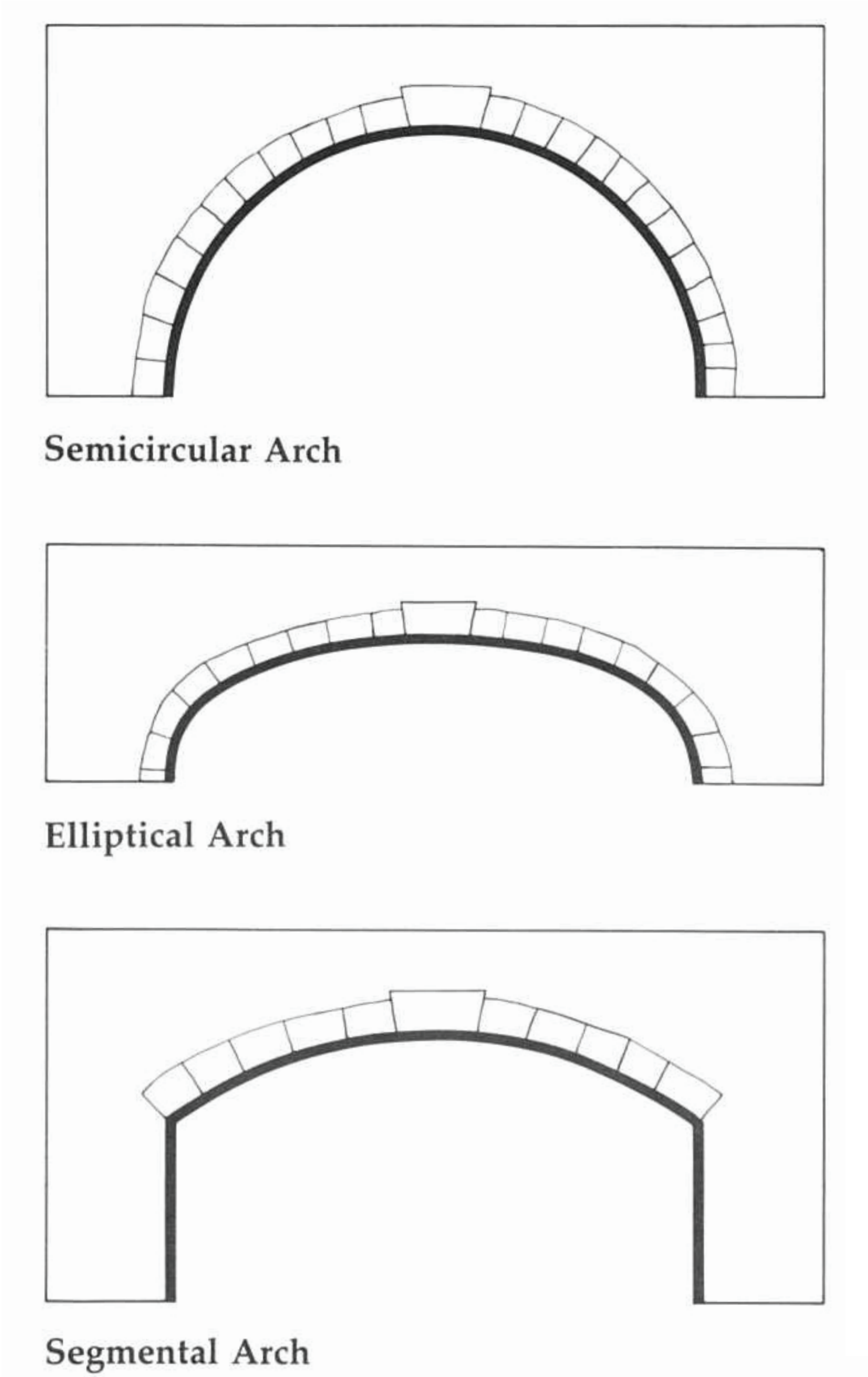
The following pages highlight some of the historic stone arch bridges found in the Commonwealth of Pennsylvania. For more information on other stone arch bridges, visit PennDOT's Cultural Resources website[1].


Bridge in Shaler Township, Allegheny County

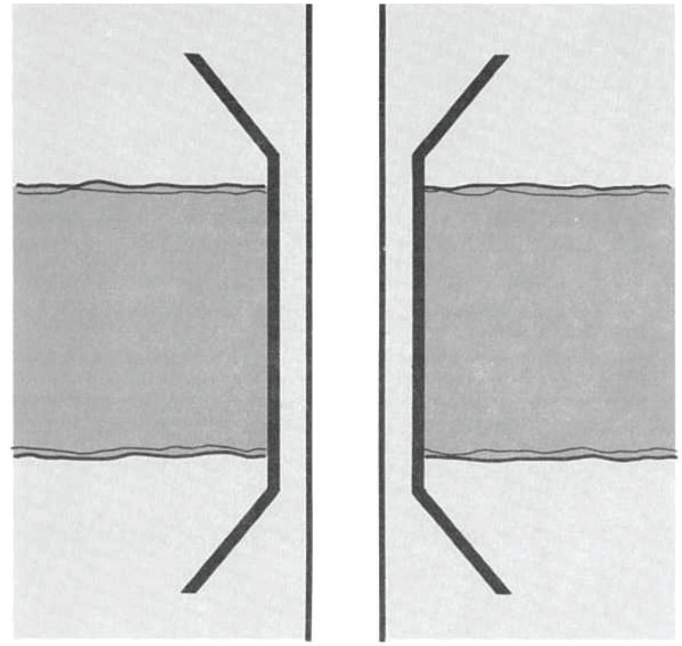

Elliptical Arch, Belmont Avenue Bridge in Philadelphia


Circular Arch, Bridge in Newport Borough, Perry County

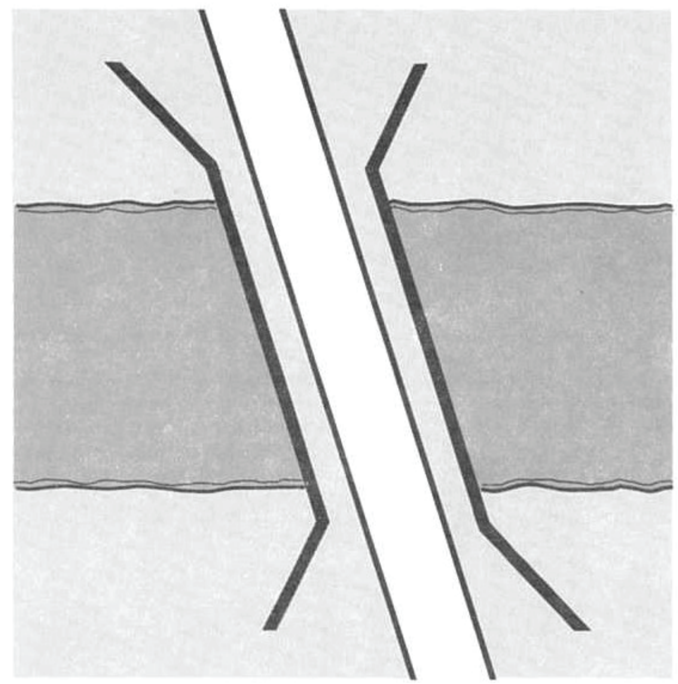

Segmental Arch, Roaring Run Stone Arch Bridge in Jenner Township, Somerset County



Geometric shapes

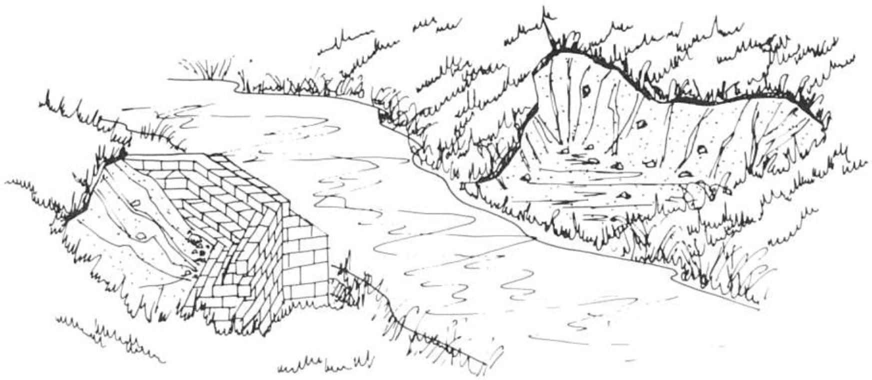


Right

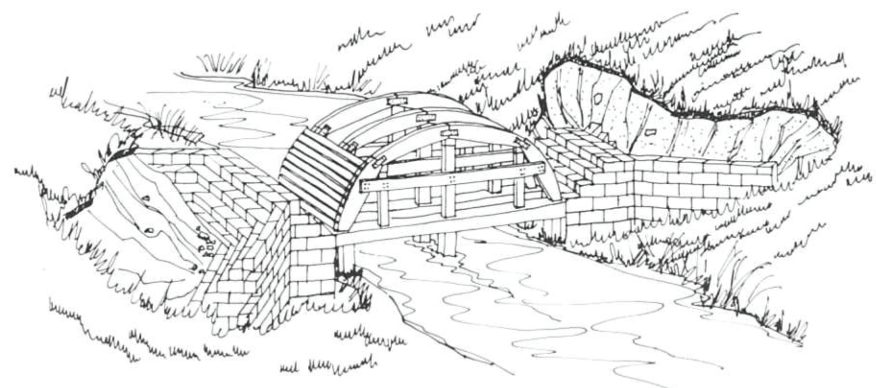


Skew

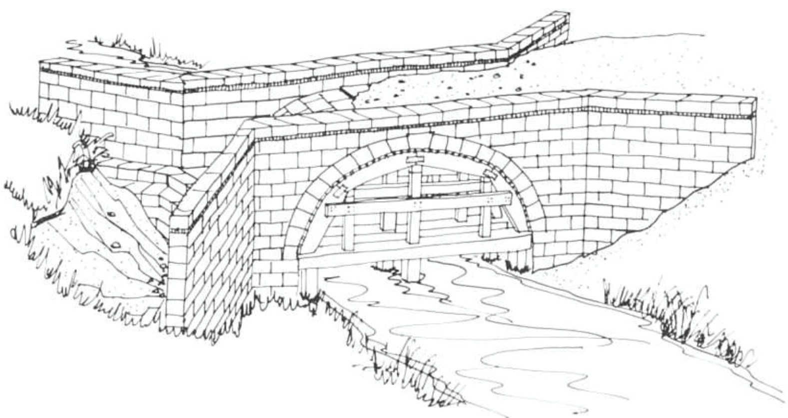
Orientation of bridges



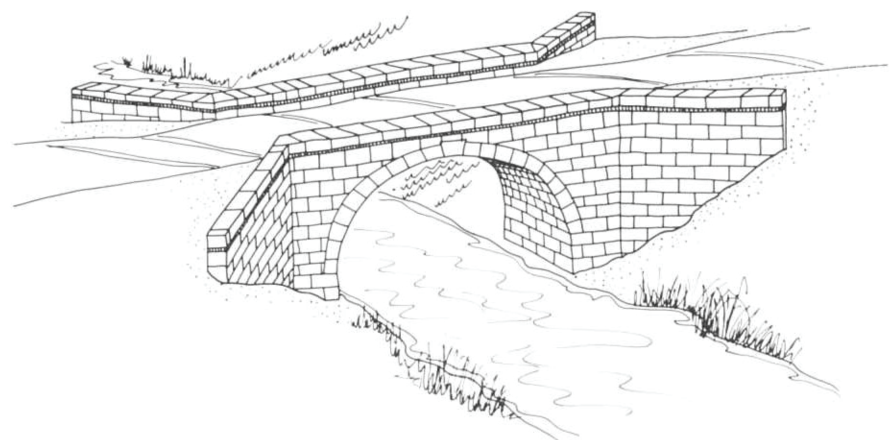
1. Excavation and Foundation Construction



2. Abutments Completed and Centering Constructed



3. Masonry Completed and Backfill Added



4. Centering Removed and Roadway Opened

Construction of Arch

PONDTOWN MILL BRIDGE

Location: Latimore Valley Road over Bermudian Creek, Latimore Township, Adams County

Year Built: Unknown

Type/Length: Multiple Span/91 Feet

This three-span camelback arch bridge was built of coursed rubble, with arches accented by the use of squared stones for the voussoirs. The center arch spans twenty-two feet, while each flanking arch spans eighteen feet. Although the date of construction is unknown, the Pondtown Mill Bridge is typical of multi-span camelback arch bridges built in Pennsylvania in the nineteenth century.

This bridge illustrates several alterations which typically occurred as stone arch bridges were repaired over the course of their service. The earliest alteration was probably the addition of seven iron tie rods. Later alterations included the addition of concrete caps to the small conical piers, replacement of stone coping with concrete coping, and repair of a damaged parapet wall with cement parging.

OLD STONE ARCH BRIDGE

Location: Pedestrian Path over Jack's Creek, Derry Township, Mifflin County

Year Built: 1813

Type/Length: Single Span/123 feet

The Old Stone Arch Bridge is the oldest single span stone arch bridge in Central Pennsylvania. Crossing Jack's Creek in Derry Township, Mifflin County, the bridge was built in 1813 by Philip Diehl as part of the Harrisburg to Lewistown section of the Harrisburg to Pittsburgh Turnpike.

The Old Stone Arch Bridge became famous thanks to a lithographic work created by Currier and Ives in 1860 which pictured the bridge. At some point, the alignment of the road changed, and the Old Stone Arch Bridge was bypassed by the new route. The bridge remains in a local public park and serves as a pedestrian crossing.

LINCOLN AVENUE BRIDGE

Location: Lincoln Avenue over Washington Boulevard (Route 8), Pittsburgh, Allegheny County

Year Built: 1906

Type/Length: Multiple Span/427 feet

Built in 1906 by the City of Pittsburgh Public Works Department, the Lincoln Avenue Bridge spans the ravine over Washington Boulevard in Pittsburgh. Made of coursed ashlar, the bridge features two semi-elliptical arches. At the northeast end of the bridge the Pennsylvania Railroad crosses overhead on the Brilliant Cutoff Viaduct, a six-span stone arch bridge. The design of the Lincoln Avenue Bridge was influenced by the larger railroad bridge, which was being built when Lincoln Avenue was in the planning stage.

HORSE VALLEY BRIDGE

Location: S.R. 4004 over Conodoguinet Creek, Letterkenny Township, Franklin County

Year Built: pre-1860

Type/Length: Multiple Span/55 feet

This three-arched limestone bridge is found in Franklin County. Although the construction date of the Horse Valley Bridge is unknown, its configuration is typical of many stone arch bridges built in Franklin County in the nineteenth century. The use of roughly coursed local limestone, the semi-pyramidal piers, and the roughly cut thin limestone coping suggest that the bridge was constructed prior to 1860.

Few of Franklin County's stone bridges remain but they are well documented in F.F. Unger's 1941 Old Bridges of Franklin County. The Horse Valley Bridge is cited in Unger's descriptions; its location is on the "old stage route from Upper Strasburg to Fannettsburg". As early as 1793 the legislature appropriated money to build bridges on this road to span the Conococheague and the Conodoguinet Creeks.

PERKIOMEN BRIDGE

Location: Ridge Pike over Perkiomen Creek, Lower Providence Township, Montgomery County

Year Built: 1799

Type/Length: Multiple Span/453 feet

This four-arched masonry brick bridge was built in 1799, widened in 1928, and rehabilitated in 2020. The Perkiomen Bridge features semi-circular arches with rounded column pier extensions and a sidewalk on one side. Designed by architect John Lewis and built by masons John Pugh, Samuel Beard, and John Berk and carpenter George Boyer, the bridge carries Ridge Pike over Perkiomen Creek in Lower Providence Township, Montgomery County. Two stone bridge plaques set into the inner parapet wall document the bridge's history and notable local figures involved.

Perkiomen Bridge is one of the oldest bridges in the United States.

PITHOLE STONE ARCH BRIDGE

Location: S.R. 1004 over Pithole Creek, President Township, Venango County

Year Built: 1897

Type/Length: Single Span/34 feet

This unusually shallow stone arch bridge was built in 1897 by R.A. Bigler. The Pithole Stone Arch Bridge, made of coursed ashlar, shows high quality craftsmanship in its construction. Stone arch bridges were generally built in semi-circular or segmental shapes. Stone arches of low rise-span ratio, like the Pithole Stone Arch Bridge, were not commonly built. The lateral force extended by a low-rise arch (horizontal thrust) is much higher than for semi-circular arches. This large thrust required massive abutments and introduced risks of excessive bridge settlement.

The Pithole Stone Arch Bridge arch ring, spandrel walls, and wingwalls were all constructed of large, cut stones which were similarly dressed. The road rests on the arch ring, accentuating the shallow appearance of the Pithole Stone Arch Bridge. There are no stone parapet walls topping this arch bridge, thus reducing the bridge's dead load. Instead of a parapet wall, the arch is capped by a slightly projecting course of stone, like a cornice. A guardrail has since been added to the bridge.

KISE MILL BRIDGE

Location: Kise Mill Road over Bennett Run, Newberry Township, York County

Year Built: 1915

Type/Length: Single Span/68 feet

A number of stone arch bridges were constructed in Pennsylvania for highway traffic in the early twentieth century. This small, single span arch bridge was built in 1915 in a style patterned after that of nineteenth century highway bridges. Built of random-coursed rubble, the Kise Mill Bridge is a single-span camelback arch, with a very narrow wall above the crown. The name, "camelback", is derived from the hump created mid-span by the incline of the roadway.

Two earlier bridges preceded the Kise Mill stone arch bridge at this site. A date stone set into the inner parapet wall identified this bridge's builders: Charles A. Williams, Engineer, and William Wagner and Brothers of Dallastown, Pennsylvania, Contractors.

The Kise Mill Bridge is part of the Kise Mill Bridge Historic District listed on the National Register of Historic Places.

COPE'S BRIDGE

Location: Strasburg Road over East Branch of Brandywine Creek, East Bradford Township, Chester County

Year Built: 1805-1808

Type/Length: Multiple Span/154 feet

This stone arch bridge over the East Branch of Brandywine Creek in East Bradford Township, Chester County is an example of an early segmental arch. Built between 1805 and 1808, Cope's Bridge features three arches with the center span being the widest. The bridge's foundation is random rubble with arches formed by cut voussoirs separated by buttresses. An 1807 date stone is located on the bridge's northern interior wall, facing the road; however, research suggests this is the second date stone for the bridge and construction started in 1805 with the bridge being finished in the fall of 1808.

STARRUCCA VIADUCT

Location: Norfolk Southern Railroad over S.R. 1009 and Starrucca Creek, Lanesboro Borough, Susquehanna County

Year Built: 1848

Type/Length: Multiple Span/1,040 feet

The Starrucca Viaduct is the oldest stone arch railroad bridge in Pennsylvania still in use today. Built of native stone in 1848, the viaduct was completed by John B. Kirkwood and J.W. Adams after three other contractors failed to complete the construction. Originally, the viaduct had a single track with a weight capacity under 100,000 pounds; however, by 1973 it featured two tracks and carried engines over 835,000 pounds. The Starrucca Viaduct served the Erie Railroad for 112 years from 1848 until 1960.

The Starrucca Viaduct consists of eighteen circular stone arches, though only seventeen are visible as one arch was buried during construction. The viaduct's piers, arch rings, and parapets walls are random ashlar bluestone. The deck is also composed of blue stone but has been covered with concrete. Instead of filled spandrels, the viaduct features vacant spaces to lighten the weight of the structure. The Starrucca Viaduct cost $320,000 to construct, making it one of the most expensive railway bridges ever constructed at the time.

ROCKVILLE STONE ARCH BRIDGE

Location: Norfolk Southern Railroad and Amtrack over Susquehanna River, Marysville, Perry County and Rockville, Dauphin County

Year Built: 1900-1902

Type/Length: Multiple Span/3,791 feet

Located north of Harrisburg, Pennsylvania, the Rockville Stone Arch Bridge was the third structure built at the same site to carry railroad traffic over the Susquehanna River. The first bridge at the site was a single-track wooden Howe truss bridge built in 1849 while the second was a two-track iron bridge built in 1877. With a total length of 3,280 feet and a width of 52 feet, the Rockville Stone Arch Bridge is believed to be the longest and widest stone arch railroad bridge in the world. Designed by William H. Brown and built by Drake & Stratton and H.S. Kerbaugh, Inc of Philadelphia, Pennsylvania for the Pennsylvania Railroad, the bridge features forty-eight segmental arches with spans of 70 feet.

In 1979, the American Society of Civil Engineers (ASCE) designated the Rockville Stone Arch Bridge as a National Historic Civil Engineering Landmark. Today, the bridge serves the Norfolk Southern Railroad and Amtrack.

