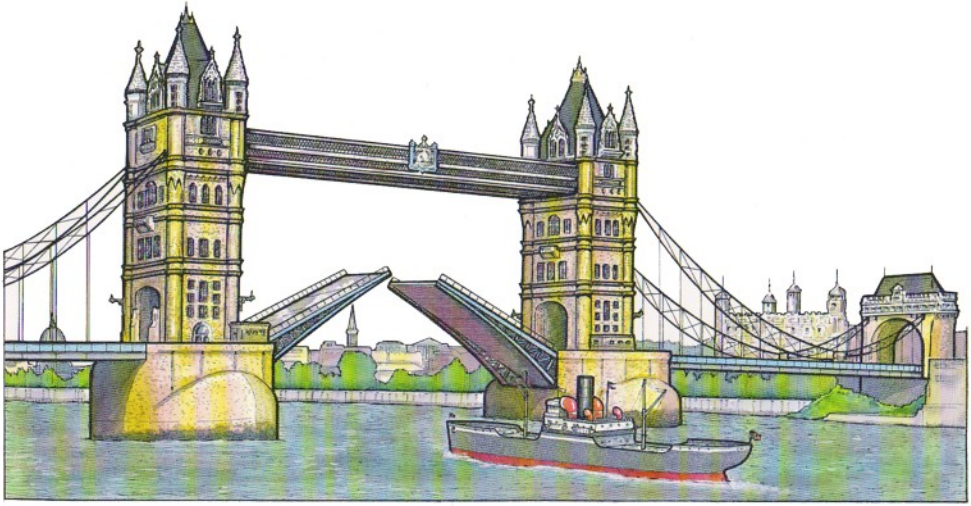
Dover Coloring Book

Bruce LaFontaine

BRIDGES OF THE WORLD
Coloring Book



Tower Bridge, London

INTRODUCTION

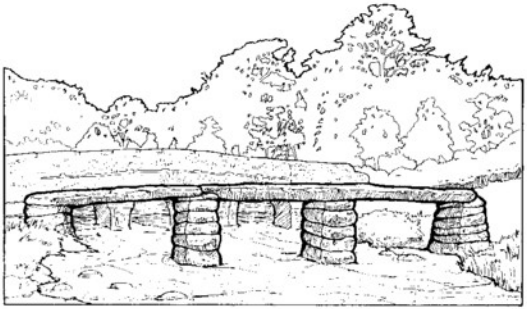
THE HISTORY OF bridges closely parallels the greater picture of the development of human civilization. This book traces that history from the ancient stone-slab bridges built in Europe around 2000 B.C. to the modern long-span, steel-wire suspension bridges that currently cross our rivers and harbors. Numerous well-preserved examples of historically significant bridges can still be found that date from the neolithic, Roman, medieval and Renaissance periods. Much of European and American history is closely intertwined with many of these bridges and the stories of their construction.

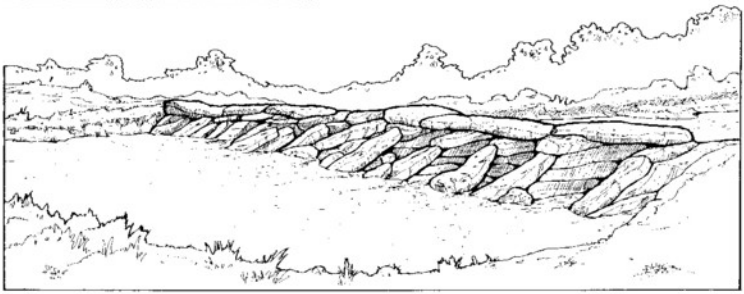
Described and depicted in this book are illustrations of famous, as well as lesser-known structures that show the three main bridge types: the beam, or girder bridge; the arch; and the suspension bridge, as well as variations of each. Though these bridges date back hundreds, even thousands of years, the principles behind their construction have remained constant. At the same time, the materials and techniques used have advanced tremendously.

The materials used for bridge construction range from stone, wooden timbers, and masonry or brickwork, to iron, steel and concrete. Most early bridges were built from natural materials that were readily available in the surrounding countryside. Stone and wood were very common for arch and beam bridges, while ropes made from plant fibers were used for early suspension bridges. As engineering and technology advanced, masonry became more widely used. During the industrial revolution of the eighteenth century, iron and steel were introduced as structural elements, opening up a whole new world of possibilities in bridge design. The twentieth century saw steel-reinforced concrete in common use.

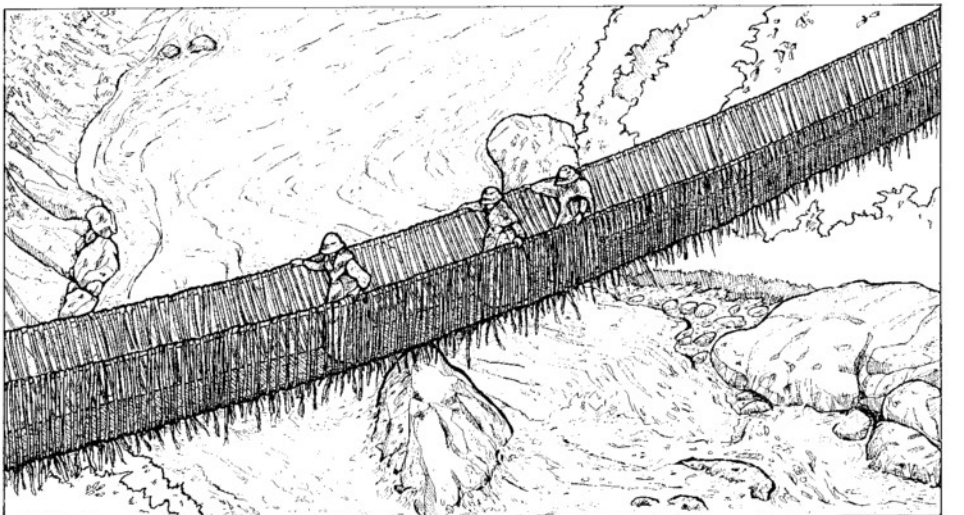
Bridges are more than just impressive examples of architectural and engineering achievement. They illustrate our highest collaborative efforts to control the environment by crossing natural barriers. Bridges are landmarks in history and romantic symbols that reflect specific places, peoples and their cultures. They represent the courage, skill and commitment of engineers, artists, scientists and skilled craftsmen, joining together for the common good. The history of bridges is a story of majestic structures, high ideals and dedicated people.

The bridges in this book are presented chronologically, by technological types (whatever their absolute date) as well as by absolute dating, beginning with neolithic-era stone-slab bridges, continuing through the great Roman bridge building period, into the medieval era, the Renaissance and concluding with the modern period of concrete and steel bridges. (Some illustrations are slightly out of chronological order to accommodate double-page spreads.)

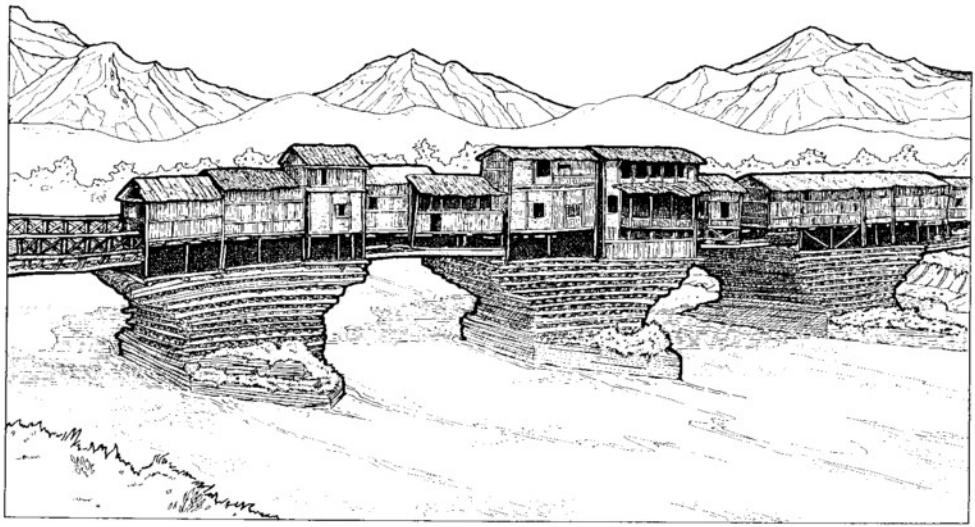




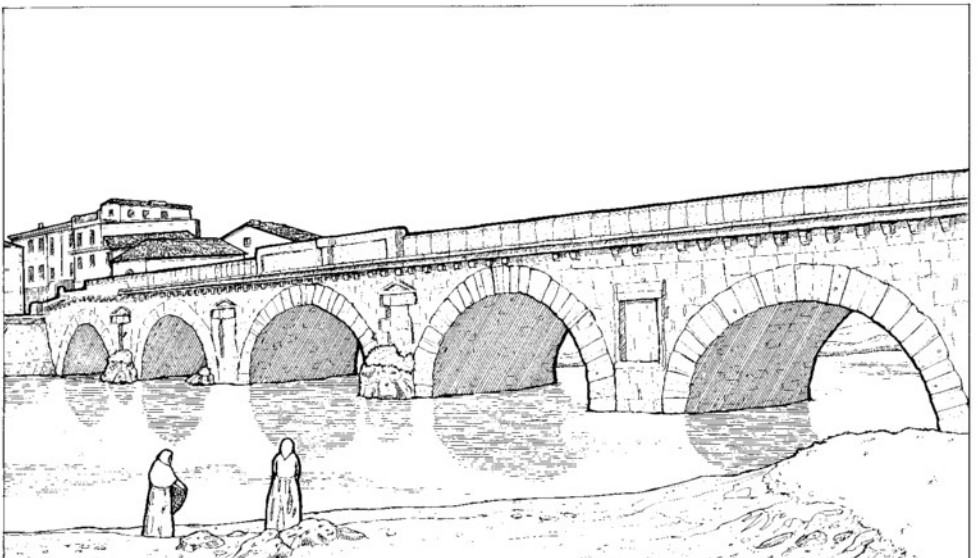
Stone-slab "clapper" bridges. Named for the Anglo-Saxon word for stepping-stones, "clapper" bridges are the oldest bridges still in existence. Stone slabs were placed horizontally from the shore to piles of smaller stones built within the river called "piers." The slabs were placed from pier to pier across the river until the opposite shore was reached. At top left is the Postbridge "clapper" bridge over the East Dart River, near Dartmoor, England. It was built using three granite slabs 15 feet long by 6 feet wide. These were placed atop two shore piers and two river piers built from stones cut or "dressed" to fit together in layers. It is thought to have been built around 2000 B.C. by the native inhabitants of England. Shown on the lower right is another stone-slab bridge, the "Tarr Steps," over the River Barle, near Winsford in Somerset, England. It is composed of 17 horizontal stone slabs laid end-to-end upon numerous river piers of piled stones. It dates from around 1000 B.C.



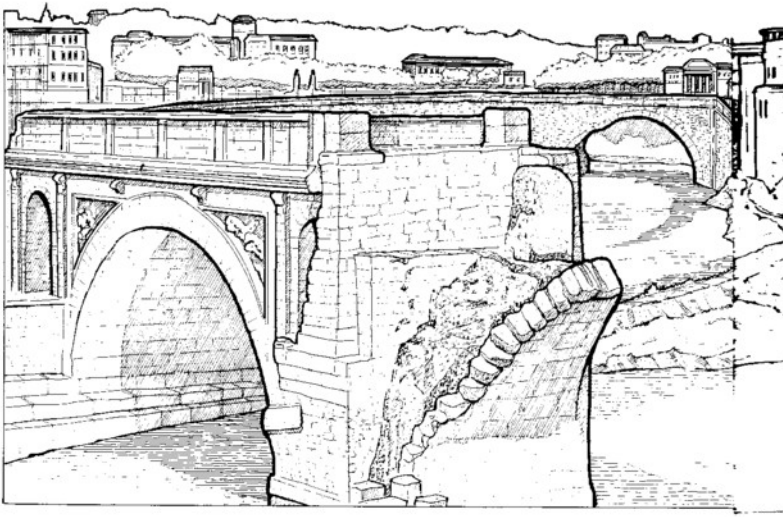
Rope suspension bridge. One of the most common forms of primitive bridge was the rope suspension bridge. These were made from vines, reeds, creepers and other plant fibers that could be braided into ropes or cables. These ropes were anchored at both shore ends and suspended over the river or gorge. Pictured above is a Peruvian "bejucos" bridge (ca. 1870), sometimes called a "tarabita" ("rope") bridge. It is constructed with four main ropes, two on the top and two on the bottom, all running parallel to one another. These main suspension ropes are woven from native plants called "bejucos." The upper ropes are used as handrails, and the lower ropes have sticks or planks intertwined to form a footpath. The top and bottom ropes are connected by more woven strands called "stringers" that add to the bridge's stability. This type of rope suspension bridge has been built on every continent for centuries and some are still in use. Although the materials used to construct rope bridges are primitive, the principle is the same as that of our modern, long-span steel-wire suspension bridges.



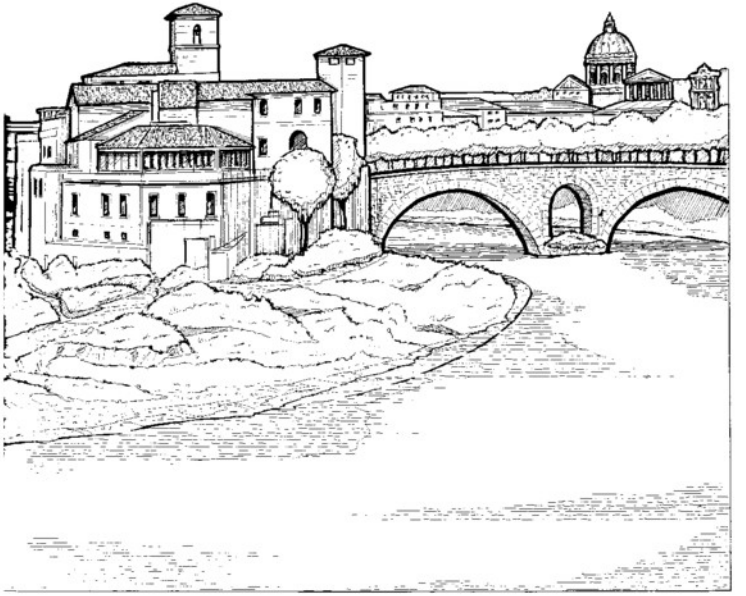
Timber cantilever bridge. One of the most colorful and interesting primitive bridges is the timber span shown above. Built during the nineteenth century, it is located in the city of Srinagar in the Himalayan valley of the Indian province of Kashmir. Constructed of timber beams and poles, the bridge crosses the River Jhelum, a span of 300 feet. It is lined with shops and houses that overhang the bridge walkway. This bridge is a type of beam bridge called a "cantilever," which has two or more sections connected by piers and whose main support is at each shore anchor point. The sections supported by the river piers reach out and connect in the middle of the span between each pier. The bases of the piers in the bridge above have pointed ends called "cutwaters" that allow for a smoother flow of water around the piers. This feature is still found in many modern bridges. Timber cantilever bridges like this one have been built for hundreds of years throughout Asia and many still remain intact.



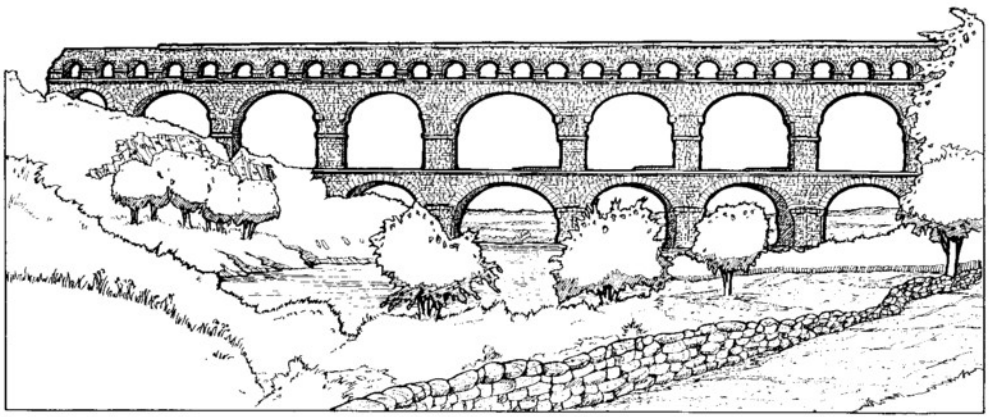
Pons Augustus, 21 B.C. One of the finest and best preserved examples of Roman bridge architecture is the Pons Augustus; construction began during the reign of the emperor Augustus and was completed by Tiberius in 21 B.C. It is located at Rimini, Italy, and crosses the River Marecchia with its five arched spans. The three center arches have span widths of 28 feet, and the two end arches span 23 feet.



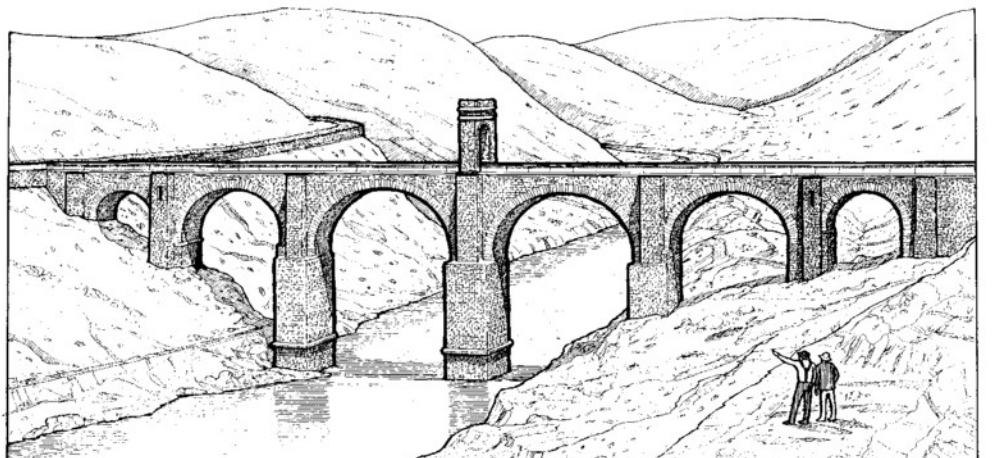
Pons Senatorius, 178 B.C.; Pons Cestius, 43 B.C.; Pons Fabricius, 62 B.C. The greatest engineers and bridge builders of the ancient world were the Romans. Using the basic principle of the arch, they built bridges and aqueducts of great size, complexity and beauty throughout their vast empire, which encompassed parts of Europe, Africa and Asia. The bridges shown above are among the oldest remaining examples of the Roman stone-arch bridge. They cross the Tiber River in Rome at a point where it is split into two channels by Tiber Island. In the foreground, with only one of its original arches showing, is the Pons Senatorius (Latin for "senators' bridge"), thought to have been constructed between 181 and 178 B.C. The original bridge had five arches but several were swept away during a flood in 1598. The Pons Senatorius is also known as the "Ponte Rotto" (Italian for "broken bridge"). The bridge in the left background is the Pons Cestius, built from 46 to 43 B.C. The bridge to the



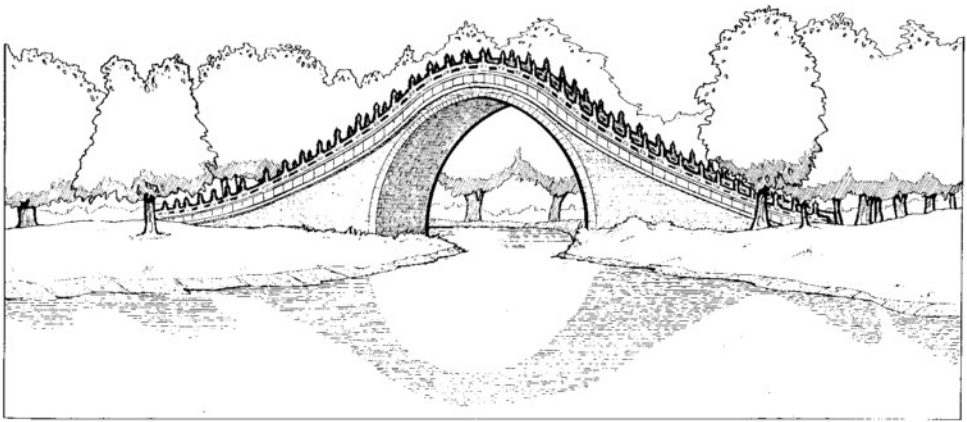
right of Tiber Island is the Pons Fabricius, named after its builder, the Roman engineer Lucius Fabricius. It is also called the "Ponte Quattro Capi" (Italian for "four-headed bridge"), for the numerous statues of Janus, the "four-faced" Roman god, carved on the bridge piers. It has two large arches, each with an 80-foot span, and one smaller arch of 20 feet. It was built around 62 B.C. The stone blocks used to build these and other Roman bridges were made from types of limestone called "peperino" and "tufa." The blocks were soft enough to allow them to be more easily cut or "dressed" to fit together. Covering these blocks and attached by iron clamps was a harder stone called "travertine." Although the first arched bridges were built in Mesopotamia around 4000 B.C., the Romans developed the practical and widespread architectural form now seen in modern concrete and steel-arch bridges.