Jack's Mountain Bridge in Adams County

COVERED

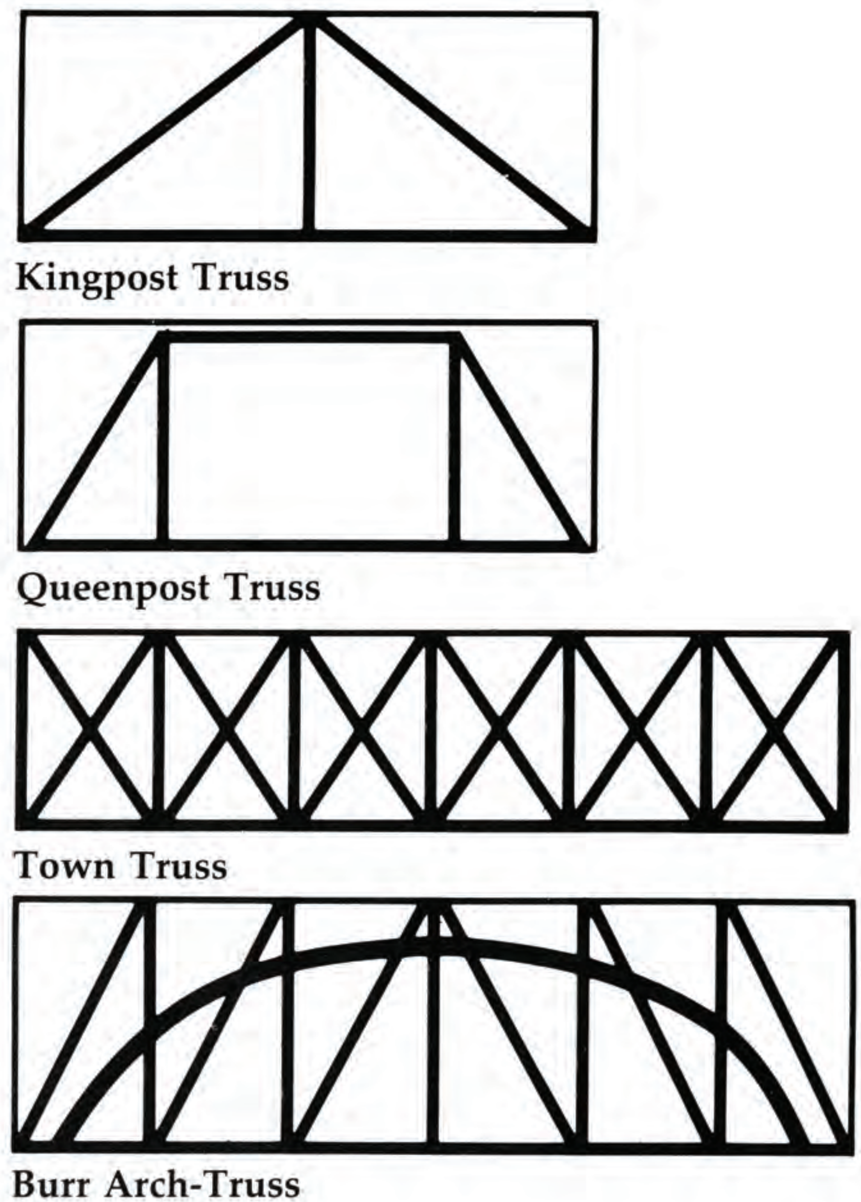
The wooden covered bridge is the most popularly recognized historic bridge type in the United States. Its status as an important part of the American engineering heritage is usually accepted without question, as is the need to preserve its type. Many books have been written about covered bridges, covered bridge societies have been organized, and a world-wide system of identification has been established. There are many covered bridges which remain throughout the United States.

The unique exterior appearance of this bridge type, with its roof and wood sheathing, obscures the structural form of the wooden covered bridge. Under the sheathing is a truss, sometimes of simple configuration and sometimes combined with an arch. The covered bridges found in Pennsylvania represent four main types of trusses. The simplest of the truss types is the Kingpost truss, which is basically a triangle with reinforcing timbers. The Kingpost truss is seldom used for spans over thirty-five feet in length.

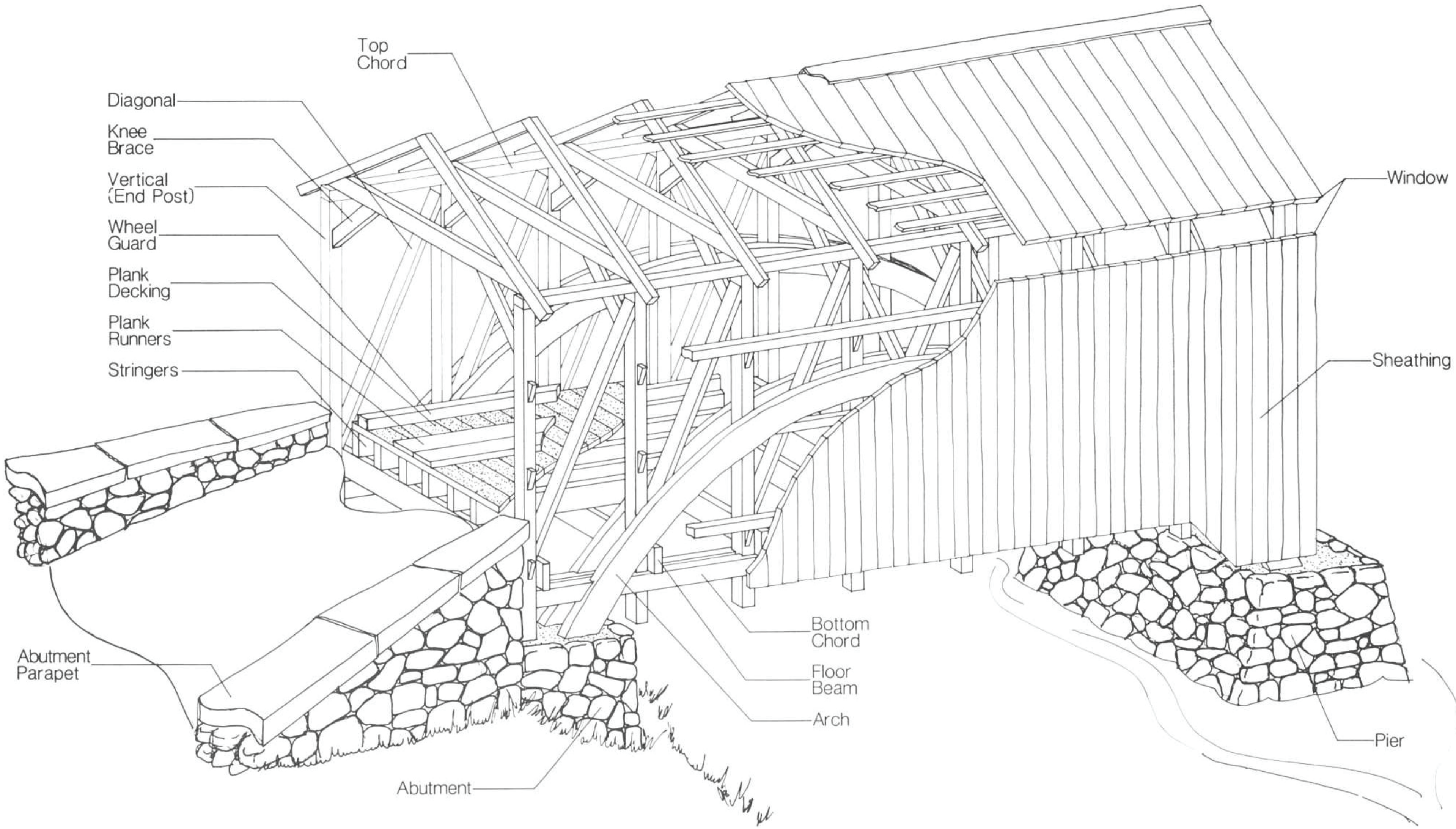
The other truss types represented are the Queenpost truss, the Town truss, and the Burr arch-truss. The Queenpost truss uses a truncated triangle with supporting posts at each end. The cross piece, which must be separate from the highest sidewall timbers, permits span lengths to be increased to seventy feet. The Town truss was designed by Ithiel Town and patented in 1820. It consists of a lattice of web members, crossing at an angle of forty-five to sixty degrees, connected by wooden pins to horizontal top and bottom chords. There are no vertical members dividing the Town truss.

By far the most common covered bridge type on this list is the Burr arch-truss. Patented by Theodore Burr in 1804, the Burr arch-truss combined great reinforced arches with multiple Kingpost trusses. The arch was pegged to each intersecting truss member throughout the truss, and the ends of the arch were anchored in the bridge piers or abutments, thus combining the action of both structural types. These arches stiffen the trusses and reduce deflections permitting wider streams and rivers to be spanned.

From the earliest known example of American wooden truss bridge construction at the end of the eighteenth century to its prolific erection in the nineteenth century, examples of long-span crossings were recorded. A variety of types developed,



Truss Types



Typical Covered Bridge

Interior of Pleasantville Bridge in Oley Township, Berks County

and thousands of wooden truss bridges were built in the United States for early highway and railroad travel. In the rapidly expanding nineteenth century transportation network, the availability and cost of timber, and the ease and speed of erection led to the widespread acceptance of long-span wooden trusses. They were covered to protect the all-wood deck and framing from the weather. This covering extended the life of a wooden bridge from approximately ten years to fifty years.

American fascination with the wooden covered bridge is not peculiar to the late twentieth century. The significance of America's wooden covered bridge was described in 1899 by Theodore Cooper, a railroad engineer, in a paper published in <u>Transactions of the American Society of Civil Engineers:</u>

> *"The crossing of the large river developed specially gifted men, like Timothy Palmer, Theodore Burr, Lewis Wernwag, and others less well known, who built timber bridges that are looked upon as wonderful structures, even to the present day. The records of the early bridges of America are very incomplete, but enough remains to show what admirable work these early bridge builders could do."*

Discussion of noteworthy early nineteenth century American timber bridges generally centers around the above-named three American bridge builders, Timothy Palmer, Theodore Burr, and Lewis Wernwag. Though of varied backgrounds, they were responsible for designing bridges with record span lengths throughout the eastern United States. All three men built major spans for Pennsylvania highways.

Timothy Palmer, of Newburyport, Massachusetts, began building bridges in New England in the late eighteenth century. In 1806, Palmer built his Permanent Bridge across the Schuylkill River in Philadelphia. The Permanent Bridge was a three-span arch-truss, with a center span of 195 feet flanked by two 150-foot spans. Each arch consisted of three ribs spanning from support to support. Abutments and piers were made of stone. The truss had a continuous upper chord which curved slightly. Palmer's Permanent Bridge carried Lancaster Turnpike traffic on Market Street over the Schuylkill River for many years, until it burned about sixty years after its construction.

Palmer's second noteworthy Pennsylvania bridge was across the Delaware River at Easton. The Delaware Bridge Company was authorized to build a timber bridge across the Delaware River at Easton by Pennsylvania legislative decree of March 1795. The piers and abutments were completed in 1798 but bridge construction was delayed until 1805 when Timothy Palmer was engaged to build the superstructure. The bridge at Easton consisted of three spans, measuring 177 feet, 199 feet, and 177 feet. It was completed in 1807 and carried traffic for almost ninety years.

Theodore Burr, born in Torringford, Connecticut, began his bridge building career in New York. One of his earliest undertakings in Pennsylvania involved the construction of three separate covered bridges crossing the Susquehanna River at McCall's Ferry, Harrisburg, and Northumberland. The Northumberland bridge, a twin bridge crossing between Northumberland and Sunbury, was built between 1812-1814. Burr's Harrisburg bridge, another twin bridge crossing and known as Old Camelback Bridge, was constructed from 1813-1817 and carried traffic until about 1900-1905. This twelve-span (210 foot each) bridge was divided

White Covered Bridge in Green Township, Greene County

Forksville Bridge in Forks Township, Sullivan County

Interior of Erwinna Bridge in Tinicum Township, Bucks County

Erwinna Bridge in Tinicum Township, Bucks County

by City Island; the spans on the east side remain in use and were removed from the site in 1902. The bridge at McCall's Ferry was the longest single span wooden arch bridge ever built and was constructed from 1814-1815. With a span of 360 feet, it crossed a deep but narrow channel of the Susquehanna River between Lancaster and York Counties. It was erected in about two weeks while there was solid ice covering the river. Two years later this bridge was destroyed by ice.

Other significant covered bridges in Pennsylvania built by Theodore Burr were the Morrisville Bridge over the Delaware River (c.1806), the Lehigh River Bridge in Bethlehem (c.1816) and the Susquehanna Bridge at Berwick. None of these bridges are presently standing. Many more bridges built by Theodore Burr were probably constructed, as he claimed in 1818 to have built forty-five bridges which ranged in span from 60 to 367 feet. Burr arch-trusses are most common in the Susquehanna River watershed, probably due to the influence of Theodore Burr himself.

Lewis Wernwag was born in Germany and settled in Philadelphia in 1786. His earliest bridge building venture in Pennsylvania was the erection of a small arched truss for the New York – Pennsylvania road. This 100-foot bridge was built in 1810, over Neshaminy Creek in eastern Pennsylvania.

Wernwag's famous Colossus Bridge was built in 1812 at Fairmount Park in Philadelphia, near the Fairmount Waterworks. Located several miles upstream from Palmer's Permanent Bridge, this single span arched truss spanned 340 feet across the Schuylkill River and carried traffic until it was destroyed by fire in 1838.

After building the Colossus Bridge, Wernwag designed an important bridge across the Delaware River near New Hope, Bucks County. Although this bridge span was not remarkable in its length (175 feet), Wernwag introduced for the first time ever wrought iron rods for the diagonals of this 1814 truss. It is believed that this bridge carried traffic until it was destroyed by a flood in 1841.

Although Palmer, Burr, and Wernwag established long-spanning bridge records, and Wernwag's experimental use of iron rods seemed to have introduced the use of metal for truss bridge building, the arch-truss had several disadvantages. The complicated joints and the horizontal thrust inherent in the arch made superstructure and substructure construction difficult. A simple solution was found in the simple truss, without an arch.

Among the earliest pure trusses constructed of wood was Ithiel Town's 1820 patented lattice truss. Town's truss was made of diagonals, with no posts, and was constructed easily of standard size timber and wooden treenails. It is an infrequently found form. A Town truss covered bridge located in Pennsylvania is the Erwinna Bridge crossing Lodi Creek in Tinicum Township, Bucks County.

Other variations in the triangularly configured truss structure followed. Despite Wernwag's early use of iron, it remained for the more simplified trusses of Howe (patented in 1840) and Pratt (patented in 1844) to establish the transition from wood to metal in truss bridge construction.

Many of the covered bridges previously mentioned represent the largest and most impressive projects of covered bridge builders in the state. Because these bridges were located at important river crossings, all have been replaced with newer bridges to ensure continuous traffic movement. Therefore, the covered bridges left in the state today are characteristically shorter spans found on lesser streams.

An example of the simplest type, the Queenpost truss, is the White Covered Bridge, located over Whitely Creek in Greene Township, Greene County. Most of Pennsylvania's covered bridges are Burr arch-trusses. One of the many Burr arch-trusses is the Forksville Bridge, crossing Loyalsock Creek, in Forks Township, Sullivan County. The following pages highlight several covered bridges found in the Commonwealth of Pennsylvania. For more information on other covered bridges, visit PennDOT's Cultural Resources website[1].

SHEEDER HALL COVERED BRIDGE

Location: Hollow Road over French Creek, West Vincent Township, Chester County

Year Built: 1850

Type/Length: Burr Arch-Truss/102 feet

This timber Burr-arch truss is the oldest covered bridge in Chester County. Built by Robert Russell and Jacob Fox in 1850, the entire two-span bridge cost $1,564. The bridge is fifteen feet wide with horizontal clapboard siding and an unusual, stepped portal. Crossing French Creek in West Vincent Township, the Sheeder Hall Covered Bridge was rehabilitated in 1996. Steel I-beams were added underneath at some point prior to this project. The bridge's abutments and wings feature random rubble stone masonry with concrete capping.

LOGAN MILL BRIDGE

Location: S.R. 2007 over Big Fishing Creek, Logan Township, Clinton County

Year Built: 1874

Type/Length: Queenpost/46 Feet

This is the only remaining covered bridge in Clinton County. The vertical timber siding and corrugated metal roof protect the unusually shallow Queenpost truss of the Logan Mill Bridge. The bridge crosses Big Fishing Creek in Logan Township, Clinton County. The bridge's abutments and wing walls are made of fieldstone rubble. A ten-inch square timber pier helps support the bridge.

SCHLICHER'S COVERED BRIDGE

Location: S.R. 4007 over Jordan Creek, North Whitehall Township, Lehigh County

Year Built: 1882

Type/Length: Burr Arch-Truss/100 feet

This slate-roofed, covered bridge is located in a rural nature preserve. Schlicher's Covered Bridge features vertical siding and a row of narrow windows under the eaves. These elements give the bridge an overall low, broad appearance. The bridge is supported by a single-span Burr arch truss. The deck, or roadway, of the bridge is made of timber planking.

KAUFMAN'S DISTILLERY COVERED BRIDGE

Location: Sun Hill Road over Chiques Creek, Rapho and Penn Township, Lancaster County

Year Built: 1874

Type/Length: Burr Arch-Truss/96 feet

While the wood pins originally used on Kauffman's Distillery Covered Bridge are still in place, the structure is now reinforced further with steel bolts. Rough vertical planks siding helps protect the bridge's Burr arch-truss. The bridge's abutments and wingwalls feature course ashlar and the deck, or roadway, is made of timber. The overall appearance of this bridge is similar to other covered bridges located in Lancaster County.

HEIRLINE COVERED BRIDGE

Location: S.R. 4007 over Raystown Branch of the Juniata River, Harrison Township, Bedford County

Year Built: 1902

Type/Length: Burr Arch-Truss/130 feet

Visible from the Pennsylvania Turnpike, Heirline Covered Bridge carries State Route 4007 over the Raystown Branch of the Juniata River in Harrison Township, Bedford County. The Burr arch truss was built in 1902 and features high exterior sidewalls with a row of narrow windows under the eaves. The high reaching Burr arches can be seen through these windows. The portals of the Heirline Covered Bridge have triangular edges. The bridge rests on stone abutments.

KIDD'S MILLS COVERED BRIDGE

Location: Bridge 1801 over Shenango River, Pymatuning Township, Mercer County

Year Built: 1868

Type/Length: Smith Cross Truss/120 feet

Built in 1868, Kidd's Mills Covered Bridge is the only remaining example of a Smith Cross Truss in the eastern United States. This truss type was patented in 1867 by Robert Smith of Tippecanoe City, Ohio. Kidd's Mill Covered Bridge crosses the Shenango River in Pymatuning Township, Mercer County is a contributing resource to the Kidd's Mills Historical Area. The bridge features high stone parapets, a distinguishing element of the structure.

PLEASANTVILLE COVERED BRIDGE

Location: Covered Bridge Road over Manatawny Creek, Oley Township, Berks County

Year Built: 1852, 1856

Type/Length: Burr Arch-Truss/126 feet

The Pleasantville Covered Bridge, carrying Covered Bridge Road over Manatawny Creek in Oley Township, Berks County, has an unusual history. The bridge was constructed in two phases by two different builders. In 1852, carpenter and bridge builder David Renno constructed a multiple kingpost truss with two sets of Burr arches and low sidewalls. Then in 1856, Jonathan Bitner was contracted by the country commissioners to fully enclose the bridge. Bitner extended the sidewalls, built the gable roof, and added a third set of arches.

JACK’S MOUNTAIN COVERED BRIDGE

Location: Jack’s Mountain Road over Tom’s Creek, Hamiltonban Township, Adams County

Year Built: 1890

Type/Length: Burr Arch-Truss/75 feet

Built by Joseph Smith in 1890, Jack’s Mountain Covered Bridge crosses Tom’s Creek in Hamiltonban Township, Adams County. The Burr arch truss, which almost reach the eaves, is covered with horizontal narrow siding and a tin covered gable roof. Jack’s Mountain Covered Bridge rests on stone abutments and features a plank deck.

Riegelsville Bridge, Bucks County

SUSPENSION

The first iron bridges built in the United States were wrought iron suspension bridges. Many of these early suspension bridges were built in Pennsylvania where three pioneer American suspension bridge designers, James Finley, Charles Ellet, and John Roebling, began their bridge building careers. James Finley built the first suspension bridge in the United States in 1801 across Jacobs Creek in Fayette County. Charles Ellet built the first vehicular wire suspension bridge across the Schuylkill River in Philadelphia in 1842. And John Roebling developed his expertise with his early Pennsylvania suspension aqueducts and bridges. Only one of these early suspension bridges, Roebling's 1848 aqueduct in Lackawaxen, remains. However, historical records document the numerous early and experimental suspension bridges of Pennsylvania.