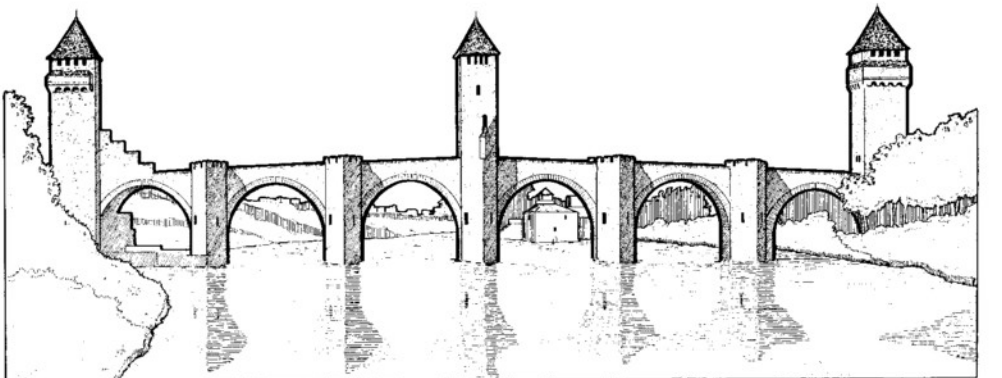
Pont du Gard, ca. 19 B.C. Because the Roman Empire stretched as far north as Great Britain and as far south as Africa, many fine examples of Roman bridges exist outside of Italy. One of the largest and most impressive structures still standing is the Pont du Gard aqueduct near Nimes, France. It was built by order of Agrippa, a deputy of Augustus, to carry water from the River Gard to the city of Nimes. The Pont du Gard consists of three levels or arcades, the top level being the water conduit, and the lower arcades having footpaths. The bottom tier has six arches ranging in span size from 81 to 51 feet. The second level is composed of 11 arches with similar span widths. The highest arcade has 36 arches, each with a span of 15 feet, stretching a total of 885 feet across the valley floor. The height at the top level reaches 155 feet above the river. An interesting feature of the Pont du Gard is that no mortar was used to join the stones together. They were cut or "dressed" so skillfully that they were able to be "laid up" without the use of mortar or cement.



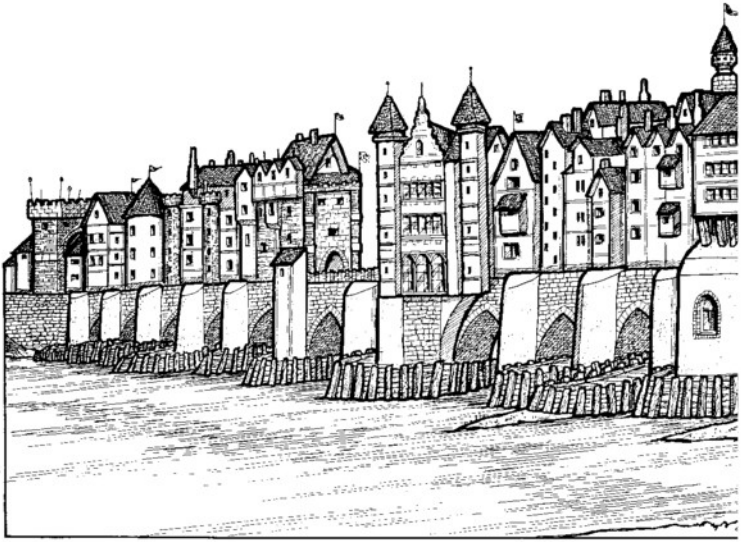
Puente Alcántara, 98 A.D. This large and sturdy Roman stone-arch bridge was built near Alcántara, Spain, over the Tagus River around 98 A.D. Named after the Emperor Trajan (who was himself a native of Spain), it was designed by the Roman engineer and bridge builder Caius Julius Lacer. Its central arches are 98 feet wide with smaller spans at both ends. It is 670 feet long and 26 feet wide and its height above the river is 130 feet.



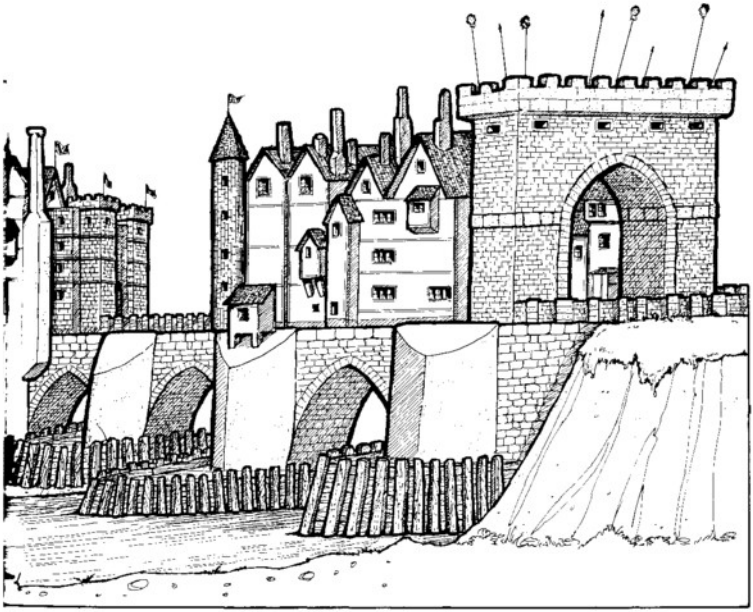
Chinese "camel-back" arched bridge, ca. 1100 A.D. While the Romans built arched bridges throughout the Western civilized world, in the East the Chinese were building and refining their own bridges, including the stone arch. They built bamboo-and-rope suspension bridges, wood-beam cantilever and truss structures, and the unique "camel-back" arch bridge shown above. These bridges were built mainly across small rivers and canals and featured high "camel-back" arches to allow boats to pass beneath. The Chinese probably learned of the arch through contact with trade caravans along the silk route from India and the Tigris-Euphrates valley, the location of the first arch bridges. The great eras of Chinese bridge construction occurred during the Han Dynasty (207 B.C. to 220 A.D.) and during the Sung Dynasty (960 A.D. to 1280 A.D.).



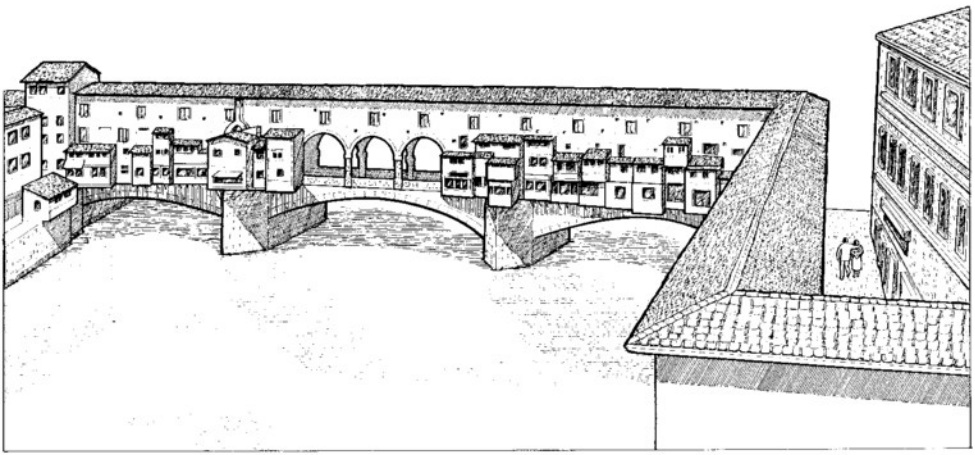
Pont Valentré, built from 1308 to 1355. An outstanding example of a medieval fortified bridge is the Pont Valentré at Cahors, France. The six arches and three fortified towers of the bridge span a distance of 370 feet across the River Lot. Its stone arches rest on river piers that are 20 feet wide with cutwaters on both the downstream and upstream sides. The center tower rises 130 feet above the river. It was built during the period from 1308 to 1355 to defend the town of Cahors. Construction was directed by Raymond Panchielli, the Bishop of Cahors. It is also known as the "Pont de la Calendre."



Old London Bridge, built from 1176 to 1209. The transition from the Roman era of bridge building to the medieval or gothic was marked by the construction of a famous and longstanding bridge, Old London Bridge, which crossed the Thames River. Built over a 33-year period beginning in 1176, it stood in one form or another for over 600 years. Its construction was supervised by Peter of Colechurch, an English monk, engineer and stonemason. The bridge consisted of 19 pointed arches with irregular span widths, as was the practice during the medieval era. Its total length across the Thames was 936 feet. The stone arches were supported by large boat-shaped river piers called "starlings," which were built by driving timber beams deep into the river bed to form the basic boat shape, then filling in this area with horizontal wooden poles and stone rubble. Oak planks were then placed atop the starlings for the

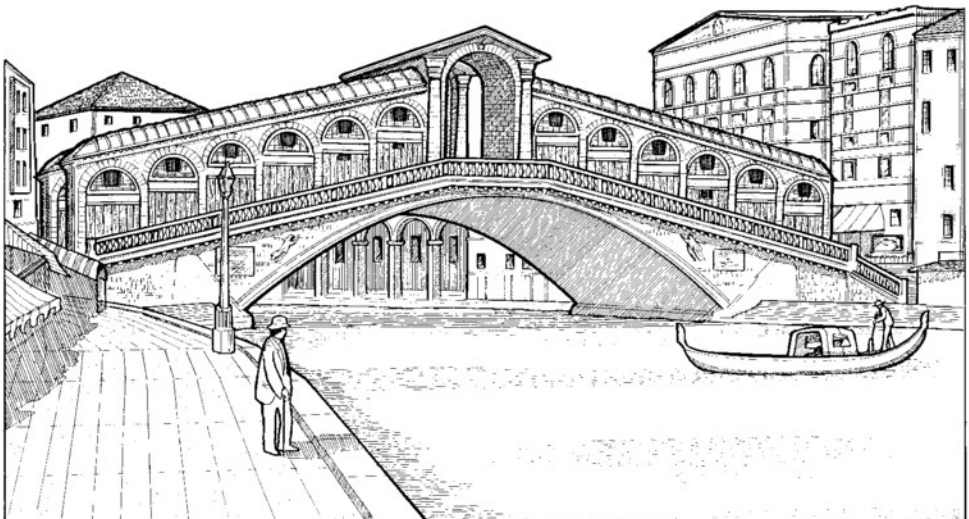


stone masonry arches and abutments to rest upon. At the center of the bridge was a chapel, and along the length of the bridge on both sides were houses, shops, apartments and various gates; at either end of the bridge were large stone gatehouses. The southern gate, called Southwark, had poles or pikes, upon which the severed heads of traitors and other criminals were displayed as a warning to potential law-breakers. This eventually became known as "Traitor's Gate." The superstructure of Old London Bridge was largely composed of wooden buildings that caught fire periodically. These structures were destroyed and rebuilt many times during the bridge's 622-year history. Old London Bridge was finally torn down and replaced with a masonry bridge in 1831.

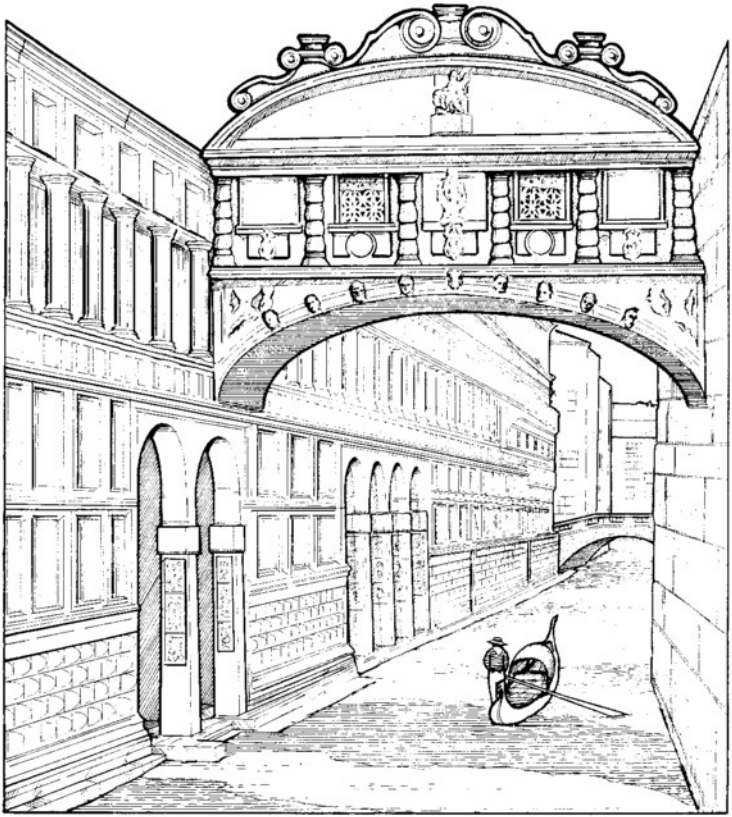


Ponte Vecchio, 1345. One of the most famous and picturesque bridges in the world is the Ponte Vecchio, which crosses the Arno River in Florence, Italy. It is a medieval stone-arch bridge completed in 1345. An unusual feature for bridges of this period was the use of flattened rather than full arches. Each arch of the Ponte Vecchio spans the considerable distance of 95 feet. Throughout its history, jewelers' shops have been built on and over the bridge superstructure. Above these shops is a gallery or pathway that connects the Pitti and Uffizi Palaces. The design of the Ponte Vecchio is attributed to the architect Taddeo Gaddi.

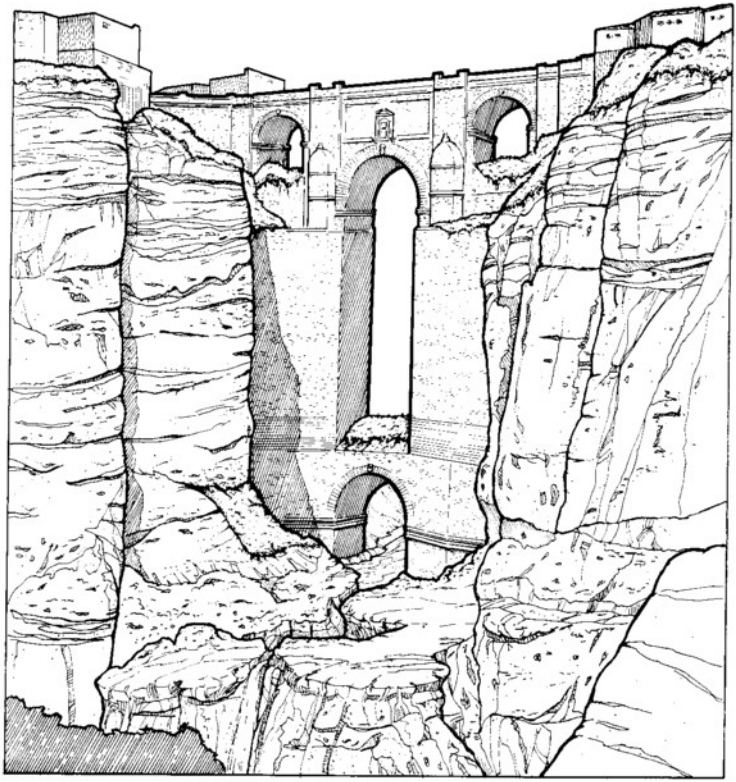
Covered bridge at Pavia, Italy, built from 1351 to 1356. Another well-preserved example of a medieval stone-arch bridge is the one shown above. It was built from 1351 to 1356 at Pavia, Italy. Its features include flattened arches of varying widths, a central gatehouse/tower, red-tiled roof and sharp cutwaters on the large river piers.



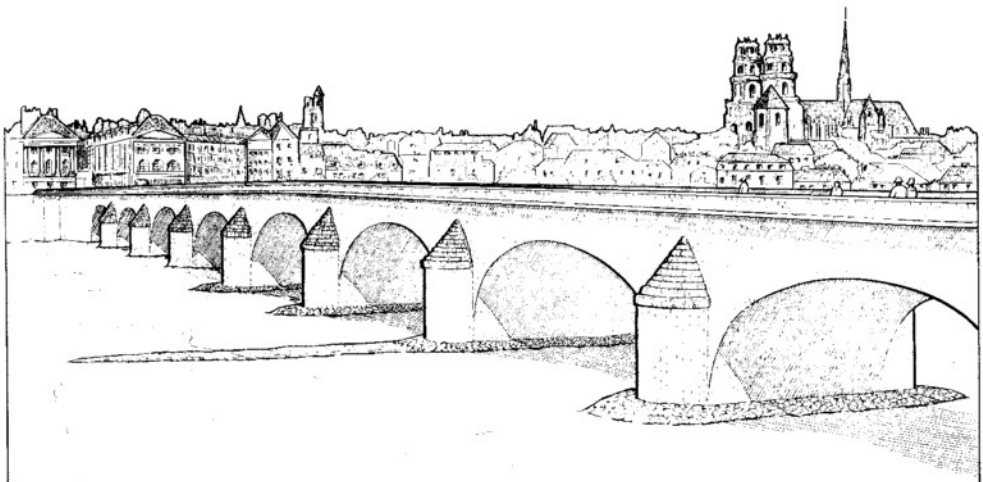
Rialto Bridge, built from 1588 to 1591. The Renaissance was a period of great artistic and scientific achievement. During this time many noteworthy bridges were designed and constructed. Shown above is one such bridge, the Rialto Bridge over the Grand Canal in Venice, Italy. Like the Ponte Vecchio at Florence, the Rialto Bridge has shops lining each side with a pathway running between. It has a single flattened arch spanning 95 feet across the canal. Built upon this main span are six smaller archways on either side flanking a larger central arch. The Rialto Bridge is 75 feet wide and rises 28 feet from the water to the bottom of the main span. Its design and construction were directed by the architect Antonio da Ponte (whose last name means "bridge" in Italian).



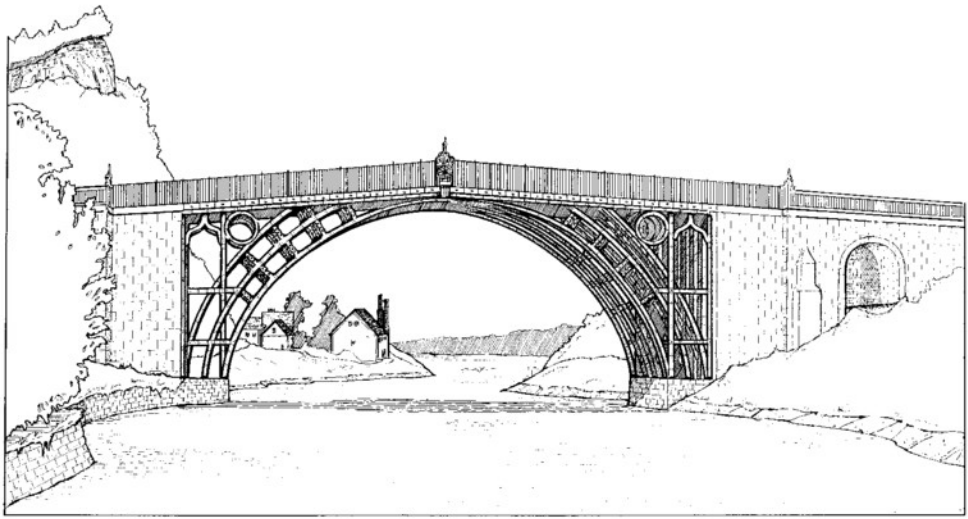
Bridge of Sighs, 1597. An equally well-known Renaissance stone-arch bridge is the highly ornamented "Bridge of Sighs," or "Ponte dei Sospiri," in Venice, Italy. Built in 1597 under the direction of Antonio da Ponte, it is one of the most famous Venetian bridges. Although quite small in comparison to many renowned bridges, its decorative motifs and romantic name have made it a must-see when touring the canals of Venice by gondola. Its decoration includes intricate scrollwork, columns and a row of sculpted human heads following the span of its single arch. The name is derived from the fact that it connects the Court of Justice on one side of the canal with the jailhouse on the opposite side, inspiring images of a sighing prisoner being led to jail.