The suspension bridge has long been acknowledged as an aesthetically striking form with potential for tremendously long-spans, whether as a primitive rope structure or as a modern wire cable version. Nineteenth century bridge engineer Gustav Lindenthal discussed suspension bridge history in an 1898 "Engineering Magazine" article:

> *"Suspension bridges, as every one knows, are as old as mankind, and are found in all parts of the world, among savages as well as among the oldest civilizations. It was natural to bridge a stream or abyss with ropes of twisted vines, sticks laid across them forming the footpath…It required only the knowledge of a stronger tension material, like wrought iron, to suggest that construction for longer spans among more advanced nations. And, indeed, all the first historic iron suspension bridges, as early as the sixteenth century in China, were built of this primitive model, the path or road resting directly on the iron chains. So also were the first wrought iron chain bridges in England, about the middle of the eighteenth century."*

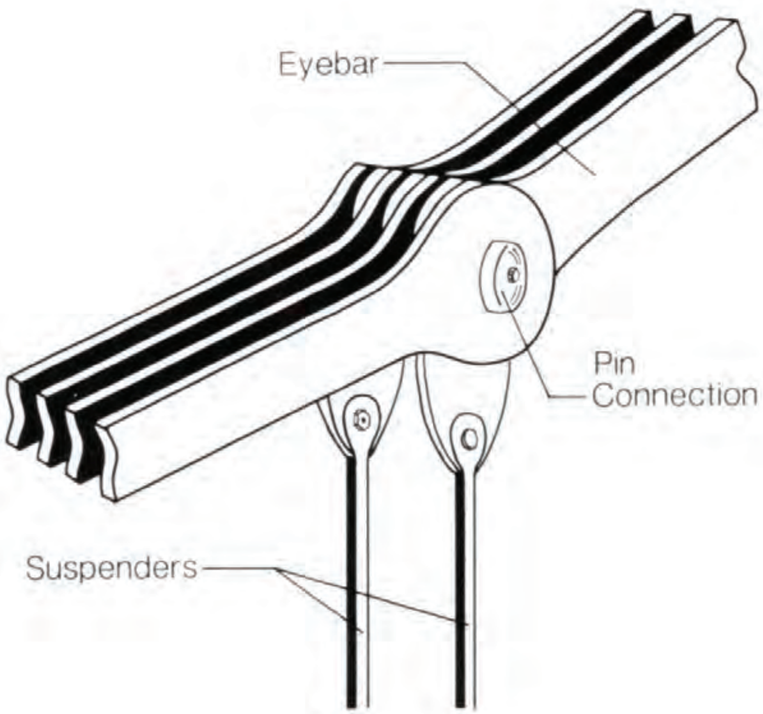
Beyond the primitive rope bridges and the iron types they inspired, the earliest modern suspension bridges consisted of cables anchored at each end with vertical tension members, called suspenders, attached to the roadway deck for support. The introduction of suspenders of varying length, generally attributed to Pennsylvanian James Finley, made possible a horizontal roadway, which had a tremendous advantage over the previous flexible curved deck. Though this improvement was a major one, it was only the beginning of the refinements made in suspension bridge design.

A suspension bridge with the roadway deck directly suspended from the main cables by hangers presented a serious structural problem. Any load applied to the deck caused a deflection in the cable at the point of application, which resulted in a rise and fall wave motion as the load moved across the bridge deck. It was crucial to design a means to distribute the loads and make the structure more rigid. An early improvement to suspension bridges was the addition of long floor joists which extended across several beams, and which had braced handrails. Later designs included a metal stiffening truss on the superstructure, so that the bridge's dead load was sustained by the cables and the stiffening trusses distributed portions of the live load over several hangers. Each hanger then could transmit an equal portion of the load to the cable.

As the suspension bridge form evolved, several types of cable systems were developed. Chain links, wire ropes and twisted strand cables were all used, and each type had its own proponents. Modern long-span suspension bridges contain a system of flexible cables, carried by towers, and anchored at the abutments. To the main cables, suspenders are attached which support the bridge deck and auxiliary stiffening structures. The stiffening structures distribute the live loads, reduce deflections and add stability to the superstructure.

Most suspension bridges consist of two sets of towers over which the main cables are draped. This configuration divides the cables into a main span and two side, or anchor, spans. Site conditions determined whether the cables extend beyond the side span. Sometimes the cables drop directly from the towers to their anchorage. In that case, the side spans are independently carried by girders or trusses.

The suspenders between the main cables and the stiffening structure are usually equally spaced and vertical. Suspenders may be eyebars, rods, or steal ropes. They are usually connected to the main cables Though more refined structural systems have enabled modern suspension bridges to exceed the spans thought possible by pioneer proponents, the basic components of the suspension bridge have not changed: flexible cables, suspenders of varying length which support a level deck, and stiffening truss members.



Eyebar Pin Connection

The man credited with the design of the first modern suspension bridge, one which had a level roadway suitable for vehicular traffic, is James Finley of Fayette County, Pennsylvania. Finley's first suspension bridge crossed Jacob's Creek on the road from Uniontown to Greensburg and was built in 1801. It had a wrought iron chain suspension system, described by Finley as consisting of chains made of one-inch square bars, forming into links ranging from five to ten feet long. The vertical suspenders of varying length fit on the chain link ends above, and their stirrup-shaped lower ends held the bridge floor beams. The bridge was stiffened with longitudinal wooden trusses. Finley's first bridge was only thirteen feet wide and spanned seventy feet. The towers, which were fourteen feet higher than the bridge deck, were supported on stone masonry piers and abutments.

James Finley is said to have built forty of his chain cable bridges. Finley's most recognized bridge was built in 1807 over the Potomac River at Georgetown. It was written about by many of his contemporaries and the site of this bridge is still known as "Chain Bridge". On June 17, 1808, Finley received a patent for his suspension bridge design. In 1809, he constructed a 308-foot span across the Schuylkill River in Philadelphia. It was a narrow bridge, much longer than his first, but the components were like those of Finley's other bridges.

Critics of Finley's chain cable suspension bridge disliked its design for fear that one broken chain would collapse the bridge. The introduction of wire rope cables led to the decreased use of chain suspension type bridges, although some continued to be built until the end of the nineteenth century, such as Gustav Lindenthal's Seventh Street Bridge in Pittsburgh, built in 1884.

An odd eyebar chain hybrid, built also at the end of the nineteenth century, was the "suspended truss" bridge. One of these suspended trusses located in Pennsylvania is the Bridge in English Center Borough over the Little Pine Creek, Lycoming County.

The chain suspension was introduced again briefly in the twentieth century, but the predominant type of cable system used from the mid-nineteenth century to the present has been the wire cable.

The earliest known wire rope bridge was a narrow footbridge spanning 400 feet across the Schuylkill River. It was constructed in 1816 as a private toll bridge by Josiah White and Erskine Hazard, owners of the Philadelphia wire manufacturing plant. This early example of a wire rope bridge was short-lived, as the bridge collapsed during its first winter.

The failure of the Schuylkill River wire rope span discouraged the use of wire in bridges in the United States for several decades. Experimentation continued in France, however, where Pennsylvania engineer Charles Ellet studied in 1830. He brought back to the United States his enthusiasm for wire suspension bridges.

Ellet's first major bridge project was built in 1841-42 to replace Lewis Wernwag's Colossus Bridge across the Schuylkill River in Philadelphia. This wire suspension bridge spanned 358 feet between its towers. There were two sets of five cables to which wire rope suspenders were attached. Ellet's Philadelphia bridge carried traffic until it was replaced in 1874.

Ellet designed another bridge, considered to be his greatest structure, shortly after building the Schuylkill River bridge. This bridge, the Ohio River Bridge in Wheeling, West Virginia, was built between 1846 and 1849 as part of the National Road and continues to carry vehicular traffic today. Its 1,010-foot main span was the longest bridge in the world for many years.

The third, and most widely recognized pioneer in American suspension bridge building, was John A. Roebling. Roebling, like Finley and Ellet, began his career in suspension bridges with a project in Pennsylvania. Roebling's first commission for a bridge came in 1844 with an aqueduct design which carried the Pennsylvania Canal over the Allegheny River. Two seven-inch diameter bundles of 1,900 wires each carried Roebling's seven span wooden aqueduct. It successfully served its design purpose from 1845 until the canal was abandoned in 1861.

Bridge in English Center Borough, Lycoming County

The success of this structure brought Roebling additional aqueduct commissions from the Delaware and Hudson Canal in northeastern Pennsylvania. Between 1845 and 1850, Roebling built aqueducts over the Rondout, Neversink, Delaware and Lackawaxen Rivers for the D&H Canal. Roebling's Delaware Aqueduct, built in 1848 over the Delaware River near Lackawaxen in Pike County, is still standing and carries vehicular traffic across the Delaware River.

While he was working on these aqueducts, Roebling was commissioned for a highway bridge in Pittsburgh. Lewis Wernwag's covered wood Smithfield Street Bridge across the Monongahela River had burned in 1845 and Roebling designed a suspension bridge of six river spans and two anchor spans to replace it. Roebling's bridge of 1,500 feet was completed in 1846 and carried traffic until it was replaced in 1883 by the present-day structure, a Lenticular truss bridge highlighted later.


Roebling's Delaware Aqueduct in Pike County


The Roberto Clemente Bridge, Andy Warhol Bridge and Rachel Carson Bridge over the Allegheny River in Pittsburgh

Roebling built a second suspension bridge in Pittsburgh between 1857 and 1860. This four span bridge carried Sixth Street over the Allegheny River and replaced a Burr arch-truss. Roebling's Sixth Street Bridge, a wire suspension bridge similar to all his other bridges, was replaced in 1892 with a metal truss bridge which was in turn replaced, in 1926, by the present structure.

It was on the site of Roebling's Sixth Street Bridge that the chain cable suspension bridge was reintroduced seventy years later. Although of differing design from the early nineteenth century types, the fourth Sixth Street Bridge, built in 1926, was an eyebar chain suspension bridge. This bridge was one of three self-anchored, eyebar chain suspension bridges designed by Pittsburgh's Department of Streets chief engineer, V.R. Covell, for Allegheny River crossings. These three bridges, Sixth (Roberto Clemente Bridge), Seventh (Andy Warhol Bridge) and Ninth Street (Rachel Carson Bridge), were the first eyebar chain bridges built since the nineteenth century. All are owned by Allegheny County and continue to carry traffic across the Allegheny River.

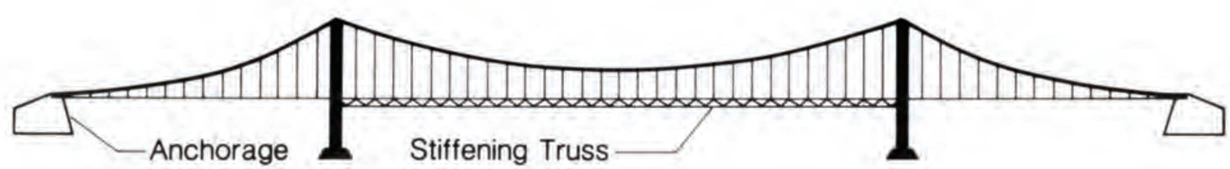
These three bridges were also the first self-anchored suspension bridges built in the United States. A self-anchored suspension bridge does not include the large, external anchorages which anchor the end of the suspended cable in the abutments. Instead, the end of the cables (of a self-anchored suspension bridge) are attached to the stiffening truss and longitudinal girders at the outer ends of the side spans. In addition to its other function, the stiffening truss acts as a compression member to resist the tension of the suspended cables. Therefore, deep external anchorages are not required.

The two primary advantages of suspension bridges as compared to other bridge types are the long-span potential with minimal river obstruction and the need for no temporary framework during construction. Self-anchored suspension bridges had an added advantage of not requiring anchorage construction. Because of increased wear to the eyebars, however, self-anchored suspension bridges are not a commonly used bridge type.

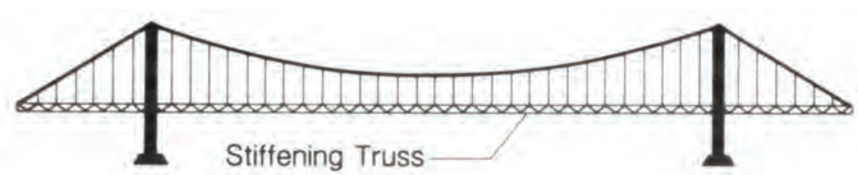
When a suspension bridge is erected, after the substructure is completed, the towers and anchorages are constructed. Anchorage steel is set and when the towers and anchorages are finished, the suspension cables are placed. The earliest suspension bridge cables had to be lifted in place, but Roebling established a method of building the cable in place, called "spinning" the cables. Small footbridges were constructed, and the wire cables were strung. The wire is strung by a traveling sheave which carries a loop of wire from one anchorage, across the two towers to the other anchorage. The wires are grouped into strands, which are each laid into position in the cradle on top of each tower. The end of each strand is secured at the anchorage. When all of the strands are complete, the cables which they form are clamped at intervals where the suspenders will be attached. The lower ends of the suspenders are attached to floor beams, which support the deck and stiffening structure.

Chain suspension spans, of course, required a slightly different method of construction. The earliest chain cables had to be assembled completely and lifted to the tops of the towers. Later, as the chains became too heavy to lift, temporary wooden structures were built, or most recently, temporary steel rope were strung.

Both these types, wire rope cables and chain suspension spans, were erected in Pennsylvania. From Finley's 1801 bridge to the more modern Benjamin Franklin and Walt Whitman Bridges, which cross the Delaware River in Philadelphia, noteworthy suspension spans have been built in Pennsylvania. Some examples of these highway bridges are illustrated in the highlighted bridges which follow. The following pages highlight several suspension bridges located in Pennsylvania. For more information on other suspension bridges, visit PennDOT's Cultural Resources website[1].

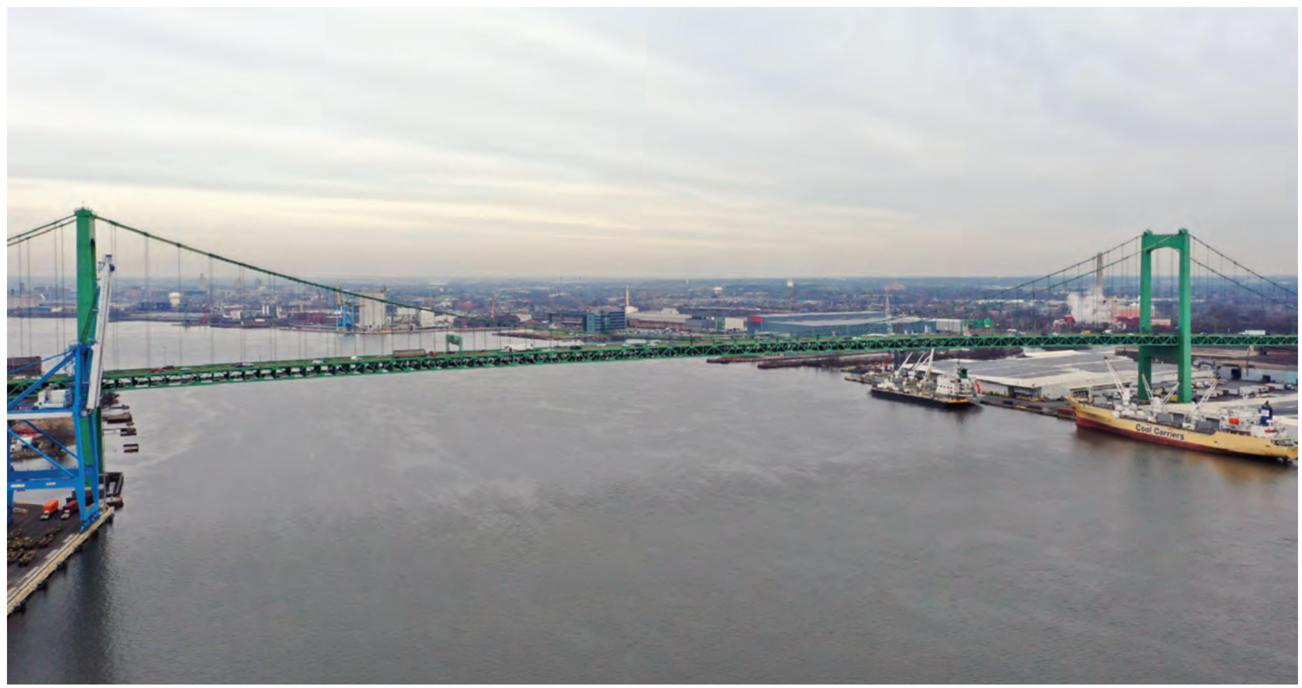


Externally Anchored Bridge

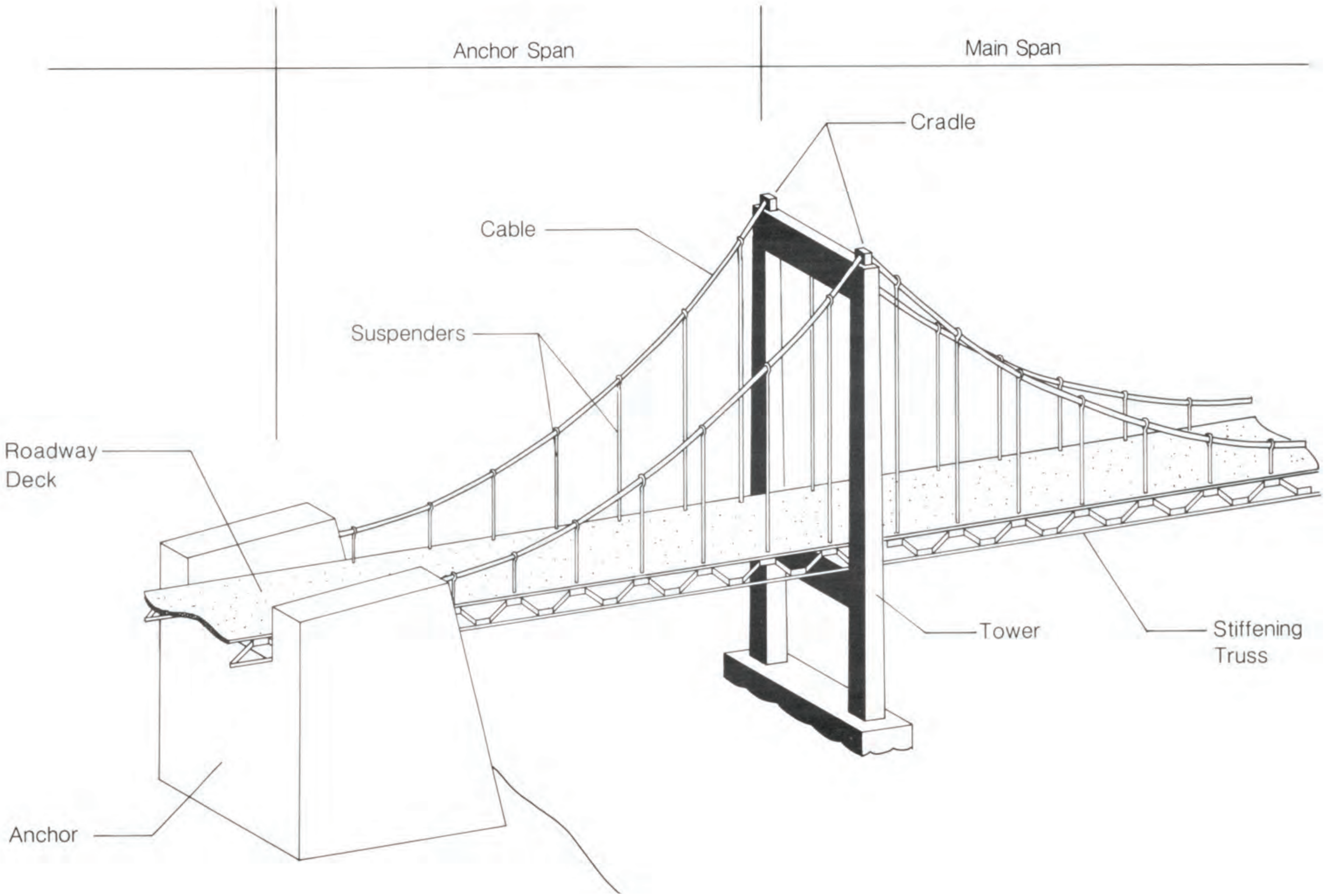


Self-Anchored Bridge

Benjamin Franklin Bridge over the Delaware River in Philadelphia



Walt Whitman Bridge over the Delaware River in Philadelphia



Typical Suspension Bridge

Rachel Carson Bridge over the Allegheny River in Pittsburgh

Philip Murray (South Tenth Street) Bridge in Pittsburgh

BRIDGE IN ENGLISH CENTER BOROUGH

Location: S.R. 4001 over Little Pine Creek, English Center Borough, Lycoming County

Year Built: 1891

Type/Length: Single Span/300 feet

This 300-foot-long steel bridge is an early extant example of a small hybrid eyebar chain suspension bridge. It was built by Dean and Westbrook, New York contractors, in 1891 after an 1890 flood destroyed all the bridges in the area.

The suspension cable is a chain of multiple eyebars which are pin connected. These cables are carried by simple steel towers constructed of riveted plates and lattice bars. The vertical members which connect the cable to the horizontal, deck-carrying girder are made of angles and lacing bars. Additional diagonal members cross from joint to joint, much like a simple truss, making the configuration of this suspension bridge unique among Pennsylvania suspension bridges.

The builders of this bridge were contractors for two other metal truss bridges in Pennsylvania. These were the Walnut Street Bridge, located in Dauphin County, and the Washingtonville Bridge, located in Montour County. Only the Walnut Street Bridge remains today.