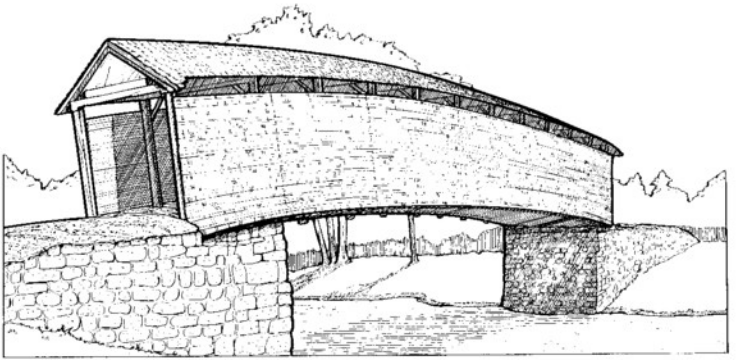
Bridge at Ronda, Spain. ca. 1650. An elegant masonry bridge at Ronda, Spain, is shown above. Designed by architect José Martín Aldegüela, it was constructed around 1650 atop earlier Roman and Moorish bridges at the site. An ironic counterpoint to its majestic beauty was the death of the architect after a fall from the bridge shortly before its completion. It is also known as the "Puente Nuevo del Tajo de Ronda" ("New bridge over the Tajo River at Ronda").

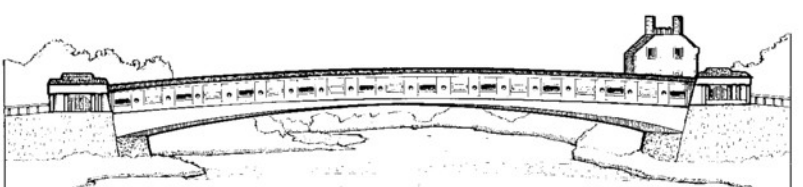


Bridge at Orléans, France, built from 1751 to 1761. The eighteenth century has been called the "Age of Reason" due to the many literary, scientific and artistic achievements that occurred during the period. The masonry arch bridge at Orléans, France, shown above, is an excellent example of the intelligent blending of aesthetic appeal and practical function representative of this era. Its nine flattened arch spans are perfectly complemented by the turreted stone river piers that support them. The bridge, built over 200 years ago, is still in use today.

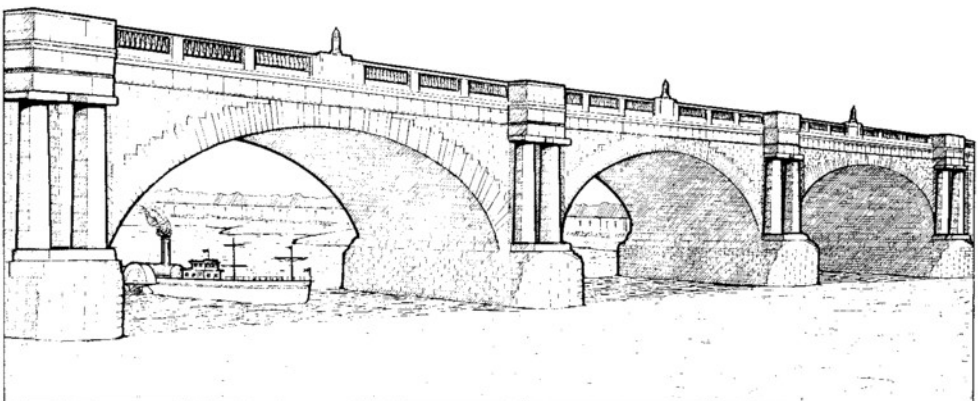


Coalbrookdale Iron Arch, built from 1776 to 1781. An important next step in the history of bridge building came with the introduction and use of iron as a main structural element. One of the finest examples of an early iron bridge is the Coalbrookdale Iron Arch, at Coalbrookdale, Shropshire, England. It has a semicircular iron arch with five main support ribs that span 100 feet across the Severn River. Built from 1776 to 1781, the bridge was designed by engineer Abraham Darby and architect Thomas Pritchard. The heavy stone pier abutments shown above eventually had to be replaced with lighter iron structures because the great weight of the stone anchor points caused the bridge to be "pinched" at the center, raising the crown of its arch to an unacceptable degree. During the Industrial Revolution, the introduction of iron and steel in architecture created new possibilities in bridge design.



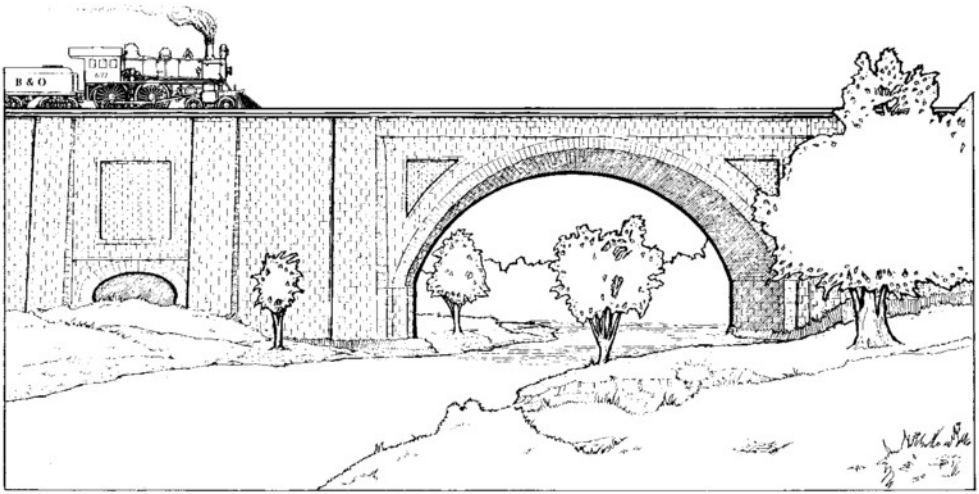


"Humpback" covered bridge (1857) and "Colossus" covered bridge (1812). The covered wooden bridge is one of the most enduring symbols in American history. Because the continent was so heavily forested, wooden bridges were fairly easy and inexpensive to erect over the many rivers and creeks of the developing country. There were numerous types of wooden bridges constructed in the eighteenth and nineteenth centuries, most of them either an arch type or a "truss" type, or a combination of both. A "truss" is a structural unit made from several timbers joined together to form a triangle. Shown in the top illustration is a beautifully preserved "humpback" covered wooden bridge near Covington, Virginia. Built in 1857, it crosses the James River with its 100-foot arched deck. It is a multiple "king-post" truss bridge with the center rising eight feet higher than the ends. The bridge shown below was one of the largest and most famous early American covered bridges, the "Colossus" Bridge over the Schuylkill River, near Philadelphia, Pennsylvania. Designed by Louis Wernwag, it was built in 1812 as a combination wooden arch/truss bridge with a fairly long span of 340 feet. Unfortunately, it was destroyed by fire in 1838. Many covered wooden bridges still remain in the northern and southeastern United States and are designated historical landmarks to ensure their preservation.

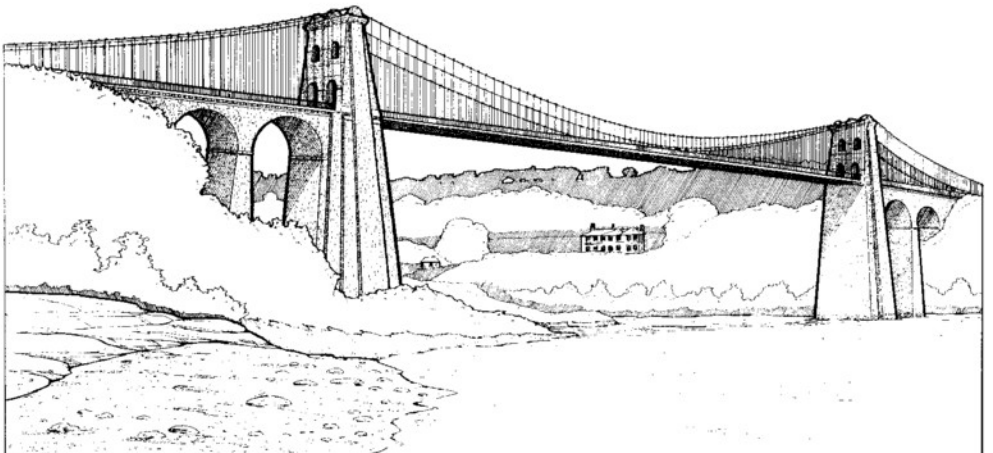


Waterloo Bridge, built from 1809 to 1817. One of the greatest bridge designers of the nineteenth century was John Rennie. Rennie was born in Scotland in 1761 and showed instinctive mathematical abilities from early childhood. In 1785, after schooling at Dunbar Seminary and Edinburgh University, he received his first contract to design and build a bridge near Edinburgh, Scotland. One of his most famous bridge designs is shown here, a stone masonry-arch bridge that connected the Surrey and Strand districts of London. It was built from 1809 to 1817 over the Thames River and originally was called the Strand Bridge. Its name was later changed to the Waterloo Bridge to commemorate Napoleon's defeat by the British at the Battle of Waterloo in 1815. It was constructed with nine arches, each with a span of 120 feet and a height of 34 feet over the river. The arches rest on 20-foot-thick stone river piers. The Waterloo Bridge is considered a classic example of nineteenth-century bridge architecture.