KELLAMS BRIDGE

Location: S.R. 1018 over Delaware River, Manchester Township, Wayne County

Year Built: 1890

Type/Length: Single Span/384 feet

Spanning 384 feet, the Kellams Bridge is an early example of a small wire-rope cable suspension bridge. Located in a remote part of the state, this one lane bridge spans the Delaware River from Stalker, Pennsylvania to Kellams, New York.

The Kellams Bridge was built in 1890. Wire rope comprises the cables. The name "Roebling" is found on the end anchor bolts, attributing the manufacture of the wire rope to John A. Roebling's Sons Company, wire rope manufacturers of Trenton, New Jersey. John A Roebling, of Brooklyn Bridge fame, not only designed and built suspension bridges, but also manufactured wire rope cables. He began making iron wire cables in Saxonburg, Pennsylvania in 1841. Roebling provided wire rope for the Allegheny Portage Railroad, and several suspended aqueducts and bridges which he had designed in Pennsylvania. In the late 1840's, Roebling moved his family and established his wire manufacturing plant in Trenton.

RIEGELSVILLE BRIDGE

Location: S.R. 1016 over the Delaware River, Riegelsville Borough, Bucks County

Year Built: 1904

Type/Length: Multiple Span/582 feet

The Riegelsville Bridge spans 582 feet over the Delaware River between the towns of Riegelsville, New Jersey and Riegelsville, Pennsylvania. The bridge is a three span, cable suspension structure built in 1904 by John A. Roebling's Sons Company for the Riegelsville Delaware Bridge Company. The Riegelsville Bridge replaced a wooden truss bridge lost to the Great Flood of 1903. In 1923, the Joint Commission for the Acquisition of Various Toll Bridges of the Delaware River purchased the bridge, and it is now owned and maintained by the Delaware River Joint Toll Bridge Commission. The bridge was rehabilitated in 2010.

PHILIP MURRAY (SOUTH TENTH STREET) BRIDGE

Location: Tenth Street over Monongahela River in Pittsburgh, Allegheny County

Year Built: 1932

Type/Length: Multiple Span/1,434 feet

Completed in 1932, the Philip Murray (South Tenth Street) Bridge is similar to the Sixth, Seventh and Ninth Street bridge in its design with its support beams raised above the deck level along with cantilevered sidewalks; however, unlike the other bridges, the Philip Murray Bridge does not use eyebar straps as suspension members. Instead, the bridge's deck is supported by suspender cables attached to the main suspension members, which are comprised of twisted cables. The Philip Murray Bridge was designed by the Allegheny Department of Works with Sidney A. Shubin as the principal designer. The bridge was then built by the American Bridge Company, who built the superstructure, and the Vann Construction Company for the substructure.

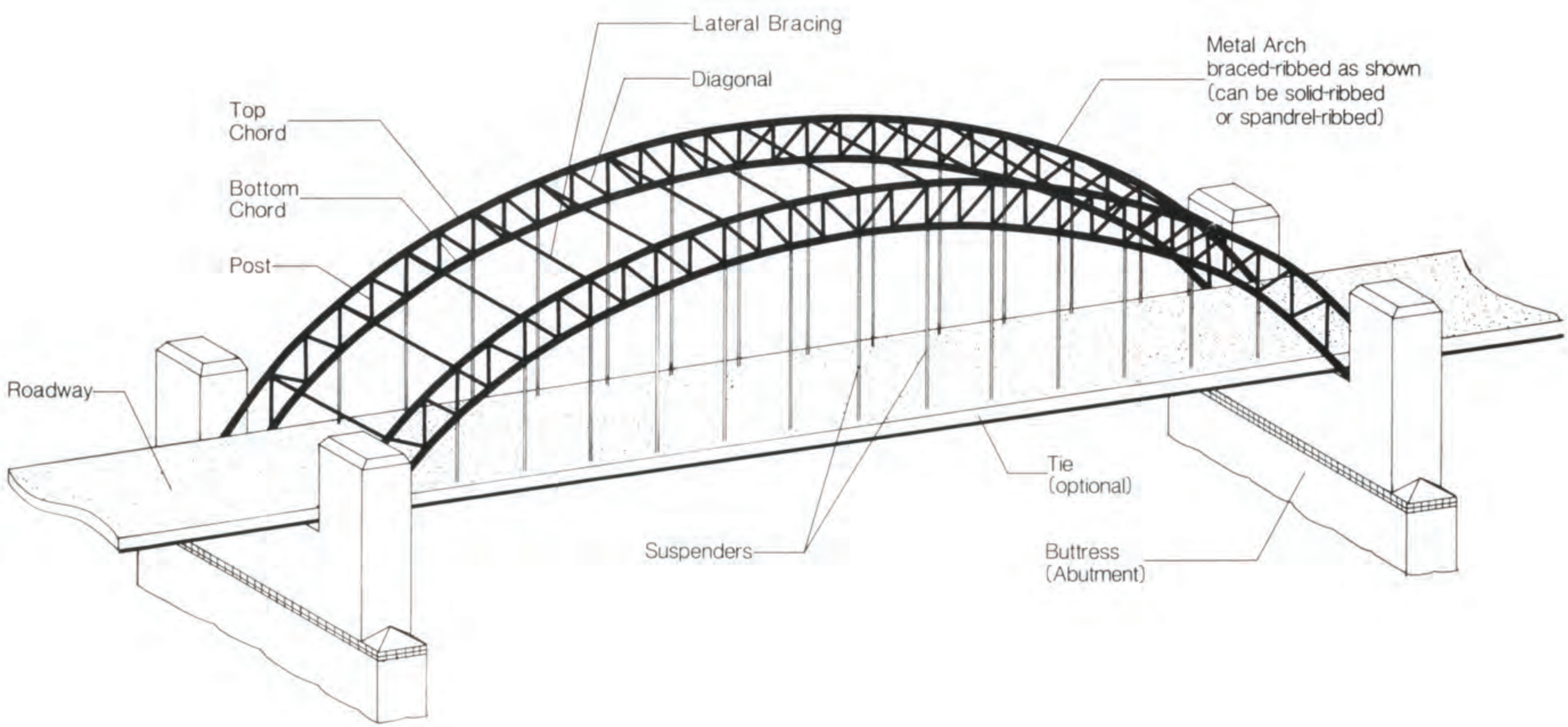
Panther Hollow Bridge, Schenley Park, Pittsburgh

METAL ARCH

Of the nine metal arch bridges included in this book, five of them are located in and around Pittsburgh. This is not surprising, since iron and steel manufacturing was a major part of this region's economy. Furthermore, the city is located at the confluence of three major rivers. The first all metal bridge in the United States was built in nearby Fayette County in 1836-1839. This bridge, Dunlap's Creek Bridge carries Old U.S. Route 40 over Dunlap's Creek in Brownsville Borough.

Dunlap's Creek Bridge is a deck arch constructed for the National Road. This early example is extremely rare, as the metal arch did not become a widely used bridge type in the United States until the later part of the nineteenth century. For most spans a metal arch bridge was not as easily designed or constructed as the metal truss bridge and, therefore, was not as readily chosen in the early years of railroad and highway expansion. Metal arches, like metal trusses, were first built of iron and then of steel.

There are several ways to classify metal arch bridges. One method is by the degree of articulation, or the type of connection found at the bridge supports and at its midpoint or crown. A fixed, or hingeless, metal arch bridge has the main spans embedded into the support to fix it against rotation. If the span is articulated with a pinned connection at each support, it becomes a two-hinged arch. An arch with the end supports pinned and a third hinge (or pin) located somewhere near mid-span makes the arch three-hinged. A one-hinged



Typical Metal Arch Bridge

arch is very rare and has a single pin connection near mid span.

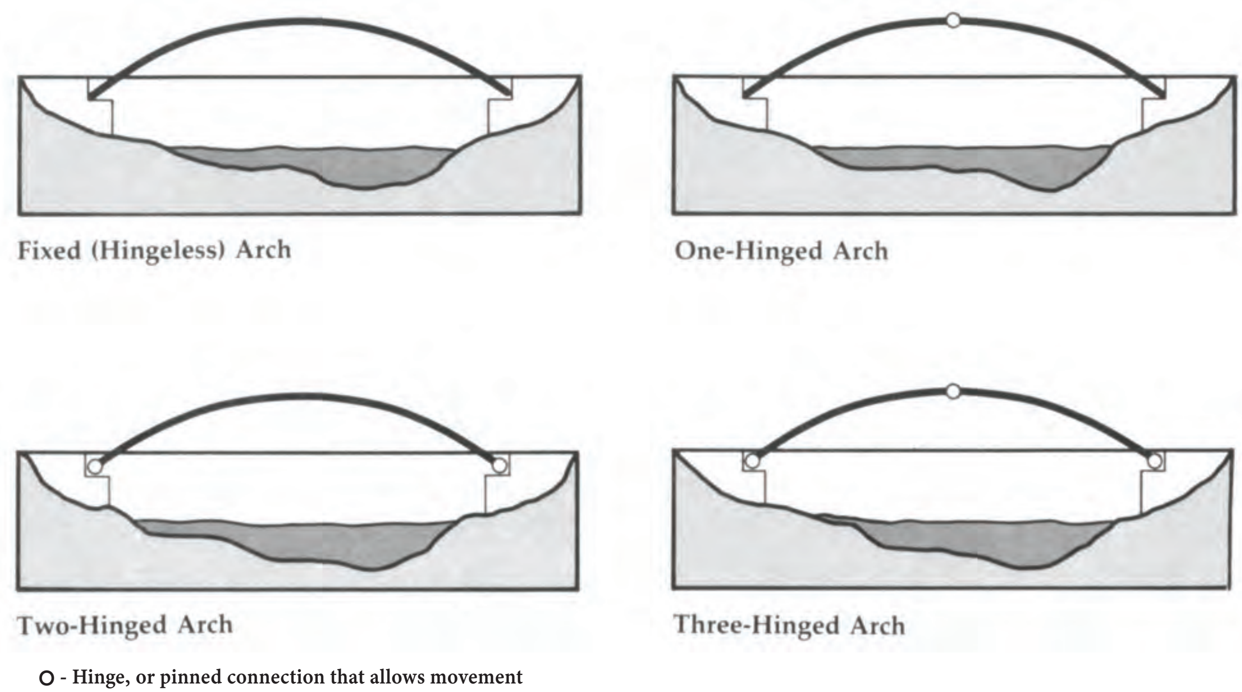
Another method of classifying metal arch bridges is by the arch configuration. Solid-ribbed arches were constructed of curved plate girder ribs. The roadway is carried on posts resting on top of the arches or suspenders hung from the bottom. Solid ribbed arches can be hingeless, one-hinged, two-hinged or three-hinged.

Brace-ribbed arches consist of two parallel, or nearly parallel, cords connected by open webbing. Brace-ribbed arches are also called truss arches since the open webbing consists of truss members. Brace-ribbed arches could be built as hingeless, one-hinged, two-hinged or three-hinged arches.

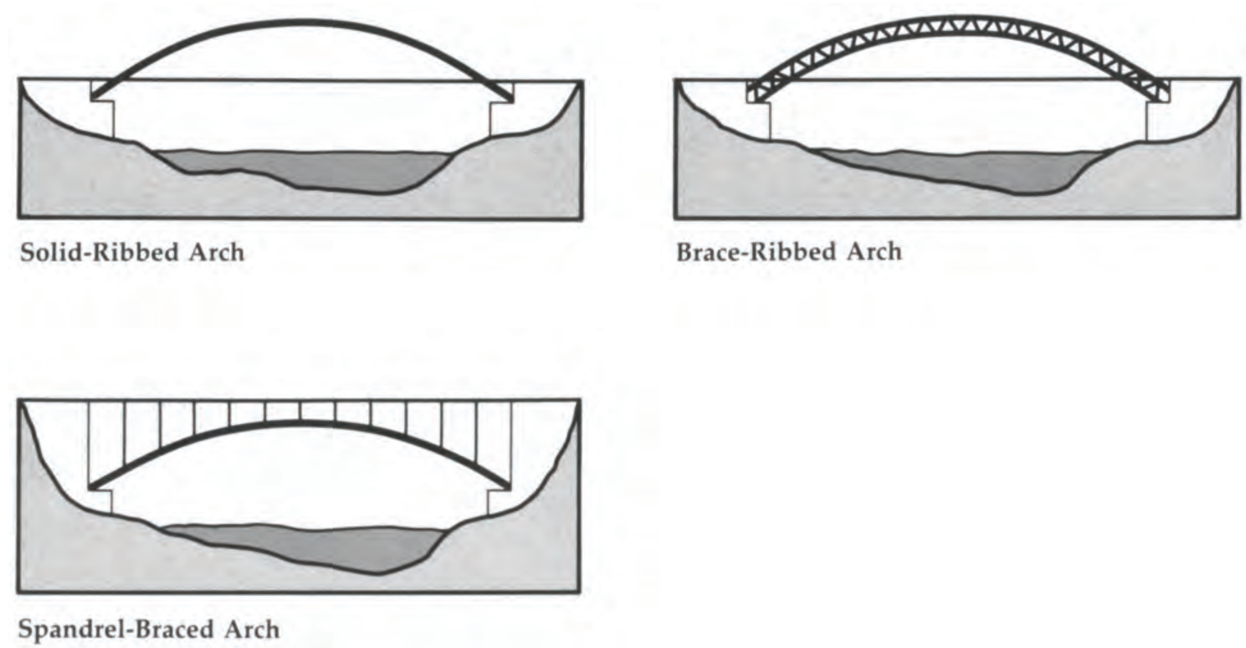
Spandrel-braced arches were constructed only as deck structures with the roadway carried on top of the arch. The main arch of spandrel-braced arches are the curved bottom members. The roadway was carried by the horizontal top cord. Web trussing, usually Pratt trusses, connected the horizontal top cords to the arch.

Dunlap's Creek Bridge, the first cast iron arch bridge built in America, is a ribbed fixed metal arch bridge.

Dunlap's Creek in Fayette County. Photograph from HAER



Hinge Connection



Arch Configuration

It was completed in 1839 by the United States Army Corps of Engineers for the National Road. This bridge contains five parallel ribs consisting of hollow elliptical tubes. Each rib was cast in nine segments and bolted at the flanges to form a solid rib. The arch ribs span eighty feet across Dunlap's Creek in a rise of eight feet. This bridge, still in use, has been designated a National Historic Civil Engineering Landmark.

Another noteworthy cast iron arch bridge, one that has not survived, was built in Pennsylvania. This bridge, cited by Gustav Lindenthal as the largest cast iron bridge in the United States at the time, was completed in 1863 in Philadelphia. Two arch spans of 185 feet had carried Chestnut Street across the Schuylkill River.

A few years later in 1869, the structurally innovative three-hinged arch was introduced into the United States by John M. Wilson, a Philadelphia engineer who worked for the Pennsylvania Railroad. No longer used, this three-hinged metal arch, built to carry the railroad over 30th Street in Philadelphia, was made of wrought iron with some cast-iron connections. At the time of its construction, the preferred arch type was fixed at the abutments and extremely rigid. This three-hinged arch was hinged at the two end points and the crown, and thus, capable of accommodating strains from expansion, contraction, and settlement.

By 1890, the three-hinged arch had become an accepted structural form for highway bridges. Built of steel, the Panther Hollow Bridge in Schenley Park, Pittsburgh has been called a classic three-hinged arch of steel construction.

Designed by H.B. Rust, Chief Engineer of Pittsburgh's Department of Public Works, this 1896 deck arch is comprised of four ribs, each three-hinged. Each arch rib is spandrel-braced with Pratt web trussing. The metal arch bridge gained its widest acceptance as a highway bridge where loads were lighter than railroads. The railroads preferred the metal truss and improved its form for increasing loads and varying site conditions. The railroads tended to be skeptical of the three-hinged arch, particularly since it lacked rigidity and required expensive temporary bracing for its construction.

The two-hinged arch provided solutions to the unacceptable qualities of the three-hinged arch. Although the presence of hinged supports required the continued need for temporary bracing during construction of the arch, the two-hinged arch was more rigid and provided adequate clearance above the water as a through arch. These advantages outweighed the disadvantages and by the end of the nineteenth century, several metal arch bridges were built for highways and railroads, with spans exceeding those thought possible for metal trusses.

The highpoint of metal arch bridge design in the early twentieth century was the Hell Gate Bridge in New York City, a railroad bridge. This two-hinged arch was designed by Gustav Lindenthal and built from 1914-1916. It is a through arch; that is, a pair of arch ribs rise from the hinges to a crown far above the bridge deck. The deck is supported from the arch ribs by hangers. The upper chord is curved and is connected to the arch rib by Pratt truss webbing; this upper section, including the curved upper chord, serves as a stiffening truss. The Hell Gate Bridge has a clear span of 977 feet.

Panther Hollow Bridge in Schenley Park, Pittsburgh

McKees Rocks Bridge over the Ohio River in Pittsburgh

Messerall Road Bridge in Crawford County, before relocation

Messerall Road Bridge in Crawford County during relocation

A two-hinged arch very similar in form to the Hell Gate main span was built in Pittsburgh to cross the Ohio River. Constructed between 1930 and 1932, the McKees Rocks bridge was designed by V.R. Covell, the Chief Engineer of the Allegheny County Department of Public Works. The McKees Rocks Bridge has a 750-foot main span, with a two-hinged through arch and a Pratt stiffening truss similar to the Hell Gate Bridge. The approach spans of this extremely long bridge consists of two-hinged deck arches, deck trusses, and girders.

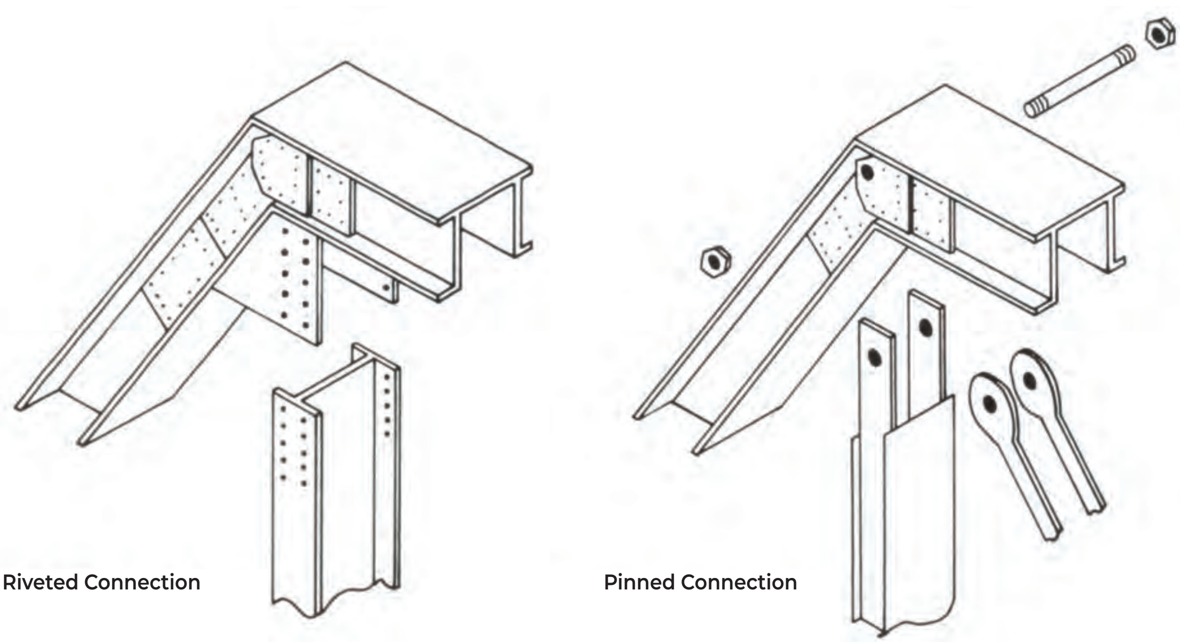
The West End Bridge, which crosses the Pittsburgh and Lake Erie Railroad and the Ohio River in Pittsburgh, was constructed at the same time as the McKees Rocks Bridge. Also designed by the engineers of the Allegheny County Department of Public Works, this 780 foot through arch is a tied arch, meaning that the ends of the arch are connected by a tension member. The arch consists of two curved ribs connected with Pratt webbing. At the main piers, this arch is tied by longitudinal members acting in tension to absorb the horizontal thrust of the arch. The bridge deck is supported by hangers suspended from the lower arch rib. Approach spans are Warren pony trusses.

In addition to these noteworthy long-span arch bridges, there are a number of small bowstring arches throughout Pennsylvania. Bowstring arch bridges were often called arch-trusses in their earliest applications in the mid-nineteenth century. Several variations were patented, some functioning as tied-arches, some as combined arch trusses, and some as trusses. The bowstring continued to be built in the twentieth century for lightly traveled roads spanning small creeks.