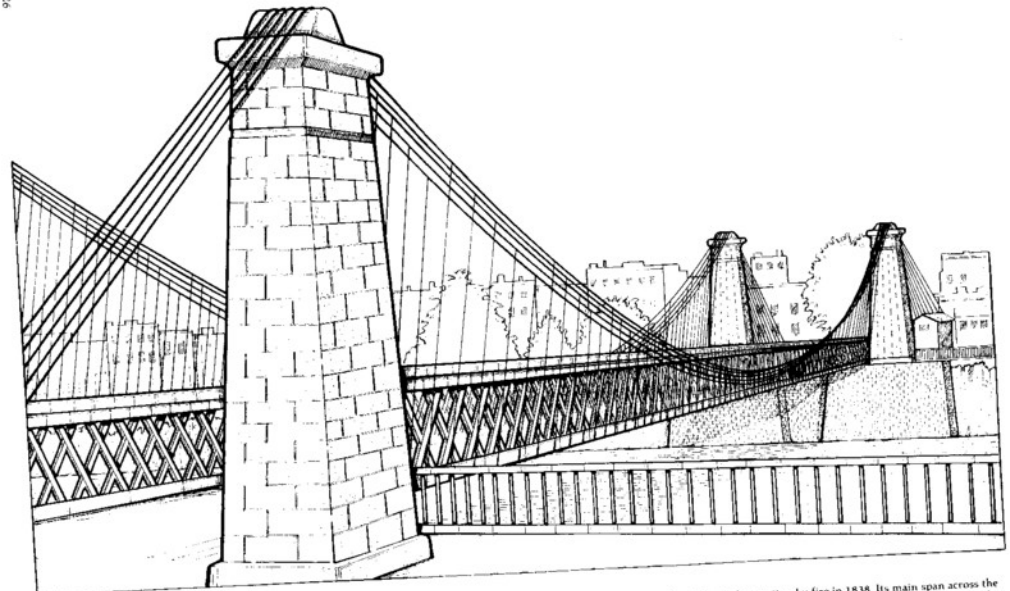
New London Bridge, built from 1824 to 1831. The job of replacing the "Old London Bridge" after 622 years of service was the last and foremost accomplishment of John Rennie's illustrious career. His design for the new bridge was accepted by the British Parliament, but before construction began, Rennie became ill and died soon after. The job of carrying out his plans was given to his son, Sir John Rennie. Beginning in 1824, as the old bridge was being demolished, the new London Bridge was erected beside it. Its five elliptical arches had a total span of 1,005 feet across the Thames River. The center span was 150 feet wide, the two flanking spans, 140 feet wide; the land arches had spans of 130 feet. The bridge roadway was originally 56 feet wide but was widened to 65 feet in 1905, and again in 1915, to 75 feet. The bridge's construction lasted from 1824 until 1831 when it was officially opened by King William IV.



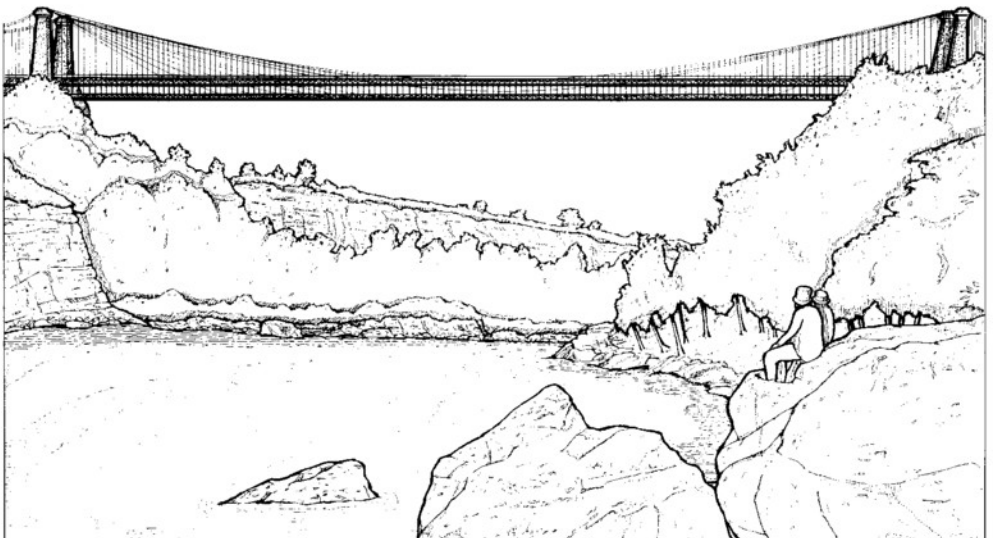
Carrollton Viaduct, 1829. A classic American stone arch bridge built in the style of the old Roman arches is the Carrollton Railroad Viaduct for the Baltimore and Ohio Railroad. Built in 1829, it is the oldest railroad bridge in the United States still standing. Its single granite arch spans 100 feet across Gwynns Falls, near Baltimore, Maryland. It was named after Charles Carroll, the last living signer of the Declaration of Independence, and was designed by Jonathan Knight.



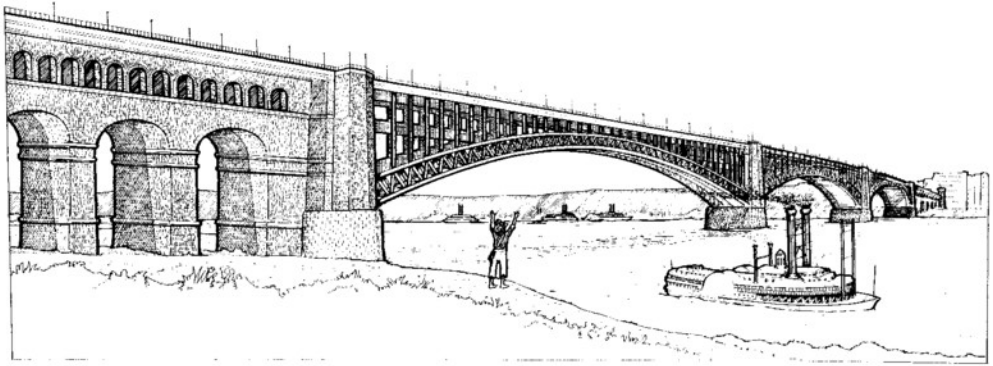
Menai Bridge, built from 1820 to 1826. Another great British bridge designer of the early nineteenth century was Thomas Telford. His pioneering use of iron as a main structural element ushered in a new era of bridge construction; his essay on bridge design written in 1812 became the standard reference for future civil engineers. Telford's greatest achievement in bridge building was the design and construction of the Menai Bridge, which spans the Menai Strait from Bangor, Wales, to the island of Anglesey. It was one of the first suspension bridges built, and used iron chains to suspend the bridge deck 100 feet over the water. (Modern suspension bridges use steel wire for their suspension.) At the time it was the longest suspension bridge in the world, with a clear center span of 579 feet. Completed in 1826, the Menai Bridge has two main suspension towers of masonry that rise to a height of 153 feet above the water; the masonry arches that support the bridge approaches have spans of 65 feet, with four arches on one side and three on the other. Each link in the main suspension chain is nine feet long, and one chain alone weighs 21 tons. The weight of all the iron structural elements in the Menai Bridge totals 2,187 tons.



Fairmount Park Bridge, 1842. While Thomas Telford was pioneering the use of iron chains for suspension bridges in Europe, an American engineer, Charles Ellet, was designing and building bridges using wrought iron wire as the suspension device. His Fairmount Park Bridge over the Schuylkill River at Fairmount, Pennsylvania, near Philadelphia, was completed in 1842— the first major suspension bridge in the United States. It was built to replace Louis Wernwag's "Colossus" wooden arch bridge after its destruction by fire in 1838. Its main span across the river was 375 feet, and ten iron cables were strung from the masonry towers, five to a side. Charles Ellet was one of the three premier American bridge designers of the nineteenth century, along with James B. Eads and John A. Roebling.

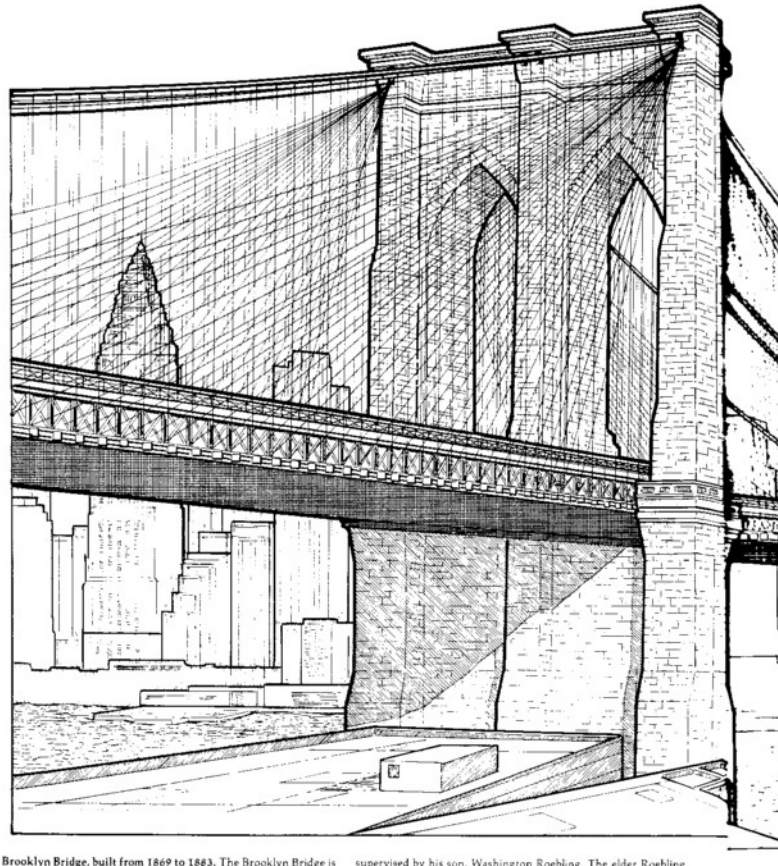


Niagara River Bridge (Grand Trunk Bridge), 1855. As engineering and technology advanced throughout the nineteenth century, so too did the spans of suspension bridges increase to reflect that progress, from the 375-foot span of Ellet's Fairmount Park Bridge in 1842 to the 821-foot-long Niagara River Bridge, designed by John A. Ruebling in 1855, and finally to the 1,595-foot span of the Brooklyn Bridge, completed in 1883 and also designed by Roebling. Roebling's iron-wire suspension bridge crossed the Niagara River gorge 245 feet above the rapids below. It was a two-deck structure, the upper level having a single railroad track and the lower level having a carriage path. The main suspension cables were ten inches in diameter and made up of 3,640 individual iron wires. They were hung from masonry towers and were anchored in the solid rock of the cliffs. At the time, the Niagara River Bridge was the longest suspension bridge in the world.

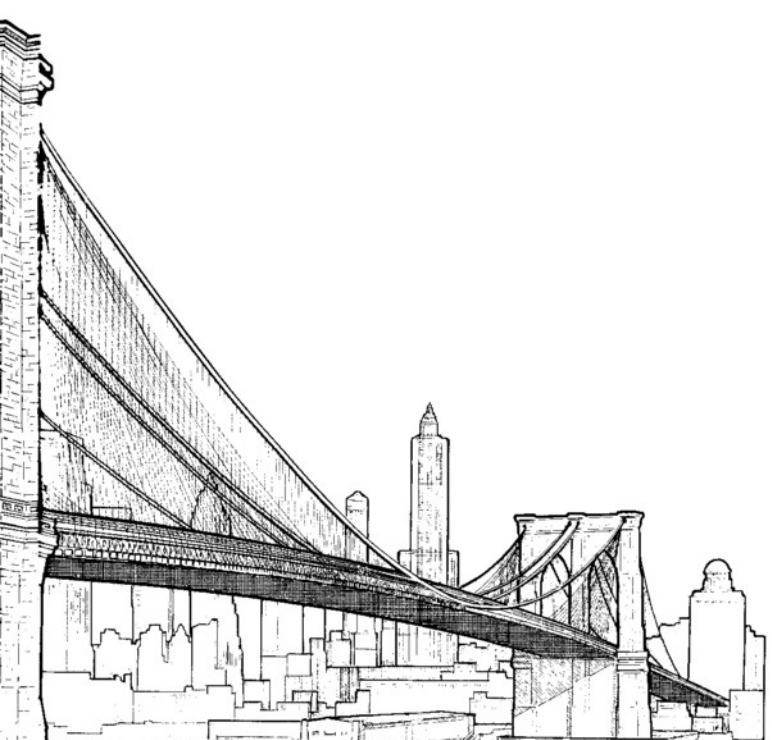


Eads Bridge, built from 1867 to 1874. As suspension bridges were increasing in size and complexity, so too were other types of bridges. In 1874 a revolutionary steel-and-iron-arch bridge was completed across the Mississippi River at St. Louis, Missouri. It was designed by James B. Eads and is still in use today. The bridge was a pioneering effort in many ways. It was the first bridge in the United States to use large quantities of steel to form its three graceful arches. At the time, the arches themselves were the longest in the world, the central arch spanning 520 feet and the two flanking arches spanning 502 feet. It was the first bridge to utilize pneumatic caissons to allow the masonry piers to be built within the river. A "caisson" is a large watertight, box-like or tubular structure sunk into the river bed. Workers (called "sandhogs") inside the caissons could dig down to the bedrock needed to support the river piers or towers; when below water level, compressed air was pumped into the caissons to allow the workers to breathe. For the east pier of the bridge, sandhogs had to dig through 47 feet of the river bottom to reach bedrock, and for the west pier, they had to burrow down to an incredible 127 feet. (Fourteen workers died from a then unknown illness aptly named "caisson disease," or "the bends," marked by neuralgic pains, paralysis and breathing difficulties. It was later discovered that the rapid change in pressure from such great depths to normal atmospheric pressure released nitrogen gas bubbles into the workers' bloodstream and body tissue causing the symptoms above.) The Eads Bridge was the first steel arch bridge built using the cantilever method of construction, in which the arches are built from the shore points until they meet at the center of the bridge. Prior to this, the river flow would be diverted and scaffolding built in the area around the construction. It was also the first bridge to use steel tubes to construct the arch ribs and truss members. The specifications of this magnificent structure are all superlatives for the era: 2,390 tons of steel, 3,156 tons of wrought iron, 806 tons of timber, 4,556 cubic yards of concrete and 97,571 cubic yards of brick masonry to build the piers and arched bridge approaches. The Eads Bridge is considered a great engineering feat, an aesthetic triumph in bridge architecture and a fitting tribute to a civil-engineering genius, James B. Eads.

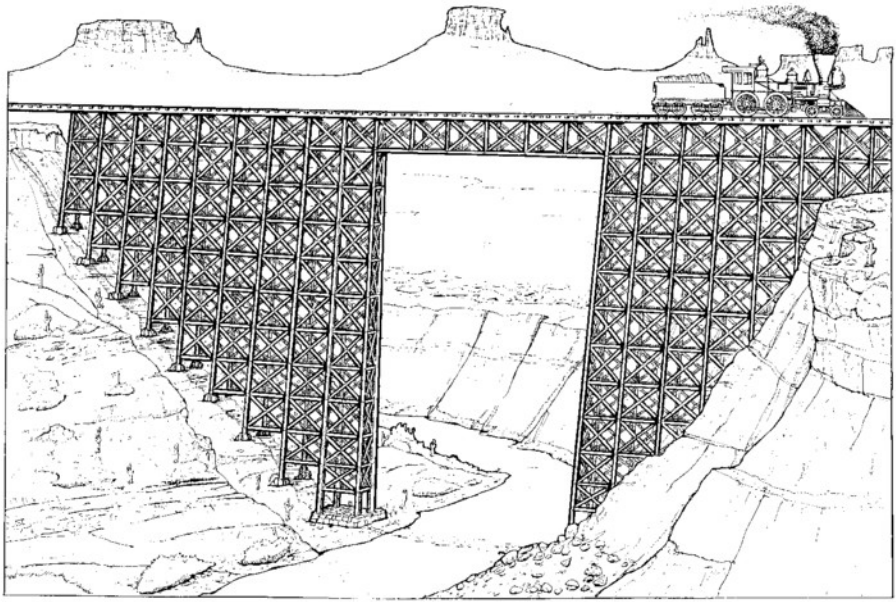
Wood cantilever bridge, ca. 1850. While the Western world was building larger and more technically demanding bridges, in Asia bridge building remained fairly constant throughout the nineteenth century. But excellence in bridge design can be attained with simple wooden beams as well as mighty steel arches. The bridge depicted above is representative of a common type of timber cantilever bridge built throughout China, India and Tibet during the 1800s. It is of simple wood-beam construction, the two cantilever arms joined by a central timber and supported at the shore ends by large stone combination abutment/gatehouses. Many bridges of this type remain throughout Asia and are still in common use.



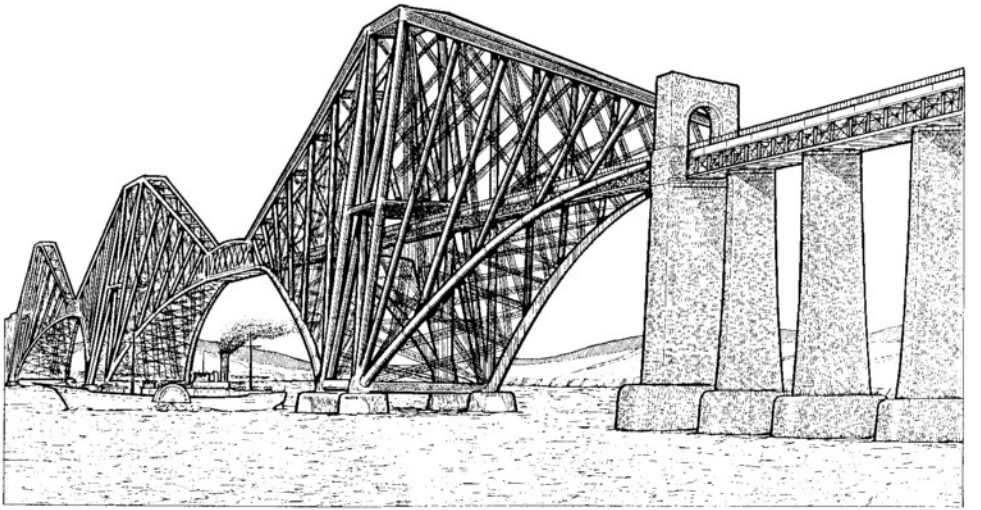
Brooklyn Bridge, built from 1869 to 1883. The Brooklyn Bridge is perhaps as famous for being sold and resold by city slickers to unwary country bumpkins as it is for its engineering accomplishments and graceful beauty. Built over a 14-year period, and at a cost of over a dozen lives, the bridge was the major technical achievement of its day. Everything about the bridge was bigger or newer than any of its predecessors: the span length, the tower size, the cable strength and the number of innovative methods employed in its construction. The Brooklyn Bridge was designed by preeminent bridge architect John A. Roebling, and its actual construction was supervised by his son, Washington Roebling. The elder Roebling first proposed a bridge connecting Brooklyn and Manhattan over the East River in 1857. For the next 12 years it was the consuming passion of his life. Tragically, in 1869—just before construction on the bridge was to begin—he suffered a freak accident. His foot was caught and crushed between a ferry boat and the dock; due to improper medical treatment, he died from an infection several days later. His son, also an engineer, was selected to carry on the project and was its director for the next 14 years. In 1869 construction began with two huge wooden caissons. These would allow the



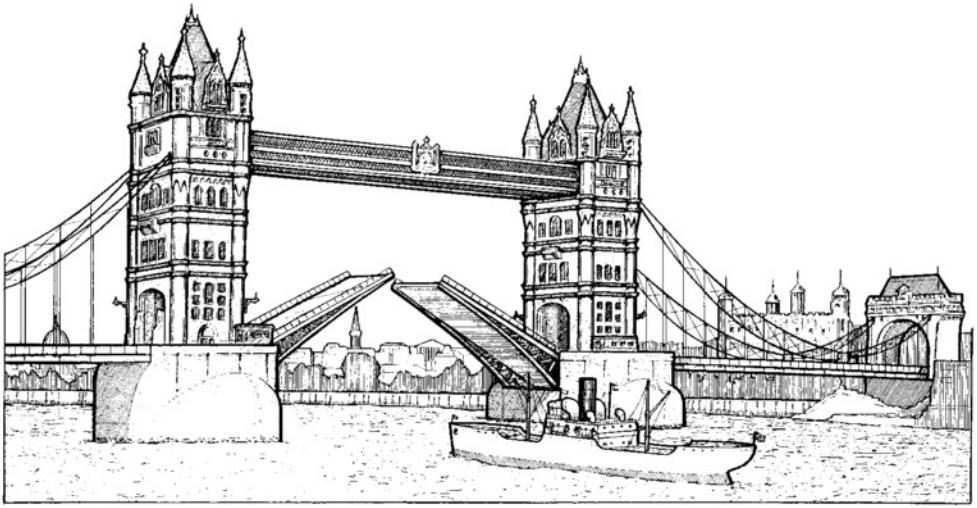
workers to dig through the river bottom to the bedrock below for the tower pier foundations. The caisson on the Brooklyn shore alone took a year to build and to move into position. Many other difficulties and dangers were encountered. The "sandhogs" working in the caisson began to suffer from the same mysterious illness that plagued workers on the Eads Bridge. Fires, falls from the bridge and cables snapping were among other reasons for loss of life. Through all of these challenges, the bridge construction continued and was finally completed in 1883. The bridge's clear span of 1,595 feet was double that of any previous suspension bridge. The masonry towers with their majestic double arches stand 276 feet high and the roadway stands at 135 feet above the river. Each of the four main cables has a diameter of 16 inches and a length of over 5,000 feet, and weighs 1,732,080 pounds. The bridge was the longest suspension bridge in the world for twenty years, finally surpassed in 1903 by the Williamsburg Bridge. The Brooklyn Bridge remains a symbol of both nineteenth-century American technical ability and of the dedication and courage of its builders.