An unusual bowstring arch built in 1869 in Chester County is the Hare's Hill Road Bridge which carries Hare's Hill Road over French Creek. This wrought iron bridge contains riveted lattice work between the arch and bottom chord. The bowstring formed by this arch rib and bottom chord is made of two riveted angles. A different type of bowstring is the Messerall Road Bridge also referred to as the Pine Creek Bridge in Crawford County. Built in 1870 the Messerall Road Bridge is a rare and remarkable complete example of a design patented by David Hammond, the founder of the Wrought Iron Bridge Company. The bridge's arch is composed of six sections riveted together to create a built-up column-like member. In 2022, the Messerall Road Bridge was removed from its original location over Pine Creek in East Titusville and, in 2023, was relocated to carry the Pymatuning State Park Spillway Trail over Linesville Creek, in Linesville, Crawford County.

Another bowstring bridge, the Mount Carbon Bowstring in Schuylkill County, was relocated from Mount Carbon to Saint Clair, approximately 4 miles

Messerall Road Bridge in Crawford County, after relocation



Connection

to the north, in 2024, to carry the Schuylkill River Greenways Trail adjacent to Centre Turnpike (State Route 61). This is at least the second move for the rare bowstring bridge, which was originally erected in Palo Alto in 1878 before being moved to Mount Carbon in 1893. The bridge was likely built by the King Bridge Company of Cleveland, Ohio.

Bowstring bridges were used for relatively small spans; the construction of most of these types were simple, like metal truss bridges, requiring little skill or equipment.

Constructing the larger metal arch bridges described previously was a different matter. The methods used depended on the size of the arch and the conditions at the site. Sometimes temporary supports or falsework were built to support the structure. Rigid arches could be built by cantilevering out from each support until the two halves met at the center, without the need for falsework. Some arches were built by combining cantilever and temporary supports, either from below with falsework or from above with tiebacks. Where tiebacks were used, temporary anchorage towers were built to carry them.

Most of these techniques were used to construct the metal arch bridges extant in Pennsylvania. Metal arch bridges found in the Commonwealth represent a variety of sizes and designs. Examples of some of these metal arches are illustrated in the following pages. For more information on other metal arch bridges, visit PennDOT's Cultural Resources website[1].

WEST END BRIDGE

Location: S.R. 19 over Ohio River and Pittsburgh and Lake Erie Railroad, Pittsburgh, Allegheny County

Year Built: 1931-32

Type/Length: Multiple Span/1,891 feet

Also known as the West End-North Side Bridge, this structure comprises three Warren pony trusses (seven at the time of construction) and a steel tied arch. The 778-foot-long steel tied arch spans the main channel of the Ohio River just below Point State Park. One of the earliest and largest long span tied arches built in the United States, this bridge is also one of the first bridges to use high strength steel.

The arch consists of two curved ribs connected with Pratt webbing. At the piers, this Pratt truss arch is tied by longitudinal members which act in tension to absorb the horizontal thrust of the arch, like a bowstring. The bridge deck is supported by pretensioned hangers suspended from the lower arch rib.

The dramatic 151-foot rise and 778-foot span of the channel arch is emphasized by the low profile of the three Warren pony trusses remaining on the southern approach. The West End Bridge was fabricated and constructed by the American Bridge Company, Harrison Construction Company, and Cunningham and Sons.

HARE'S HILL ROAD BRIDGE

Location: Hare's Hill Road over French Creek, East Pikeland Township, Chester County

Year Built: 1869

Type/Length: Bowstring Arch, Single Span/105 feet

This bridge was designed by Thomas Moseley and is the only one of this design surviving. It is made of a wrought iron bowstring truss with lattice infilling. The truss is comprised of two Z-shaped members riveted to form a T-section. Tension members run diagonally downward from the bow to the center of the deck cord. The fifteen-foot-wide deck today is open mesh steel grid. The abutments are made of local stone. The bridge was rehabilitated in 2010. Repairs to the stone masonry approach walls were performed in 2018.

JEROME STREET BRIDGE

Location: Lysle Boulevard over the Youghiogheny River in McKeesport City, Allegheny County

Year Built: 1935

Type/Length: Single Span/762 feet

Built in 1935 by the Fort Pitt Bridge Works and designed by the Allegheny County Authority, the Jerome Street Bridge is a two-hinged through metal arch bridge. The bridge spans the Youghiogheny River in McKeesport City, Allegheny County.

Made of steel, the braced-ribbed arch is 455 feet in length with riveted connections. The hinges can easily be seen at the piers and the roadway is supported by hangers suspended from the lower arch rib.

WASHINGTON'S CROSSING BRIDGE

Location: 40th Street over the Allegheny River, Pittsburgh, Allegheny County

Year Built: 1919-1924

Type/Length: Multiple Span/2,366 feet

The Washington's Crossing Bridge was opened to traffic on December 24, 1924, the one hundred and seventy-first anniversary of the day George Washington crossed the Allegheny River. Washington, then a young major, was returning from his mission. The colony of Virginia challenged the French authority in the Ohio River Valley, a challenge which led to the French and Indian War. The Allegheny River was full of ice and proved treacherous. On December 24, 1753 the river froze, and Washington was able to cross successfully. Commemorating this event, the bridge was designed by Janssen and Cocken, architects, and Charles Stratton David, engineer.

Massive concrete piers support three steel arch spans, each 350 feet long. Fifteen total spans stretch over railroad tracks and the Allegheny River. Abstract classical detailing, along with railing plaques representing the original thirteen colonies, support the historic theme of this bridge.

At the time of this bridge's construction, the Allegheny County engineers responsible for plan review were J.G. Chalfont and V.R. Covell. V.R. Covell later became the Chief Engineer for Pittsburgh's Bureau of Bridges and was responsible for the design of several innovative bridges in Pittsburgh.

STRAWBERRY MANSION BRIDGE

Location: Strawberry Mansion Drive over the Schuylkill River, Philadelphia

Year Built: 1897

Type/Length: Multiple Span/1,242 feet

The Strawberry Mansion Bridge, which crosses the Schuylkill River in Fairmount Park, was built in 1897 by the Phoenix Bridge Company for the Fairmount Park Transportation Company. The bridge consists of six deck truss approach spans and four steel arch truss river spans with spandrel bracing. The bridge originally carried two Woodside trolley tracks and two lanes of traffic. Theodore Cooper assisted with the overall design of the bridge.

The Strawberry Mansion Bridge set records for its overall length and speed of construction. It was the longest bridge of its type when completed in 1897 and all four arches have different dimensions. The Phoenix Bridge Company used an unconventional construction sequence. Instead of erecting the chords and the spandrel bracing one panel at a time, the company built the arches' lower chords in their entirety. Three of the main spans were completed, including the roadway and trolley tracks, in one month. The bridge

Strawberry Mansion Bridge in Philadelphia

Smithfield Street Bridge in Pittsburgh

METAL TRUSS

Truss bridges are structures whose individual components are connected in a series of triangles. The truss bridge type was originally constructed in timber, and often had a roof and sheathing; today it is as easily recognizable as the American covered bridge, described in an earlier section. The truss form has been used since the early nineteenth century and continues to be used widely in American bridge building. Trusses have evolved from wooden structures through a combination of wood and metal to an all-metal structure. Metal truss bridges were developed in the mid-nineteenth century as an inexpensive, easily assembled bridge type, and appealed to the smaller, rural localities in Pennsylvania that were developing improved transportation routes.

An example of a simple truss bridge has been included to illustrate its basic components. Prominent in a truss bridge are the top and bottom chords, which are the structural members that resist the forces induced by bending. These chords carry the major loads exerted on the bridge.

The web members are categorized as verticals or diagonals and are connected to the top and bottom chords at joints. It is the arrangement of the chords and web members that determine the specific truss type, as a wide variety of configurations are possible. Since different truss types have different characteristics and capabilities, many truss variations were patented throughout the nineteenth and early twentieth centuries for use in both railroad and highway bridges.

Other basic components of a truss bridge are the portal, stringers, floor beams and deck. The portal is the space of a truss which forms the entrance to the bridge. Stringers are the longitudinal members, set parallel to the direction of traffic, which are used to transmit loads to the floor beams. The floor beams are set transverse to the direction of traffic to transmit the deck loads to the trusses. The deck is the structural element providing direct support for vehicular loads. The truss rests on the top of the pier or abutment at a point called the bearing seat.

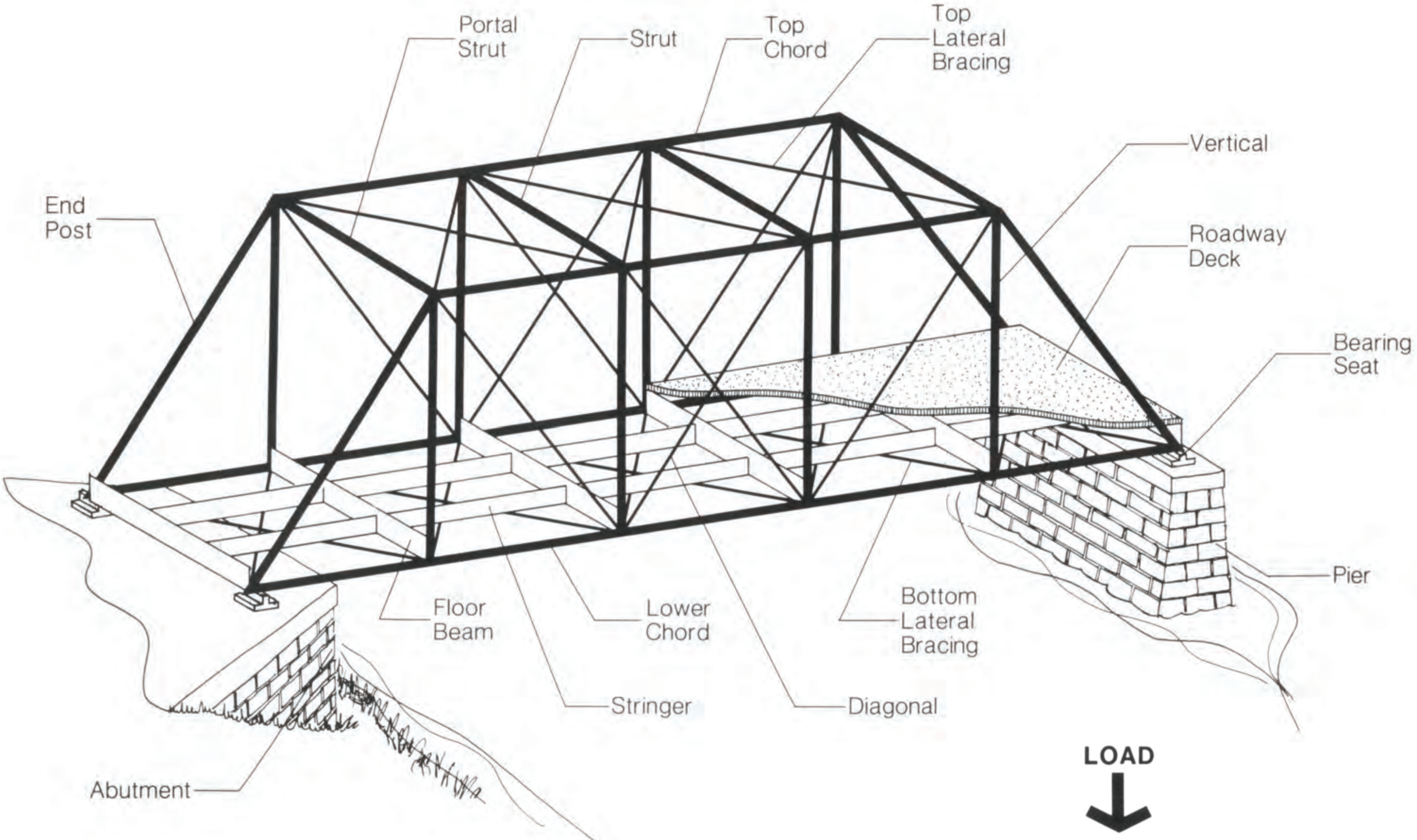
Analysis of the functioning of a simple truss assumes that joint connections will allow joint rotation, and that application of loads occurs only at the joints so that members are subjected only to direct stresses. The loads and reactions which act on a truss cause internal forces, or stresses, in the members. If the individual member is stressed by a pulling action, the stress is called a tensile stress and the member is said to be in tension. If a member is stressed by a pushing action, it acts in compression under compressive stresses.

Large-scale wooden truss bridges of several types were built in the United States beginning in the late eighteenth century. In the 1840's, cast iron truss members were first introduced, and records indicate that some iron truss bridges were built on the Erie Canal in that decade. Most builders made the transition to iron more conservatively. Early patents, like the Howe and Pratt in the 1840's, used iron rods solely for tension members, and wood for the rest of the truss. In a book published in 1847, Squire Whipple pointed out the logic of using cast iron in compression and wrought iron in tension. Cast iron fractures upon impact and cannot carry tensile loads while wrought iron is a ductile rather than brittle material and is stronger than cast iron in tension.

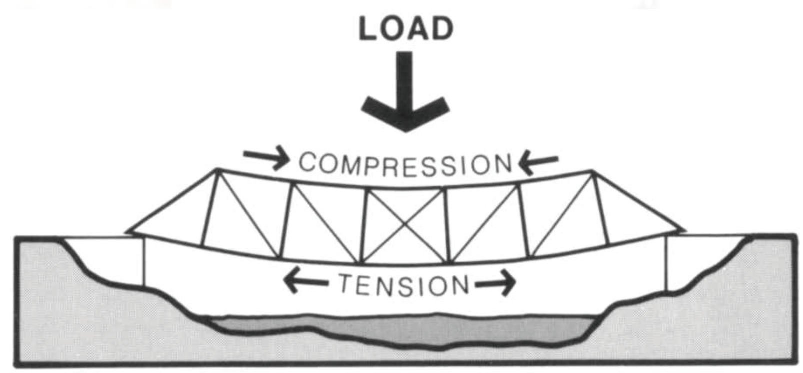
By 1850 rolled wrought iron shapes were widely available for construction purposes and more all metal bridges were built. The post-Civil War years saw the development of large bridge building companies, the increase production of rolled iron shapes at lower prices and the rapid growth of the railroads. As a result, new truss forms evolved, and improvements were made to existing ones. In the 1880's mills began to roll structural steel, which quickly became the predominant metal building material. By 1895, most mills had discontinued rolling wrought iron. In the transition years it was not unusual for trusses to include both iron and steel members.

The Walnut Street Bridge, also known as Wagner's Bridge, in Hellertown, Northampton County is one of the oldest metal truss bridges in the country. The bridge, built in 1860, incorporates construction details patented by bridge engineer Francis C. Lowthorp of Trenton, New Jersey and is the only thru truss built by the Beckel Iron Foundry of Bethlehem, Pennsylvania. The Walnut Street Bridge features cast iron floor beams and Lowthorp's "straining plate" lower panel point connection detail that he patented in 1857 and 1860. In 1994, the bridge was relocated north of Walnut Street for pedestrian traffic.

Metal truss types are distinguished by name according to the configuration of the component triangles and the way in which individual members are stressed. The most common metal truss types represented by Pennsylvania's historic highway bridges are of the following named types: Pratt, Pratt Double Intersection, Parker, Pennsylvania (Petit), Baltimore, Lenticular, Warren, and Warren Quadrangular. Most of the extant historic truss bridges are Pratt or a variation of Pratt.



Typical Metal Truss Bridge



Simple Truss Stresses

Calhoun Street Bridge over the Delaware River in Bucks County

Petroleum Center Bridge in Venango County

PRATT TRUSS

The Pratt truss was originally patented by Thomas and Caleb Pratt in 1844. In its earliest form, the Pratt truss was a combination wood and iron truss. The top chord and verticals acted in compression and were made of wood while the bottom chord and inclined members acted in tension and were made of iron. This combination Pratt truss was built through the nineteenth century and was cited as a continued form by bridge engineers as late as 1908. However, no combination wood and metal trusses remain in Pennsylvania.

The Pratt truss survived the transition to metal construction and was widely built as an all metal truss well into the twentieth century. In 1916, bridge engineer and historian J.A.L. Waddell claimed that the Pratt truss was the most commonly used truss type for spans under 250 feet. One example of an all-metal Pratt truss is the Calhoun Street Bridge crossing the Delaware River in Bucks County. The seven span Pratt through trusses were built by the Phoenix Company of Phoenixville, Pennsylvania in 1884. Another example of a Pratt truss is the Petroleum Center Bridge, a through truss, crossing Oil Creek in Venango County. As these bridges show, the truss could be adapted to a wide range of sizes.

Sheep Bridge Road Bridge in York County

DOUBLE INTERSECTION PRATT TRUSS

The double intersection Pratt truss, also termed Whipple, Whipple-Murphy, or Linville truss, added additional diagonals to the basic Pratt truss which extended across two panels but kept the parallel top and bottom chords of the simple Pratt profile. Squire Whipple's double intersection truss was patented in 1847. In 1863 John W. Murphy, Chief Engineer of the Lehigh Valley Railroad, slightly modified the Whipple truss by adding crossing diagonals. The double intersection Pratt truss was widely used for long span railroad bridges. Sheep Bridge Road Bridge in York County is one of the few surviving examples of the Whipple truss design. Constructed in 1889, this bridge was built by the Wrought Iron Bridge Company, prolific bridge builder one of the nation's leading metal bridge builders in the late-19th-century.

West Newton Bridge over the Youghiogheny River in Westmoreland County

County Bridge No.42 in Main Township, Columbia County

PARKER TRUSS

The Parker truss, developed by C.H. Parker, is a Pratt truss with an inclined top chord. An example of the Parker truss which is found in Pennsylvania is the West Newtown Bridge crossing the Youghiogheny River in Westmoreland County. This bridge consists of three Parker trusses and was built in 1907. Another example of a Parker truss can be found in Columbia County. County Bridge No. 42 was built in 1903 over the Catawissa Creek in Main Township. This single span Parker truss is 228 feet in length and was built by Nelson and Buchanan of Chambersburg, Pennsylvania, one of the state's most prolific builders of highway bridges.

Brownsville Bridge Over the Monongahela River in Brownsville Borough, Fayette County

PENNSYLVANIA (PETIT) TRUSS

The Pennsylvania (Petit) truss modified the Parker truss by introducing sub-struts or sub ties which are members of the truss acting to resist or transmit stresses, respectively. An unusually long example of a Pennsylvania (Petit) truss is the Brownsville Bridge over the Monongahela River in Brownsville Borough, Fayette County. Built in 1914 by the Fort Pitts Bridge Works, this bridge consists of three spans for a total length of 945 feet.

Bairdstown Bridge over the Conemaugh River between Indian and Westmoreland County.

BALTIMORE TRUSS

The Baltimore truss changed the basic Pratt configuration by adding additional, auxiliary members, like the Pennsylvania truss, but it does not have an inclined upper chord; the upper and lower chords of a Baltimore truss are parallel, like the Pratt truss. Both the Baltimore and Pennsylvania truss types were developed by the engineers of the Pennsylvania Railroad in the 1870's. Both types were also used for highway bridges. The Bairdstown Bridge, which crosses the Conemaugh River and connects the counties of Indiana and Westmoreland, consists of two Baltimore trusses and is the fourth bridge at the crossing. Built in 1935 by the Pennsylvania State Highway Department, the bridge spans 358 feet.

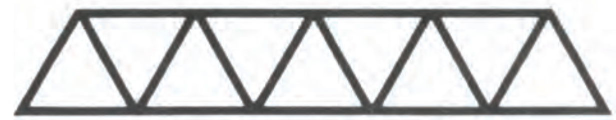
Pine Creek Bridge in Porter Township, Lycoming County

Tunkhannock Creek Lenticular in Lazy Brook Park, Wyoming County

LENTICULAR TRUSS

The Lenticular truss derives its name from the lens-like shape of its curved upper and lower chords. The diagonals of the lenticular truss are like those of a Pratt truss. The Pine Creek Bridge, built in 1889 by the Berlin Iron Bridge Company of East Berlin, Connecticut, is a single span lenticular truss which crosses Pine Creek in Porter Township, Lycoming County. Another Lenticular, built in 1881 by the Corrugated Metal Company of East Berlin, Connecticut, was originally constructed over Tunkhannock Creek in Wyoming County. In 2015, the bridge was lifted off its abutments for rehabilitation and relocated to Lazy Brook Park where it remains today as a pedestrian crossing.

W. Bollman and Company Bridge located on the Great Allegheny Passage Trail.



WARREN TRUSS

The Warren truss was patented in 1848 by two British engineers, James Warren and Willoughby Monzoni. The original form of a Warren truss was a series of equilateral triangles and as such represents one of the earliest, simplest truss types. Later modifications included subdivision by verticals or addition of alternate diagonals. The Warren truss was widely built throughout most of the United States from about 1860 to the twentieth century. An early Warren truss in Pennsylvania is the W. Bollman and Company Bridge. Constructed in 1871 by W. Bollman and Company, it uses cast iron for some of the compression members and wrought iron for the tension members and the end posts. This bridge was relocated to the Great Allegheny Passage Trail in 2007.

Upper Slate Run Bridge, Lycoming County

WARREN QUADRANGULAR TRUSS

The Warren Quadrangular truss is a double intersection Warren truss in which two series of equilateral triangles intersect to form a lattice-like configuration. The Upper Slate Run Bridge, crossing Pine Creek in Lycoming County, illustrates the Warren Quadrangular truss type. This bridge was built in 1890 by the Berlin Iron Bridge Company of Berlin.

Old Mill Road Bridge in Gregg Township, Union County

Old Mill Road Bridge in Gregg Township, Union County

OTHER CLASSIFICATION SCHEMES FOR TRUSS BRIDGES

In addition to classifying metal truss bridges by name, their form is further distinguished by the location of the bridge deck in relation to the top and bottom chords and by their structural behavior. The superstructure of a typical truss bridge consists of two trusses on either side of a floor system which carries the bridge deck. Lateral bracing occurs at the bottom chords and sometimes the top chords.

On most truss bridges, the deck is located inside the main trusses, with the floor beams attached to the bottom of the verticals. When the deck is located near the bottom chord, the truss is called a through truss, such as the Miller Farm Road Bridge in Venango County. Another example of a through truss is Old Mill Road in Gregg Township, Union County. A through truss with insufficient depth for upper lateral bracing, like the Northampton County Bridge No. 16 also known as Old Mill Road Bridge, in Lower Saucon Township which spans Saucon Creek in Northampton County, is called a pony truss or half through truss. A truss bridge which carries the deck on its upper chord is a deck truss. The Liberty Bridge, which spans the Monongahela River in Pittsburgh, is a deck truss.

Trusses generally exhibit beam behavior. Trusses are therefore either simple spans, continuous spans or cantilever spans. The most commonly built truss bridge was a single simple span or a series of simple spans, made of wood, where each truss span had its own bearing at a pier and no stresses were transferred to adjacent spans. All the truss bridges illustrated to this point have been simple spans.

The continuous truss has a chord and web configuration which continues uninterrupted over one or more intermediate supports or piers. The use of the

Liberty Bridge in Pittsburgh

Homestead Grays Bridge over the Monongahela River in Pittsburgh

continuous truss was rare until the late quarter of the nineteenth century, and it was not until the twentieth century that this form acquired widespread acceptance in bridge design. The reluctance of bridge designers to use this form was primarily a result of unpredictable stresses which could occur as a result of intermediate pier settlement. This problem was solved in one form by E.M. Wichert of Pittsburgh in 1930. Wichert's truss eliminated the potential problems involved at the intermediate piers by introducing hinged quadrilateral sections over these piers. The Homestead Grays Bridge, formally known as the Homestead High Level Bridge, was constructed in 1937 to cross the Monongahela River in Pittsburgh and was the first major Wichert truss bridge in the country.

The cantilever truss is configured so that one or both of its end sections extend beyond the supports. The main span of a typical cantilever truss has two projecting arms extending from piers supporting the suspended span. The secondary spans are projecting arms from the anchor piers which counterbalance the main span. The Northampton Street Bridge in Northampton County is a typical cantilever truss of Pratt truss configuration. It was built between 1895-1896 by the Union Bridge Company of New York.

The cantilever truss was not widely used in the United States until the last quarter of the nineteenth century. By the end of that century, it was clearly understood that the longest spans were possible with truss bridges of the cantilever type, and twentieth century bridge designers used the cantilever truss frequently for spanning major rivers. One Pennsylvania example of a long span, cantilever truss bridge is the Ambridge-Aliquippa Bridge which crosses the Ohio River, State Route 65, and two railroads in Ambridge Borough, Beaver County. This Warren truss, built in 1927, has a main span of approximately 230 feet.

CONSTRUCTION AND OTHER DETAILS

The metal truss bridge, represented by forms as different as the simple span Pratt pony truss and the long-span cantilever truss, has played a major role in the extension of roadways across the United States. Its ease of construction made the metal truss bridge the most common bridge type built from the mid-nineteenth to the early twentieth century. It was preferred because field construction of a metal truss bridge could be accomplished with unskilled labor and minimal equipment.

Several methods of construction were possible, depending on the size of the bridge and the site conditions. Very small trusses could be shipped completely assembled from the shop and lifted onto piers and abutments which had been constructed according to the needs of the site. For larger trusses, the individual members were fabricated and riveted at the bridge shop and shipped to the site, where the truss was assembled by matching the marked members and inserting pins at the joints.

Some metal trusses were erected on temporary framework of wood. In other cases, cantilever

Belvidere Riverton Bridge, Northampton County

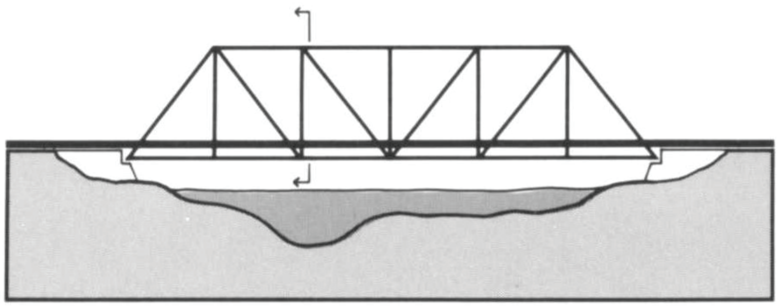
Ambridge-Aliquippa Bridge in Ambridge Borough, Beaver County

Bridge plaque on the Calhoun Street Bridge in Bucks County

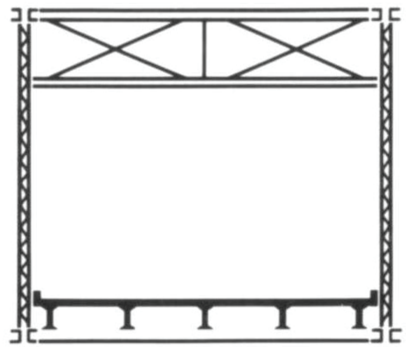
Bridge details on the Lattice Truss in Brown Township

Bridge details on the Calhoun Street Bridge in Bucks County

Bridge detail on the Bairdstown Bridge between Indian and Westmoreland County



Elevation
Through Truss



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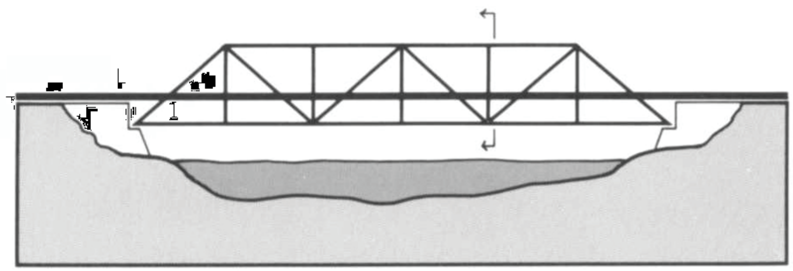
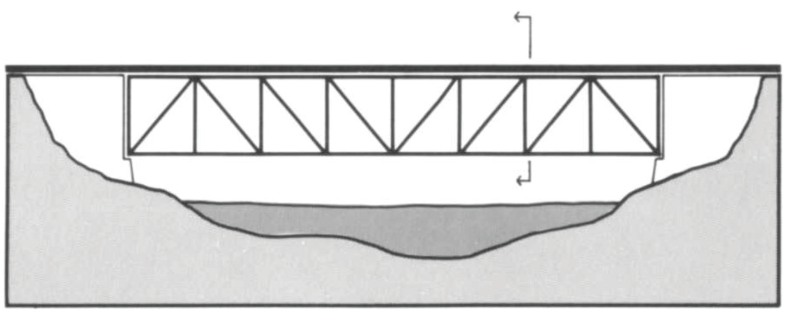
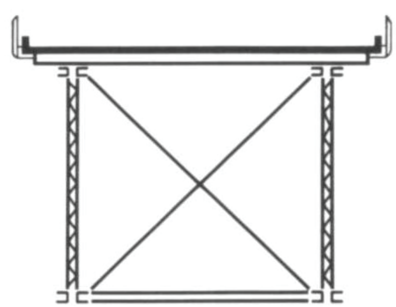


Elevation
Pony Truss

Section



Elevation
Deck Truss



Section

construction methods were used, whereby sections were built out from the pier to the center with elaborate anchorage systems tying back the upper portion of the unfinished trusses. Another method of construction involved assembling the truss on a barge near the site, floating it to the bridge, and lifting it into position; this technique was frequently used for erecting the suspended span of a cantilever bridge.

Various bridge members were invented to increase strength and stability during the most active period of truss construction. One type of truss member used in bridge construction during the mid to late 1800's was the Phoenix column, manufactured by the Phoenix Bridge Company of Phoenixville, Chester County. The Phoenix column, patented by Samuel J. Reeves of June 17, 1862, was usually used as a compression member and composed of a series of segments riveted together forming a cylindrical column. The Phoenix Bridge Company became nationally and internationally known, and built bridges in Canada, Mexico, and Brazil. There are several bridges using Phoenix columns remaining in Pennsylvania, such as the Walnut Street Bridge crossing the Susquehanna River in Harrisburg, Dauphin County, the Ross Fording Road Bridge which carries Ross Fording Road over Octoraro Creek in Chester County, and the Kinzua Viaduct.

When the original Kinzua Viaduct was completed in 1882, it was the highest railroad viaduct in the world with a height of 301 feet. Spanning 2,033 feet over Kinzua Creek, the original bridge consisted of twenty towers with wrought iron Phoenix columns. The railroad track was supported on lattice trusses between these towers. In 1900, the original bridge was replaced with a new structure to accommodate the increasing weight of railroad cars and locomotives. The second Kinzua Viaduct was identical to the first in height and length and was designed by Octave Chanute. The Commonwealth of Pennsylvania acquired the bridge in

1963 and established the Kinzua Bridge State Park, which opened in 1970. In July 2003, while the Kinzua Viaduct was closed to all traffic for repairs, a tornado with wind speeds between 73 to 112 miles per hour struck the side of the bridge. Eleven of the twenty towers were torn off their foundations and fell to the forest floor. Today, the damaged bridge towers remain at the bottom of the valley and can be viewed by park visitors from the pedestrian skywalk and observation deck.

Sometimes an attempt was made by bridge designers to embellish the truss with decorative ironwork at the portals or the railing. In addition, most bridge companies would attach a bridge plate to the structure, which may have included the name of the bridge company and the date of the bridge's construction.

Metal truss bridges representing a variety of truss types, configurations, and bridge companies were constructed across Pennsylvania. The following pages highlight several metal truss bridges located throughout the Commonwealth. For more information on other metal truss bridges, visit PennDOT's Cultural Resources website[1].

Blairsville Bridge Plaque

Northampton County Bridge No. 16 in Lower Saucon Township, Northampton County

Blairsville Bridge in Indiana and Westmoreland County

SMITHFIELD STREET BRIDGE

Location: Smithfield Street over the Monongahela River, Pittsburgh, Allegheny County

Year Built: 1881-83

Type/Length: Lenticular, Multiple Span/1,184 feet

The Smithfield Street Bridge is one of the few multiple long-span Lenticular trusses remaining in the United States. It was the first major work of the prominent, German-born American civil engineer, Gustav Lindenthal. The American Society of Civil Engineers designated this bridge a National Civil Engineering Landmark as a unique adaptation of contemporary European practice, the use of the Lenticular truss, to American needs.

Lindenthal designed the two channel spans across the Monongahela River of steel Lenticular trusses. One of many patented truss systems devised in the nineteenth century, the Lenticular truss derives its name from the lens-like shape of its upper and lower chords. In addition to using an unusual truss type, Lindenthal specified the use of steel for all the members of the trusses. In 1881, this was an early use of steel for truss design, making the Smithfield Street Bridge a technological pioneer as well.

In order to separate vehicular and trolley traffic, Lindenthal anticipated necessary modifications to his plan. In 1890-91, the bridge was widened twenty feet through the addition of parallel two-span Lenticular trusses. Lindenthal designed this urban bridge, which replaced Roebling's 1846 suspension bridge, with heavily ornamented portals. The original, single arched entrance was polychrome, with a bracketed cornice and a mansard roof. It was made of cast and wrought iron. The portals of the Smithfield Street Bridge were altered after the bridge's modifications, but they maintained the heavily ornamented character of Lindenthal's original design. The portals in place at present are the 1915 replacement made of cast steel.

BRIDGE IN JOHNSTOWN

Location: S.R. 3022 over Stony Creek, Johnstown, Cambria County

Year Built: 1890

Type/Length: Pennsylvania Petit, Single Span/225 feet

This bridge, part of the Inclined Plane Railway, was originally built as a "Lifesaver" for the citizens of flood-prone Johnstown and is currently used as the lower entrance over Stony Creek for cars and pedestrians to enter or exit the railway. Supported by immense stone abutments, the bridge was constructed with three-foot thick iron girders.

It was constructed in 1890 by the Cambria Iron Company, a predecessor of Bethlehem Steel Company. Along with the Inclined Railway, it provided transportation up Yoder Hill to Westmont, the Steel Company's residential development.

WALNUT STREET BRIDGE

Location: Walnut Street over the Susquehanna River, Harrisburg, Dauphin County

Year Built: 1890

Type/Length: Baltimore, Multiple Span/2,850 feet

The Walnut Street Bridge is one of the few surviving multi-span Phoenix bridges in the United States and the longest known extant bridge with Phoenix columns. It originally comprised fifteen long-span, pin-connected Baltimore trusses, a late nineteenth century modification of the Pratt truss. The upper chords and the inclined end posts of each Baltimore truss are Phoenix columns, patented compression members manufactured by the Phoenix Iron Company.

The wrought iron Phoenix column was originally patented by Phoenix Company's Samuel Reeves in 1862. It was made of rolled flanged segmental sections, riveted together to form a cylindrical member, or column. The tube could be made in four-, six- or eight-piece sections to vary its diameter for different load requirements.

The Walnut Street Bridge illustrates this use of varied diameter Phoenix columns. The nine remaining spans which measure approximately 172 feet use four-section Phoenix columns, while the three spans measuring approximately 240 feet use six-section Phoenix columns.

The superstructure was fabricated at the Phoenix Bridge Company of Phoenixville, Pennsylvania, a company which grew out of the Phoenix Iron Company. The bridge was erected at the site by Dean and Westbrook of New York, builders of several other bridges in Pennsylvania and is listed as a National Historic Civil Engineering Landmark.

The long-span bridge is divided into two sections by City Island, seven spans to the east and originally eight spans to the west. The bridge was owned and operated by the People's Bridge Company as a toll bridge, including a trolley service that operated from 1893 to 1936. In 1954 the bridge came under the control of the Pennsylvania Department of Highways. Most of the original cast iron fence posts for the railing between the two parts of the bridge, bearing the date 1899, still exist.

Damage from Hurricane Agnes in 1972 led to the permanent closure of the bridge to vehicles. It was converted to a bicycle and pedestrian bridge connecting the city center to the amenities of City Island. In 1996 flooding and ice jams resulted in the collapse of spans 3, 4, and 5 between the west shore and City Island.

TEN MILE CREEK BRIDGE

Location: Mahle Road over Ten Mile Creek, Morgan Township, Greene County

Year Built: 1878

Type/Length: Whipple, Single Span/163 feet

This pin connected double intersection Pratt (Whipple) was built in 1878 by the Massillion Iron Bridge Company of Massillion, Ohio, a processor of the Toledo-Massillion Bridge Company. The Ten Mile Creek Bridge, also known as Pollocks Mill Bridge, features several details that showcase the early period of metal truss experimentation including unusual I sections for the verticals, which may have been unique to the bridge company. Another common trait of Massillion built bridges, and included on the Ten Mile Creek Bridge, are the semi-circular brackets used for connecting the upper lateral bracing.

The Ten Mile Creek bridge in Morgan Township, Greene County is one of the most significant surviving early truss bridges in the state.

BRADFORD COUNTY BRIDGE #13

Location: T-348 over Towanda Creek in Franklin Township, Bradford County

Year Built: 1904

Type/Length: Double Intersection Warren,Single Span /90 feet

Bradford County Bridge #13, also known as the Cons Road bridge, which carries T-348 over Towanda Creek in Franklin Township, Bradford County, features a rare design. This riveted Double Intersection Warren has a second set of diagonals to increase the capacity of the bridge. This design was more often used for railroad bridges. There are very few examples of this design being used in highway application in Pennsylvania. Bradford County Bridge #13 is the oldest of three Double Intersection Warren trusses built in Bradford County between 1904 and 1907. The bridge, built in 1904 by the Owego Bridge Company, spans 93 feet and rests on concrete abutments.

BRIDGE IN BROWN TOWNSHIP

Location: TR 414 over Pine Creek, Brown Township, Lycoming County

Year Built: 1890

Type/Length: Warren Quadrangular, Single Span/202 feet

This lattice truss bridge was built by the Berlin Iron Bridge Company of East Berlin, Connecticut. The lattice truss type is unusual and was infrequently built due to its structurally indeterminate nature. This truss configuration, also termed a "Warren quadrangular", was fabricated of riveted plates, angles, and lacing bars. All joint connections are also riveted.

The Berlin Iron Bridge Company was most commonly associated with the design and construction of Lenticular trusses. However, lattice trusses were also illustrated in the company's late nineteenth century advertisements. Material testing has confirmed that the truss members are wrought iron.

READING-HALLS STATION BRIDGE

Location: Muncy Township, Lycoming County

Year Built: c. 1846

Type/Length: Howe Metal Truss, Single Span/70 feet

Reading-Halls Station Bridge is the oldest all-metal railroad bridge still in active service today carrying a private drive over the railroad. Built in 1883, the bridge originally carried tracks for the Reading Railroad but has since been relocated for vehicular traffic. The Reading-Halls Station Bridge was designed and built by Richard B. Osborne, chief engineer of the Philadelphia and Reading Railroad. The Howe pony truss spans 70 feet and features Egyptian Revival decorative motifs, a unique style from the start the 19th century. The Howe truss design, patented in 1840 by William Howe, combined the benefits of wood and iron together. For additional strength and to fireproof the structure, the Reading-Halls Station Bridge replaced the wooden members of the Howe design with iron.

Tunkhannock Creek Viaduct - Nicolson Bridge in Wyoming County

CONCRETE

Concrete was used in building as long as 2450 B.C. In mass, it served well through sheer weight of material. The modern development of concrete as a popular construction material was roughly simultaneous with that of steel. Concrete was first used in the mid-nineteenth century as monolithic masonry without metal reinforcement, commonly called plain concrete. By itself, concrete can work only in compression, but if reinforced with iron or steel bars, the elastic metal will take the tensile stresses. Reinforcing schemes of varying shapes and types were introduced in the late nineteenth century. By the early twentieth century reinforced concrete was well established as one of the preferred materials for highway and rail bridges. This trend continues today.

The components of a typical historic concrete arch bridge are shown. Visually, concrete arches can be described as having an open spandrel or a solid spandrel. Open spandrel arches have pierced spandrel walls and solid spandrel arches have solid spandrel walls. In its lightest structural shape, the open spandrel arch does not contain fill material and the deck loads are carried by the arch ribs that support spandrel columns. A solid, filled, spandrel concrete arch is similar to a stone arch wherein a barrel arch carries fill, and the solid spandrel wall serves as a retaining wall containing the fill material.

The arch ring can be a single unit, termed an arch barrel, or it can be divided into several parallel arch ribs. The interior surface of the arch ring is termed the intrados, while the exterior surface of the arch is labeled the extrados.

Like stone arch bridges, both open and solid spandrel concrete bridges contain parapets, constructed at the outer-most edge of the roadway or sidewalk portion of the bridge to serve as a guiderail. Unlike the solid parapets normally found on stone arch bridges, parapets found on concrete arch bridges are more elaborate and are called balustrades. A balustrade is a railing system composed of a top rail, supporting balusters and a bottom rail. A balustrade allows for openings in the parapet and can be designed to be a significant decorative element of the bridge.

Arch bridges made of reinforced concrete had many advantages over masonry arches. Stone bridges were generally constructed with arches following a semi-circular, or segmental curve. These forms necessarily limited the span length. Stone bridges having a low rise to span ratio were extremely rare but reinforced concrete lent itself to a low rise to span ratio, and this allowed for longer span length. In addition, concrete bridges generally required less handwork during erection than stone arch bridges, which decreased their cost and construction time.

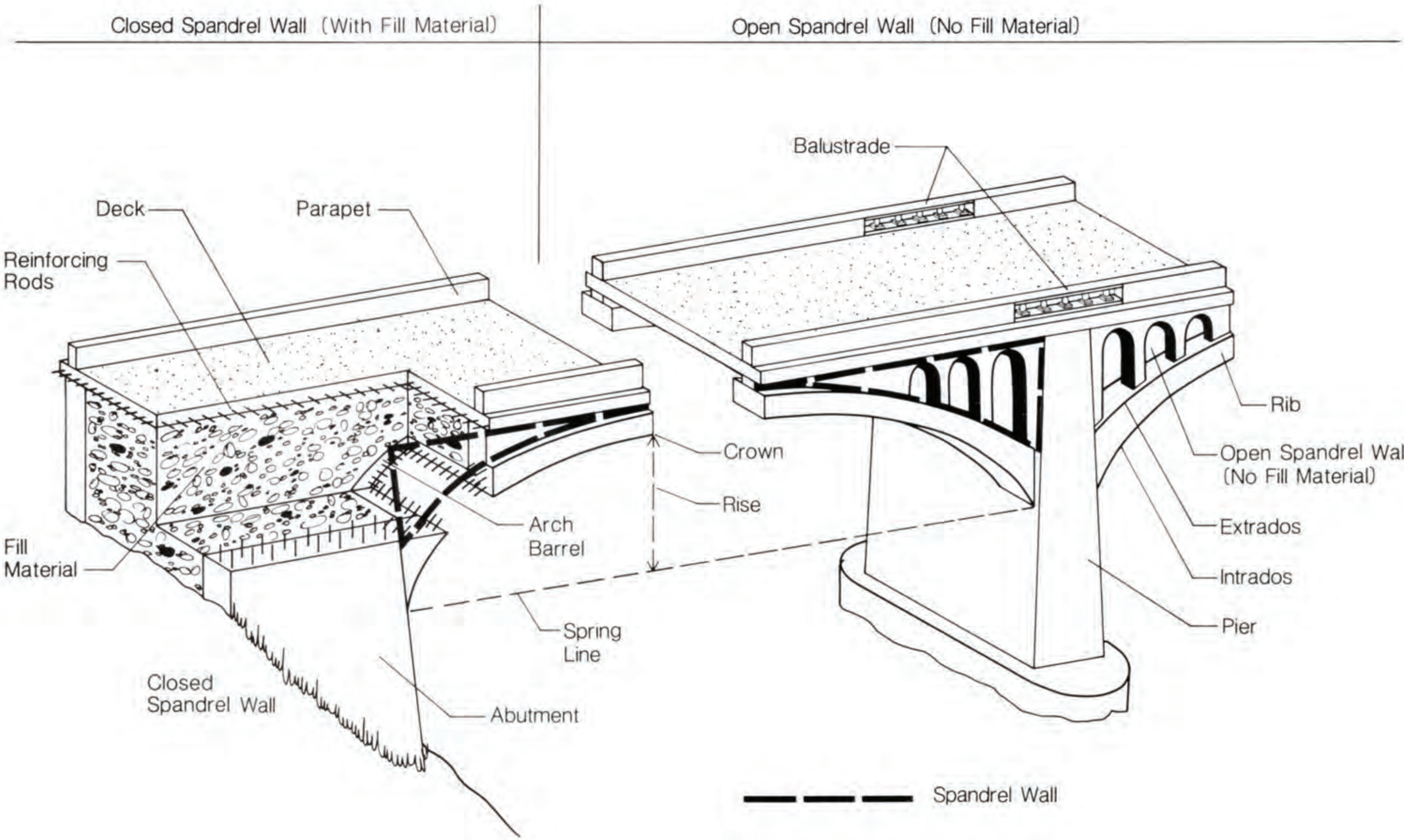
Because of the plasticity of concrete, various architectural and aesthetic designs can be incorporated into these bridges. Open spandrel arches can be formed to a variety of shapes and thicknesses, while closed spandrel arches could include aesthetic treatments on the surface of the concrete.

The first concrete arch bridge in the United States was built of plain concrete in Prospect Park, Brooklyn in 1871. The first reinforced concrete arch was built in Golden Gate Park, San Francisco in 1889. Although these structures were built with some understanding of the structural behavior of concrete, they were treated on the exterior to imitate stone. Concrete arch bridges in parks and cities were designed with voussoirs of molded concrete and rusticated or bush-hammered spandrel walls because designers felt the need to embellish the stark appearance of the concrete. Several of these embellished concrete arches were built in Pennsylvania, such has the Holme Avenue Bridge crossing Wooden Bridge Run in Philadelphia.

By the second decade of the twentieth century there were many methods used for finishing concrete surfaces. Slightly green concrete, a term applied to concrete where the forms were removed before the concrete was completely cured, could be washed and brushed. Acid washes were used, surfaces were rubbed with abrasives, sand blasted, and bush hammered. Bush hammering was attempted only after the concrete was well hardened, which usually took at least two months, and the material was tooled just as if it had been stone.

The aesthetic treatment of concrete bridges was not the only feature of concrete bridges which was governed by stone masonry traditions. Early structural designs for concrete arches also took their cues from stone arch construction. The earliest concrete arches were shaped as traditional masonry barrels with solid, filled arches. These closed spandrel walls acted as retaining walls for the fill material and carried the roadway loads to the arch.

Without the fill material in the barrel of the bridge, the structure consisted of arch ribs, a system of vertical supports resting on the ribs, and a horizontal deck



Typical Concrete Arch Bridge

Holmes Avenue Bridge over Wooden Bridge Run in Philadelphia

construction which is supported by the ribs. As the structural advantages of reinforced concrete were explored, the heavy, filled barrels were lightened into ribs. Spandrel walls were pierced and opened, eventually diminishing into column size which carried the deck loads to the arch ribs.

With the introduction of metal reinforcement in concrete, and the lightening of arch ribs, concrete arch curves became flatter and multi-centered, with longer spans becoming possible. The arch ribs narrowed, and reinforcement schemes abounded. As with metal bridge types, patented, technological innovations were prolific in the late nineteenth and early twentieth century. By 1905, the construction of ribbed arch bridges was well established. Narrows Bridge, spanning the Raystown Branch of the Juniata River in Snake Spring Township, Bedford County, is an open spandrel double ribbed arch built by the Pittsburgh Construction Company in 1935.

Narrows Bridge in Snake Spring Township, Bedford County

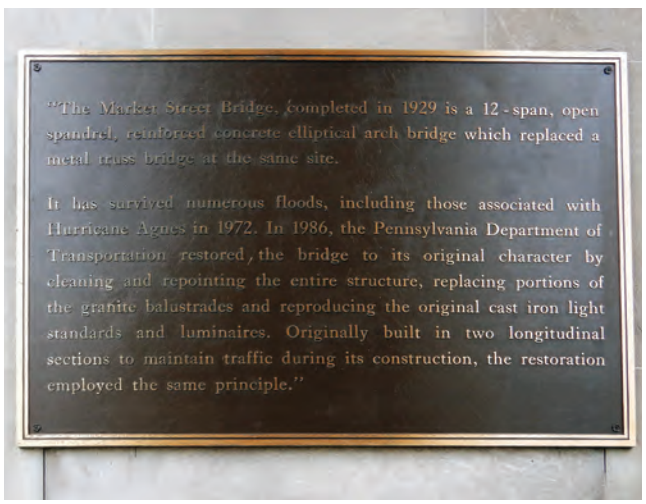
Market Street Bridge in Wilkes-Barre, Luzerne County

The phased procedure for constructing concrete arch bridges was similar to that used for stone arches: construction of foundations, abutments and piers, erection of falsework or scaffolding, construction of the arch ring, completion of spandrel walls and fill, and removal of the centering. The actual construction, of course, required a temporary structure for forming each part of the concrete bridge, since the form acted as molds for the liquid concrete. Once the piers and abutments were completed, the centering, or temporary forms for the arch, was set. It was initially constructed of wood, later of combination of wood and steel, or steel alone. In the case of through ribs, it was often integral centering, not a temporary structure but steel arch ribs to which the framework was attached by hanger bolts.

With the centering carefully set, steel reinforcement was placed in the form. Early reinforcements consisted of curved solid structural sections or deformed bars of varying shapes. Experimentation with reinforcement schemes produced many patented systems by the early twentieth century. When bars were used, they were sometimes placed at both the intrados and the extrados and sometimes followed a single line, curving with the intrados to designated bend points and then following the extradosal curve to the abutments.

Experimentation quickly showed that the preferred placement for the main longitudinal reinforcement

Wissahickon Memorial Bridge over Lincoln Drive and Wissahickon Creek in Philadelphia



Market Street bridge plaque in Luzerne County detailing the history of the bridge installed as part of the 1986 rehab

Bridge over Hickory Run in Carbon County was at both the intrados and the extrados as tension could occur at either surface under certain loading conditions. In barrel arches, transverse bars were placed at the top and bottom to better distribute the loads and to counter temperatures and shrinkage stresses. In ribbed arches, extradosal and intradosal reinforcement could be connected by an assortment of methods.

After the arch reinforcement was securely fixed, the concrete was placed in the forms. In the case of wide arch bridges, the arch was sometimes constructed in sections, moving the centering as each adjacent part set. It was important to load the centering evenly and symmetrically, pouring the concrete from each end at the spring-lines and moving inwards to the crown. Small spans, up to eighty feet, could be completed in one pour. Spandrel walls, posts or arches were formed after the arch ring was completed.

A large, 1,273-foot, twelve span concrete bridge that used an interesting method of formwork and construction was the Market Street Bridge in Wilkes-Barre. Designed by the nationally known New York City architectural firm of Carrere and Hastings, this bridge spans the Susquehanna River between Wilkes-Barre and Kingston in Luzerne County and was built in two longitudinal sections using adjustable steel truss centering to construct arches varying from 82 to 120 feet in length. The bridge, completed in 1929, utilized a 1,700-foot cableway to handle the concrete forms, reinforcing steel and centering trusses.

Barrel arches, which would contain earth fill, were waterproofed and prepared to provide adequate drainage for the fill. Asphalt, waterproof plasters, and saturated, coated fabrics were used for waterproofing the surface of the barrel arch and the inside of the spandrel walls. Drainage was generally accomplished by tiles or pipes laid parallel to the extrados and running to outlets at the piers or abutments.

When the arch structure was sufficiently set, the centers were gradually released. The time necessary to allow the concrete to set was usually governed by the accepted standard of twenty-eight days but varied according to weather or other conditions. Centering for concrete arches was supported by wedges, much like that for stone arches. The wedges were removed carefully, starting first at the crown and then moving from both sides to the supports. For multiple arch bridges, the centers were removed simultaneously from all the arches.

After the temporary structure was removed, the work of finishing the concrete surface began. The framework, unless lined with smooth material or steel plates, left marks on the surface of the concrete. The treatment applied to the concrete surface was usually determined by the location and use of the bridge. Sometimes stone facing was applied, such as is found on the Wissahickon Memorial Bridge in Philadelphia. If the concrete was left exposed, the surface was either worked to provide a surface texture or it was smoothed. A smooth surface was accomplished by plastering the surface or rubbing it. Textured surfaces were either made by hand tools which simulated stone surfaces, or power chisels which uniformly roughened the surface. Other methods, described earlier, were also commonly used.

Just as it allowed greater flexibility in structural expression, concrete masonry lent itself to a wider range of architectural treatments and became more prevalent than stone arch construction early in the twentieth century.

The Walnut Lane Memorial Bridge, built between 1947 and 1949 by the City of Philadelphia, was the first prestressed concrete girder bridge built in the United States. Crossing Lincoln Drive and Monoshone Creek in Philadelphia, the Walnut Lane Memorial Bridge was designed by Gustav Magnel, who was regarded as a leading authority on concrete prestressing. The use of prestressed concrete girders, which are large, reinforced concrete beams formed at the manufacturing site and shipped to the construction site, continues to be a popular modern day bridge design. Although the Walnut Lane Memorial Bridge did not last long, it was replaced with a new structure in 1990, other smaller concrete beam bridges from the 1950s are scattered throughout the Commonwealth. One of the oldest extant examples is the Bridge over Hickory Run in Carbon County. Located within Hickory Run State Park, this 1950 prestressed concrete beam carries the Scenic Drive over Hickory Run and features a unique rustic log railing.

Market Street bridge details

GEORGE WESTINGHOUSE MEMORIAL BRIDGE

Location: Lincoln Highway over Turtle Creek, North Versailles Township, Allegheny County

Year Built: 1931

Type/Length: Open Spandrel, Multiple Span/1,598 feet

The central span of the George Westinghouse Memorial Bridge, measuring 460 feet, is one of the longest concrete arch spans in the United States. The bridge is located near the main factories of the Westinghouse Company, which was founded by the nineteenth century industrial giant, George Westinghouse, after whom this bridge is named.

The five parabolic arch spans of this bridge are two-ribbed open spandrel arches. The Westinghouse Bridge carries Route 30 traffic 200 feet above the streambed as it spans the wide Turtle Creek Valley. Adding to this bridge's dramatic appearance is the extremely high rise-to-span ratio of its arches; the central span rise is 153.5 feet for its 460-foot span. The great height of the bridge is accented by decorative pylons at each pier.

This fixed-arch bridge was designed by Vernon R. Covell, Chief Engineer of the Bureau of Bridges in Pittsburgh's Department of Public Works. During construction, the reinforced concrete arches were supported on steel centering. The central arch centering consisted of a three-hinged steel arch which was used for both ribs. The contractor for the bridge construction was Booth and Flynn Company.

LARIMER AVENUE BRIDGE

Location: Larimer Avenue over Washington Boulevard, Pittsburgh, Allegheny County

Year Built: 1911-1912

Type/Length: Open Spandrel, Single Span/546 feet

With a clear arch span of 312 feet, the Larimer Avenue Bridge in Pittsburgh over Washington Boulevard broke the record for longest reinforced concrete arch in the world when it was constructed in 1912, surpassing Walnut Lane Bridge across the Wissahickon Creek, the previous recordholder. The Larimer Avenue Bridge was designed by the City of Pittsburgh Public Works Department with John F. Casey serving as a contractor and built by the Phoenix Bridge Company. The bridge was built as part of Pittsburgh's City Beautiful Movement.

MARKET STREET BRIDGE

Location: Market Street over the Susquehanna River, Harrisburg, Dauphin County

Year Built: 1928

Type/Length: Solid Spandrel, Multiple Span/1,415 feet

The Market Street Bridge was designed by the engineering firm of Modjeski and Masters and a consulting architect, Paul Philippe Cret. The sixteen low rise arch spans of this bridge were built of concrete and faced with stone. Viewed in elevation, the stone-faced arches recall the 200-year tradition of building stone highway bridges in Pennsylvania. This bridge is located in Harrisburg and connects City Island to the mainland. Its traditional and monumental quality is enhanced by the two ionic columns standing at the eastern approach. A plaque on the bridge informs that these columns were taken from the former state capitol which had been destroyed by fire in 1879.

The facing of the arches and piers is coursed rusticated ashlar with smoother ashlar used for the voussoirs and spandrel walls. The massive rough ended piers were originally topped with specially designed light standards. The construction of the Market Street Bridge was carried out by the Harrisburg Bridge Company and the James McGraw Company.

SOLDIERS AND SAILORS MEMORIAL BRIDGE

Location: State Street over Paxton Creek and Cameron Street, Harrisburg, Dauphin County

Year Built: 1930

Type/Length: Closed Spandrel, Multiple Span/1,312 feet

Built as a memorial to those who fought in World War I, the Soldiers and Sailors Memorial Bridge carries State Street to the Capitol Plaza. Designed by John E. Greiner Company, engineers, and Gehron and Ross, architects, the main structure consists of seventeen reinforced concrete segmental arches. These arches are supported by reinforced concrete piers faced with granite and limestone. The concrete arches are scored to simulate stone. Begun in 1926, the 1,312-foot-long structure was completed in 1930.

The fortress-like quality of this massive concrete structure, with its 300-foot-high obelisks, evokes the military subject of the monument. Remarkable care was taken to design decorative military details throughout the bridge. The arch keystones, each formed in the shape of a different military object, exemplify the attention that was given to the design of this bridge.

OLD COLUMBIA-WRIGHTSVILLE BRIDGE (INDEX NO. C-3)

Location: Route 462 over the Susquehanna River, between Columbia Borough, Lancaster County and Wrightsville Borough, York County

Year Built: 1929-30

Type/Length: Open Spandrel, Multiple Span/6,657 feet

When completed, this forty-eight-span bridge, designed by James B. Long, was the longest multiple arch concrete highway bridge in the world. It consists of twenty-eight arches across the river and twenty girder spans supporting the land approach. In 1984, the Old Columbia-Wrightsville Bridge was designated as a National Historic Civil Engineering Landmark.

The river piers carry twenty-eight three-ribbed open spandrel reinforced concrete arches, each spanning 185 feet. The surface of the concrete segmental arches is scored to imitate voussoirs. Due to the length of this bridge, a unique system was devised by the bridge engineers for its construction. It included reusable steel forms and a parallel construction railway. The bridge construction progressed smoothly and was organized for continuous day and night work which resulted in completion approximately 140 days ahead of schedule. It was dedicated on Armistice Day, 1930, to the memory of Lancaster and York County citizens who had served their nation in war.

This concrete bridge is the fifth bridge located at this historic river crossing. Its predecessors included three covered bridges and a metal truss bridge. The site was served by its first covered bridge from 1812 to 1833, following years as a significant ferry crossing. A tablet placed on the bridge by the Colonial Dames of America, reading "Near this bridge was located the first important ferry over the Susquehanna River, gateway for emigration into the great west", commemorates the ferry.

WALNUT LANE BRIDGE OVER WISSAHICKON CREEK

Location: Walnut Lane over Wissahickon Creek, Philadelphia

Year Built: 1907

Type/Length: Open Spandrel, Multiple Span/565 feet

When the Walnut Lane Bridge over Wissahickon Creek in Philadelphia was completed in 1908, it was the world's longest and highest concrete arch bridge with a main span of 233 feet and a height of 147 feet. Built in Fairmount Park, a National Register-listed historic district, the Walnut Lane Bridge took inspiration from a 1904 masonry bridge in Luxembourg over the Petrusse River and serves as a connection between the neighborhoods of Roxborough and Germantown.

Designed by chief engineer George S. Webster and his assistant engineer, Henry H. Quimby, from the Philadelphia Department of Public Works, this two-ribbed, open spandrel bridge uses a minimum amount of reinforcing steel. In contrast, the Walnut Lane Bridge contains a large quantity of stone, which was embedded in the concrete mixture to provided additional strength.

The bridge features several ornamental details including a reinforced concrete sidewalk and balustrade. The sidewalk is supported on cantilevered floor beams, the ends of which are encased in concrete brackets. A set of four commemorative plaques were installed and record the construction history of the Walnut Lane Bridge. A rehabilitation project started in 2015 and completed in 2016 included the careful replication of the original exposed aggregate finish of the 884 balusters using a scheme of embedding vertical stainless-steel rods in newly placed structural concrete sidewalk slabs and anchoring precast concrete balustrade sections to them.

MARKET STREET BRIDGE

Location: Market Street over the North Branch of the Susquehanna River, between Wilkes-Barre and Kingston, Luzerne County

Year Built: 1926-29

Type/Length: Open Spandrel, Multiple Span/1,274 feet

One of the most architecturally significant bridges crossing the Susquehanna River, this monumental twelve-arch reinforced concrete and granite structure incorporates two pylons at each end; each pylon is topped with a giant carved limestone eagle. The bridge was designed by Carrere and Hastings, a renowned New York City architectural firm that also claims the New York Public Library among its important commissions, and built by the Pittsburgh contracting company, Walter S. Rae, Inc.

A water gauging station (inoperable since 1943) and ornamental light standards were included in the original construction. A rehabilitation project in the 1980s included replication of the original light standards. The six longer spans over the river comprise open spandrel arches of three wide ribs each. The end spans over the floodplain consist of shorter barrel arches with solid spandrel walls.

Construction of the twelve arches of this long-span concrete bridge was accomplished using adjustable steel trusses for centering. A 1,500-foot cableway hung from large towers on each bank of the river to convey concrete in hoppers to the middle spans. To allow a continuous flow of traffic, the bridge was built in two longitudinal sections. Until the first section was completed, traffic was carried by the metal truss bridge which this concrete bridge replaced.

FRANKFORD AVENUE BRIDGE

Location: Frankford Avenue over Poquessing Creek, Philadelphia

Year Built: 1904

Type/Length: Solid Spandrel, Single Span/73 feet

This early concrete structure was built in 1904 by the City of Philadelphia. It is a good example of a filled barrel arch bridge, a type commonly used for small-span highway bridges in the early twentieth century. A variety of surface treatments and parapet designs was used for these concrete arch bridges. On the Frankford Avenue Bridge, the concrete of the spandrel walls was scored to imitate stone courses and the arch ring was articulated to simulate voussoirs. The parapet features urn-shaped balusters. This treatment of concrete, and the use of decorative balusters, was typical for bridges built in parks or cities in the early 20th century.

This reinforced concrete arch shows careful craftsmanship in its construction. The reinforcement used in the segmental arch was a combination of beam/bar reinforcement; a steel rib was constructed of four angles connected by ¼ inch reinforcing bars. John McMenamy was the contractor.

TUNKHANNOCK CREEK VIADUCT

Location: Norfolk Southern Railway over Tunkhannock Creek, Nicholson Borough, Wyoming County

Year Built:1912-1915

Type/Length: Open Spandrel, Multiple Span/2,375 feet

Featuring ten semicircular arches, the Tunkhannock Viaduct, also known as the Nicolson Bridge, was built between 1912 and 1915 for the Delaware, Lackawanna and Western Railroad. The viaduct was part of the Nicholson Cutoff, which relocated the mainline of the railroad, and spanned the valley 240 feet above the Tunkhannock Creek. The viaduct was designed by Abraham Burton Cohen, who also designed the Martin Creek Viaduct, and built by Flickwir & Bush, Inc. At the time the Tunkhannock Creek Viaduct was constructed, it was the largest reinforced concrete railroad bridge ever built with a total length of 2,375 feet.

In 1975, the American Society of Civil Engineers (ASCE) designated the Tunkhannock Creek Viaduct as a National Historic Civil Engineering Landmark. Today, the bridge serves the Norfolk Southern Railway and is still used for freight service.

HILL-TO-HILL

Location: PA378 over the Lehigh River, Bethlehem City, Northampton County

Year Built: 1921-1924

Type/Length: Solid Spandrel, Multiple Span/1,607 feet

When the Hill-to-Hill Bridge was completed in 1924, the structure included a ten arch solid spandrel bridge, two Hudson truss spans, and six access ramps. The bridge eliminated dangerous crossings over railroad tracks and connected three boroughs in the City of Bethlehem: Bethlehem, West Bethlehem, and South Bethlehem. Clarence W. Hudson, a former design engineer for the Phoenix Bridge Company, designed the trusses and served as lead engineer in the construction of the Hill-to-Hill Bridge. The Hudson truss spans, the only known example of this design, were built by the Bethlehem Steel Company, a subcontractor on the project whose flagship plant was located directly adjacent to the bridge site. Hudson created the unique through truss design to accommodate the need for a vehicular access ramp between the vertical members by eliminating and shifting diagonal members' locations.

The concrete arch bridge was built by Rodgers & Hagerty, Inc. of New York City, the general contractor. Construction of the Hill-to-Hill Bridge involved new, advanced techniques including a system of distribution towers used to transport concrete from the mixing plant to placement on the bridge. Other features on the bridge included a concrete balustrade and bronze streetlamps on reinforced concrete poles. Since 1965, four of the eight elaborate access ramps were removed, and the northern approach was altered; however, the concrete arches and the two Hudson trusses remain.

Hill-To-Hill bridge details Northampton County

Holmes Avenue Bridge Southwest Pylon in Philadelphia

APPENDIX • BRIDGE COMPANIES

The following annotated list of bridge companies comprises firms known to have built highway bridges throughout Pennsylvania. Each company was identified by bridge plates on the historic bridges or by data found in PennDOT files. The descriptive information for each bridge company was compiled from several sources, including published histories of various Pennsylvania counties, newspapers, the Virginia, West Virginia and Ohio DOT bridge inventories, the Ohio SHPO files and Victor Darnell's Directory of American Bridge Building Companies.

A & P Roberts Company
Philadelphia, PA

A & P Roberts Company functioned as proprietors for the Pencoyd Iron Works. Sometimes bridge plates would list A & P Roberts Co.

Allentown Bridge Company
Allentown, PA

The Allentown Bridge Company was organized in 1911 by a trolley company, The Lehigh Valley Transit Company, for the sole purpose of building and maintaining the Albertus L. Meyers Bridge, commonly known as the 8th Street Bridge, in Allentown.

Berlin Iron Bridge Company
East Berlin, Connecticut

The Berlin Iron Bridge Company began as the Corrugated Metal Company. The firm advertised iron highway and railroad bridges, iron buildings, general wrought iron construction and the manufacture of heavy plate girders, chord bars and corrugated iron. The firm is most associated with lenticular truss bridges but built other types as well. It was acquired by American Bridge Company in 1900.

Canton Bridge Company
Canton, OH

Canton Bridge Company was incorporated in 1891. The company's principal products were bridges, turntables, and iron work. In 1925, the company was bought by the Massillon Steel Joist Company. The two companies operated separately for four years, then merged into the Macomber Steel Company. During its 33 years of existence, the Canton Bridge Company did business throughout the United States.

Champion Bridge Company
Wilmington, OH

Champion Bridge Company began as Zimri Wall and Company in 1860. In 1871, Zimri and Jonathan Wall formed Z & J Wall and Company, a bridge building firm that erected timber and wrought iron bridges. In 1874, the company named was changed to Champion Iron Bridge Company. From 1878-1881 it was called Champion Iron Bridge and Manufacturing Company and in 1881 the name became Champion Bridge Company. In the early 1880's, the firm was one of the first to promote and use steel for smaller highway bridges. The firm expanded, opening regional offices in Atlanta, Birmingham, and Chattanooga, between 1885 and 1910. Champion Bridge Company diversified ed into general steel erection and structural work and remains in business.

Cleveland Bridge Company
Cleveland, OH

This firm was incorporated in 1893 for the manufacture, construction and contracting of bridges and other structures. Cleveland Bridge Company became part of King Bridge Company in 1923.

Columbia Bridge Works
Dayton, OH

Columbia Bridge Works began in 1848 as a builder of wooden bridges under the ownership of D.H. and C.C. Morrison. The bridges fabricated by the company included Pratt, Whipple, Triangular, and Arch Trusses, and several rigid suspension bridges. Morrison received three patents for his bridge design in 1858, 1867, and 1871.

Concrete Steel Bridge Company
Clarksburg, W. VA

Concrete Steel Bridge Company was incorporated in 1914 by Frank McEnteer and P.M. Harrison. The firm specialized in reinforced concrete bridges and industrial buildings. By 1925, branch offices were opened in Pittsburgh and Harrisburg. The Concrete Steel Bridge Company was liquidated in 1931.

Corrugated Metal Company
East Berlin, CT

This firm was the predecessor company to Berlin Iron and Bridge Company. Corrugated Metal Company began making iron roof trusses around 1875 and bridges by 1878. They advertised as engineers and contractors for the Douglas patented wrought iron bridge. The firm's name was changed to Berlin Iron Bridge Company in 1883.

Dean and Westbrook
New York, NY

From circa 1885 to 1895, Casper Dean and John Westbrook acted as agents for the construction of Phoenix column highway bridges. Dean and Westbrook were responsible for bidding the project, signing contracts with local officials, and providing information to engineers. The Phoenix Bridge Company prefabricate the truss bridges and they were erected on stie by Dean and Westbrook.

Fort Pitt Bridge Works
Pittsburgh, PA

Fort Pitt Bridge Works' main office was located in Pittsburgh. In 1894, the firm purchased Pittsburgh Architectural Iron Works, located in Cannonsburg, PA. The bridge works were probably located in Cannonsburg. In 1933, Fort Pitt Bridge Works purchased the Massillon Bridge Company.

Groton Bridge and Manufacturing Company
Groton, NY

This firm was founded in 1877 as Groton Iron Bridge Company. The name was changed to Groton Bridge and Manufacturing Company in 1887 and Groton Bridge Company in 1901. Groton also manufactured punches, straightening machines and woodworking machinery.

Harrisburg Bridge Company
Harrisburg, PA

The Harrisburg Bridge Company was incorporated July 6, 1812 to build the first Market Street Bridge in Harrisburg, Theodore Burr's Camelback covered bridge built between 1813-1817. The Harrisburg Bridge company continued as a viable business, building the Market Street steel replacement bridge, completed in 1906 and the concrete and stone arch bridge completed in 1928. Company presidents were: Thomas Elder (1812-1847), Jacob M. Haldeman (1847-1857), James McCormick (1857-1871), Henry McCormick (1871-1900), Henry McCormick Jr. (1900-1910), Robert McCormick (1910-1918) and Richard C. Haldeman (1918-1928).

King Bridge Company
Cleveland, OH

The King Bridge Company traces its beginnings back to 1858 under the proprietorship of Zenas King. He began to build iron bridges as well as wood and combination spans. In 1859, he designed and built his first all-iron bridge. His reputation was established on the tubular arch bridge, which he patented in 1861. In 1871, Zenas King incorporated King Iron Bridge and Manufacturing Company. By 1884 the company was able to claim the largest highway bridge works in the United States. Its name was changed to King Bridge Company about 1893. King Bridge Company continued to build bridges until a few years after World War II.

Massillon Bridge Company
Massillon, OH

Joseph Davenport, credited with building the first cantilever bridge, established the Massillon Iron Bridge Company in 1869. In 1887, it was incorporated as the Massillon Bridge Company. The name was changed about 1900 to the Toledo-Massillon Bridge Company. From 1909 to 1933, the firm did business as Toledo-Massillon Bridge Company. The company continued its business until 1933 when it was purchased by Fort Pitt Bridge Works.

Morse Bridge Company
Youngstown, OH

Morse Bridge Company was founded 1878. The name was changed to Youngstown Bridge Company between 1888 and 1891.

Nelson & Buchanan
Chambersburg, PA

Nelson and Buchanan were agents for the Pittsburgh Bridge Company until about 1900, when bridge plates began listing Nelson and Buchanan solely as the bridge builders.

Oswego Bridge Company
Owego, NY

Established in 1891, this regional fabricator built metal truss bridges with standardized details. This firm may be the same as the Oswego Bridge Company.

Pencoyd Iron Works
Philadelphia, PA

Pencoyd Iron Works was operated by the A. and P. Roberts Company. Iron production began at Pencoyd about 1852 and bridge fabrication began 1887. The plant was located at Pencoyd, and the office was located in Philadelphia. American Bridge Company acquired Pencoyd Iron Works in 1900.

Penn Bridge Company
Beaver Falls, PA

This firm was organized by T.B. White & Sons in 1868, with its plant located in New Brighton. The bridge works were moved to Beaver Falls in 1878. The firm reorganized and incorporated in 1887 as the Penn Bridge Co. Products included wrought iron, steel and combination bridges; iron substructures, buildings and roof trusses; plate, box and lattice girders and architectural ironworks.

Phoenix Bridge Company
Philadelphia, PA

In 1827, Benjamin and David Reeves purchased the Phoenix Iron Works, a foundry, rolling mill and nail factory. The company grew and was incorporated as the Phoenix Iron Company in 1855. The Phoenix Iron Company manufactured rolled beams and various structural shapes and constructed bridges. In 1870 a subsidiary company was established by the Reeves family and Thomas Clarke, called Clarke, Reeves and Company. The plant, located in Phoenixville, was called Phoenixville Bridge Works and their offices were located in Philadelphia. In 1874 the firm's name was changed to Phoenix Bridge Company. Phoenix built bridges throughout the nation, one of its trademarks being the patented Phoenix column. In the 1940's the company was acquired by the Barium Steel Corporation and was renamed the Phoenix Steel Corporation.

Pittsburgh Bridge Company
Pittsburgh, PA

This firm was established in 1878, incorporated in 1881 and purchased by the American Bridge Company in 1900.

Schuylkill Bridge Works
Phoenixville, PA

This firm built the Pratt pony truss bridge over White Clay Creek in Chester County. John Denithorne Son and Co. was the proprietor for Schuylkill Bridge Works, but the name was also used by Lewis Shoemaker in 1903 in Pottstown.

Smith Bridge Company
Toledo, OH

Robert W. Smith founded his bridge building firm in Toledo in 1867. He began by producing patented pre-cut timber Smith trusses. In 1870, he formed the Smith Bridge Company. By 1875, the Smith Bridge Co. began to build wrought iron truss bridges and later advertised the capability for iron, wood and combination bridges. Smith sold the company in 1890 and the name was changed to Toledo Bridge Company. In 1901, it was sold to American Bridge Company.

West Penn Bridge Company
Canton, OH

The Wrought Iron Bridge Company was organized in 1864 by David Hammond and incorporated in 1871. The company's base was its patented arch bridge. In 1874, the company published its Book of Designs which included its patented "Hammond and Abbott Arch Bridge." The firm was among the early advocates of wrought iron bridges over wood or cast iron. By circulating agents and erecting a wide variety of structures throughout the continental U.S., the Wrought Iron Bridge Co. became one of the leading bridge building firms in the United States.

Youngstown Bridge Company
Youngstown, OH

This firm was established in 1878 as Morse Bridge Company. The name was changed to Youngstown Bridge Company between 1888 and 1891. In 1900, the American Bridge Company bought the Youngstown Bridge Company.

Starrucca Viaduct in Susquehanna County

Kidds Mill Bridge in Mercer County

APPENDIX • GLOSSARY, ACKNOWLEDGEMENTS & REFERENCES

Abutment – Substructure supporting the end of a span, retaining or supporting the approach embankment.

Anchor Span – Located at the outermost end, it counterbalances and holds in equilibrium the arm extending in the opposite direction from the major point of support.

Arch Barrel – The surface of the inner arch that extends the full width of the structure.

Arch Ring – The outer course of stone or brick; also called voussoirs.

Ashlar – Masonry composed of rectangular units of burnt clay, shale or stone, generally larger than brick, and having sawn, dressed or squared beds and joints laid in mortar.

Balustrades – An entire concrete or stone railing system including a top rail, balusters (vertical members) and sometimes a lower rail.

Beam – A structural member laid horizontally carrying vertical loads along its length by resisting bending.

Bearing – A device at the ends of beams and/or girders which is placed on top of the sub-structure (pier or abutment) and upon which the beam and/or girder rests. They can be fixed or expansion bearings.

Bearing Seat – Top of masonry substructure supporting bridge bearing.

Belt Course – A horizontal band of masonry, generally narrower than other courses, extending across the façade of a structure; may be flush or projecting. Also called a strong course.

Bottom Chord – The horizontal tension beam supporting the flooring system and other members of a truss.

Brace-ribbed arch – Two parallel or nearly parallel chords connected by open webbing; also called trussed arched.

Buttress – A bracket-like wall, projecting from another wall, to reinforce it. Generally, a buttress runs vertically on the face of a wall and protrudes further from the wall at the bottom than at the top.

Cable – Part of a suspension bridge, its function is to receive the bridge floor loads and transmit them to the tower and anchorages.

Cantilever – A structural member which projects beyond its supporting wall or column and is supported at one end only.

Centering – Temporary structure which supports the masonry while the arch ring is being constructed.

Closed Spandrel Wall – A masonry or concrete wall which encloses the fill material.

Compression – Type of stress involving pressing together.

Continuous Span – A superstructure designed to extend continuously over one or more intermediate supports.

Corbelled Arch – Masonry built over a wall opening by uniformly advancing courses from each side until they meet at a midpoint. No arch action is produced. Also called a false arch.

Counter – A truss web member which functions only when the span is partially loaded.

Coursed Rubble – In stone masonry, a layer of cut or uncut pieces laid with horizontal or slightly longitudinally inclined joints.

Cradle – Located on top of the towers of a suspension bridge. The cable that is draped over the tower rests in the cradle.

Deck – The floor of a bridge intended for vehicular and/or pedestrian use.

Deck Truss – A bridge having its floor elevation nearly at the elevation of the uppermost portion of the superstructure.

Dressed Stone – Stone that has been worked to the desired shape and finished. The faces that are exposed are smooth.

Elliptical Arch – A multi-centered arch.

End Post – The end compression member of a truss either in a vertical or inclined position.

Extrados – The curve defining the exterior surface of an arch.

Eyebars – Structural member consisting of a long bar body with enlarged forged ends or heads; each head has a hole through it for engaging connecting pins.

False Arch – Masonry built over a wall opening by uniformly advancing courses from each side until they meet at a midpoint. No arch action is produced. Also called a Corbelled Arch.

Falsework – A temporary wooden or metal framework built to support a structure during its construction and until it becomes self-supporting.

Fill – Material, usually soil, used to raise or change the surface contour of an area, to construct an embankment, or to be placed within a stone or concrete arch bridge.

Fixed Arch – A structure anchored in its location.

Flange – The horizontal parts of a rolled I-shaped beam extending transversely across the top and bottom of the web.

Floor Beams – A horizontal member located transversely to the general bridge alignment which supports the bridge deck.

Footing – The enlarged lower portion of a substructure, which distributes the structure load either to the earth or to supporting piles. Generally found below the surface of the ground and not visible.

Girder – Any large beam, especially if built of steel plates, which acts as a primary support, usually receiving loads from floor beams and stringers.

Hinged Arch – An arch which is supported by a pinned connection either at each end support and/or a pin located near mid-span.

Humpback – A term used generally to describe a combination of approach roadway and bridge structure characterized by steep grades approaching the bridge from both directions.

I-Beam – A structural member with a cross-sectional shape similar to the capital letter "I". The top and bottom horizontal portions are the flanges, and the center vertical portion is the web.

Intrados – Curve defining the interior surface of the arch.

Joint – The space between individual stones in a masonry bridge usually filled with mortar. In concrete, it is a division in continuity of the concrete.

Keystone – The symmetrically shaped, wedge-like stone located in a head ring course at the crown of the arch.

King Post – Two triangular panels with a common vertical; simplest of triangular system trusses.

Lacing – An assemblage of bars, channels or angles on a truss composed of diagonal members. Also called lattice.

Laggings – Ribs spanned by narrow planks which support the arch stones temporarily during construction of the bridge arch.

Lateral Bracing – The bracing assemblage engaging a truss perpendicular to the plane of the truss intended to resist lateral movement and deformation resulting from wind and lateral vibration.

Lattice – An assemblage of bars, channels or angles on a truss composed of diagonal members.

Live Load – A dynamic moving loads such as traffic which is suddenly applied to a bridge; also accompanied by vibration or movement affecting its intensity.

Masonry – That portion of a structure composed of stone or brick.

Obelisk – A monumental, four-sided stone shaft, usually monolithic and tapering to a pyramidal tip.

One-Hinged Arch – See Hinged Arch.

Open Spandrel Wall – An unfilled spandrel where the arch ring receives its loads through interior spandrel walls, ports, columns, or transverse walls.

Parapet – A low wall along the outside edge of a bridge deck (floor) running longitudinally along the bridge. Its purpose is to protect vehicles and pedestrians.

Pier – Stone, concrete, brick, steel, or wood structure to support the ends of the spans of a multi-span superstructure at an intermediate location between its abutments.

Pile – A shaft-like linear member driven into the earth to carry loads through weak soil strata to a depth capable of supporting necessary loads.

Pin – A cylindrical bar used to connect the members forming a truss.

Pony Truss – A truss having insufficient height to use a top chord system of lateral bracing.

Portal – The clear space of a through truss bridge forming the entrance.

Post – Sometimes used synonymously for "column". Located perpendicular to the bottom chord of a truss.

Pylons – A large, monumental structure usually marking the entrance to a bridge or forming part of gateway. Alternatively, pylons are used synonymously with "towers" on a cable-stay bridge from which cables are attached to support the bridge deck.

Reinforced Concrete – Concrete with steel reinforcing bars added to it which bond to the concrete and supply tensile strength to the concrete.

Rib – Curved structural member supporting a curved shape or panel.

Rubble – Irregularly shaped pieces of stone in the undressed condition obtained from a quarry and varying in size.

Segmental arch – A circular arch in which the intrados is less than a semi-circle.

Semi-Elliptical Arch – See Elliptical Arch.

Simple Span – Span of a bridge which is carried by longitudinal members that are not continuous over intermediate supports.

Skew Angle – When the longitudinal members of a bridge are not perpendicular to the substructure; the skew angle is the acute angle between the alignment of the bridge and the centerline of the substructure.

Spandrel – An area, roughly triangular, included between the extrados of an arch and the horizontal member above it.

Spring Line – A horizontal, transverse line along the face of an abutment or pier at which point the intrados of an arch takes its beginning.

Squared Stone Masonry – Stone squared by a mason which still has a rough finish; second-class masonry.

Stringer – A longitudinal beam supporting the bridge deck.

Strut – A general term applying to a piece or member acting to resist compressive stress.

Substructure – The abutments, piers or other constructions built to support the span of a bridge superstructure.

Superstructure – The entire portion of a bridge structure which primarily receives and supports traffic loads and in turn transfers the reactions resulting there to the substructure.

Suspenders – On a suspension bridge, a wire cable, metal bar or rod connecting a suspension member at one end and the bridge floor system at the other, transferring load tension from the road to the main suspension member.

Tension – Type of stress involving an action which pulls apart.

Three-Hinged Arch – See Hinged Arch.

Through Truss – A truss where the floor elevation is nearly at the bottom rather than the top of the superstructure, so that traffic travels between the supporting trusses.

Tie – a rod-like or bar-like member in a truss functioning to resist tension.

Tied Arch – An arch that has a member across the bottom connecting one side of the arch to the other.

Tower – A pier or frame supporting the cable of a suspension bridge.

Truss – A jointed structure made up of individual members arranged and connected, usually in a triangular pattern, so as to support longer spans.

Two-Hinged Arch – See Hinged Arch.

Uncoursed Rubble – Masonry not in layers with continuous horizontal joints but laid irregularly.

Undressed Stone – Unsmoothed stone as it was cut from a quarry.

Upper Chord – The top longitudinal member of a truss.

Voussoirs – One of the truncated wedge-shaped stones composing a ring course in a stone arch.

Web – The vertical center portion of an I-beam.

Web Members – The intermediate members of a truss, not including the end posts, usually vertical or inclined.

Wing Walls – The retaining wall extension of an abutment intended to retain the side slope material of an approach roadway embankment.

Riegelsville Bridge Bucks County

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Endnotes

[1] https://www.pa.gov/agencies/penndot/programs-and-doing-business/environment/cultural-resources-management-program.html

Panther Hollow Bridge in Schenley Park, Pittsburgh

Columbia/Wrightsville Bridge in York and Lancaster County

Dunlap's Creek in Fayette County

Frankford Ave Bridge over Pennypack Creek in Philadelphia

Bridge in English Center Borough, Lycoming County

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