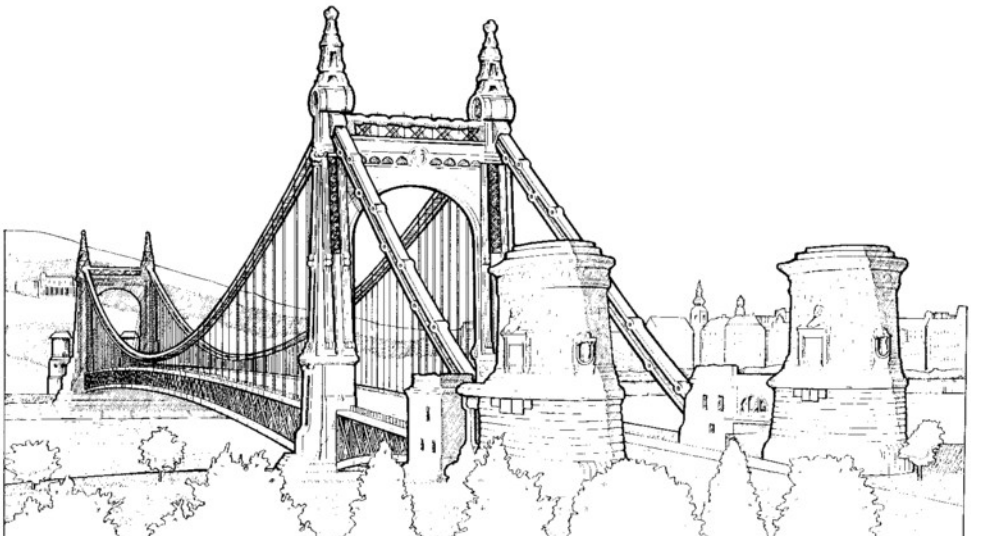
Timber-truss railroad bridge, ca. 1870. While wood cantilever bridges were widely used in the Far East during the nineteenth century, timber-beam bridges were being constructed in the United States. To accommodate the nation's westward expansion across the continent, hundreds of wooden truss "trestle" bridges were built. In 1869 the east and west coasts were finally linked by rail when the Central Pacific Railroad and the Union Pacific Railroad were joined together at Promontory Point, Utah. Along this route and many other rail lines, timber bridges, like the one pictured here, were used to cross creeks, rivers and canyons. Relatively easy and inexpensive to erect, they were a vital part of the American westward movement.



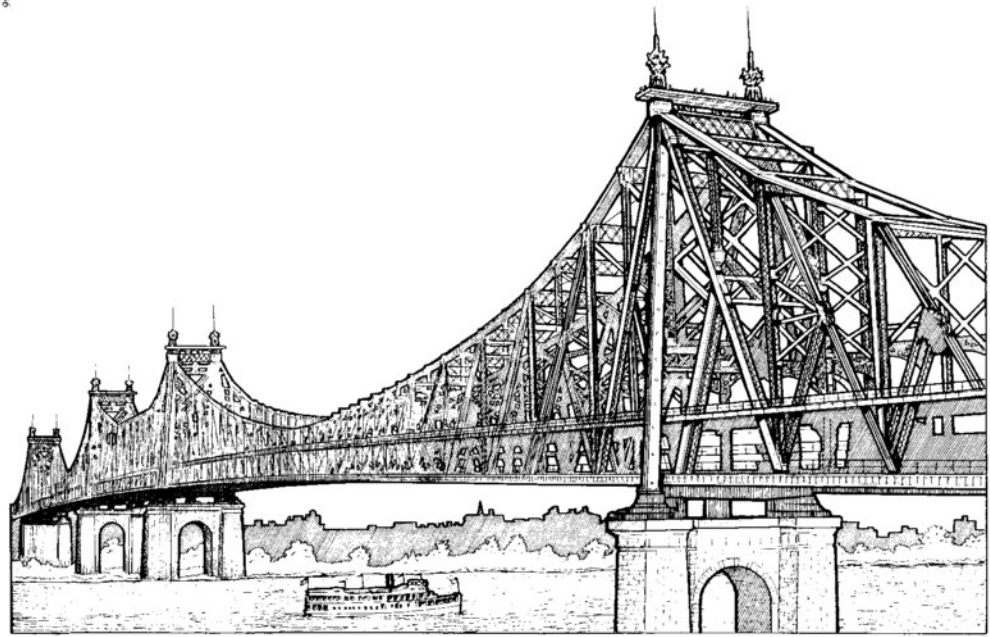
Forth Railway Bridge, built from 1883 to 1890. One of the most visually stunning bridges in the world is the steel-cantilever "Forth Bridge" near Edinburgh, Scotland. Resembling the humpbacked skeletal form of some huge dinosaur, the bridge stretches across the water, a unique and impressive sight. Built as a railroad bridge across the Firth of Forth, it connects nearby Edinburgh with such cities as Aberdeen, Perth and Dundee on the other side of the firth (a bay or inlet of ocean water). Designed and built by Sir Benjamin Baker and Sir John Fowler, its cantilever construction has three main sections connected by two very long, clear spans of 1,710 feet each. The bridge's towers and cantilever arms are made from enormous steel cylinders, with the towers rising 336 feet above the water and resting on masonry piers anchored to the bedrock beneath. The bridge deck and rail line are at the 150-foot level. Connecting the cantilever spans in the middle of the entire structure are two smaller suspended spans of 350 feet each. The total length of the bridge, including its approaches supported by masonry towers, is 8,296 feet. It is one of the strongest bridges in the world, containing 58,400 tons of steel and 140,000 cubic yards of masonry. The Forth Railway Bridge can be considered a very close rival to the Brooklyn Bridge as the engineering triumph of the nineteenth century.



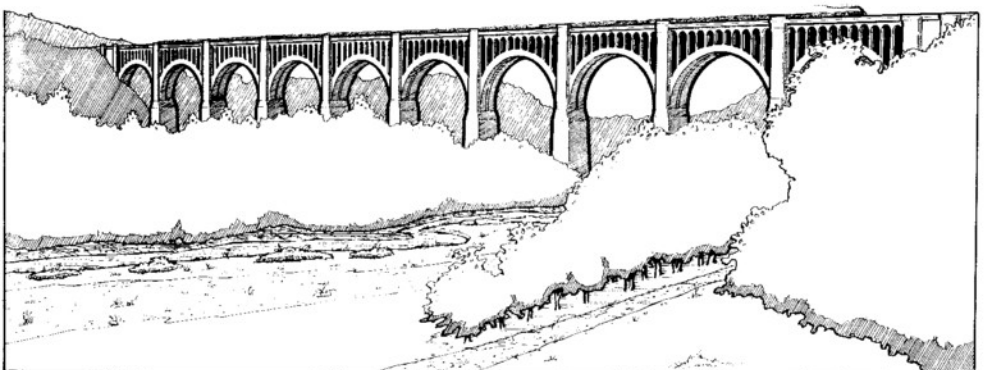
Tower Bridge, built from 1886 to 1894. One of the most recognizable bridges in the world is London's famous Tower Bridge, so called because of its proximity and visual similarity to the Tower of London. It is a type of movable bridge called a "double bascule" bridge because its center span separates at the middle and lifts to an almost vertical position allowing ships to pass through. This type of bascule bridge is a direct descendant of the castle drawbridge made famous during the Middle Ages. Each deck section weighs 1,100 tons and is lifted by powerful electric motors; when raised, there is an opening of 250 feet. The towers themselves are 200 feet high. Although the bridge is covered with brick and stone to resemble the architectural style of the Tower of London, beneath this facade it is a modern steel structure.



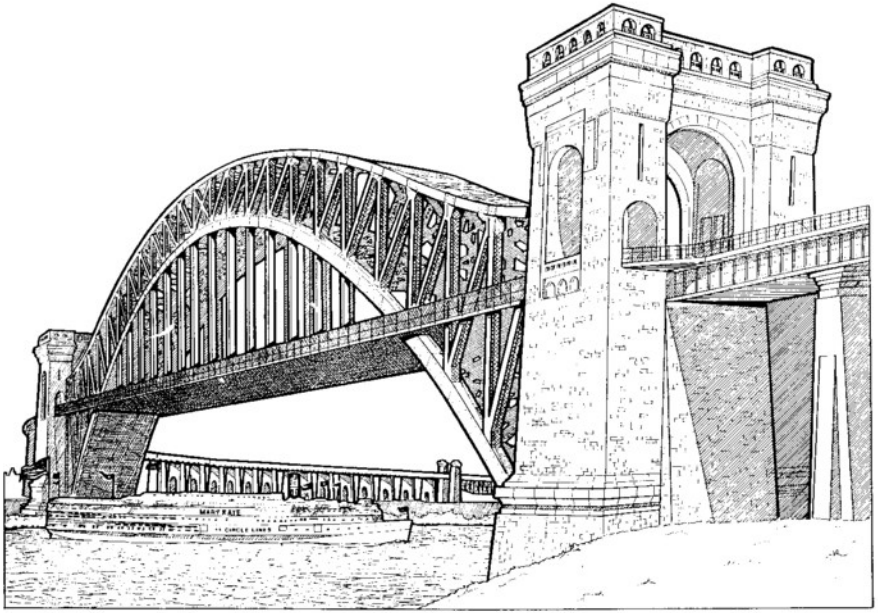
Elizabeth Bridge, 1905. Around the turn of the century, a beautiful example of European-style suspension bridges was built in Budapest, Hungary. The Elizabeth Bridge (Erzsébet-híd) crosses the Danube River, suspended by an "eyebar chain." Unlike the steel wire used as the suspension device in American bridges, an "eyebar" is a bar or shaft of metal with holes at both ends allowing them to be connected by a pin or bolt to form a continuous chain. When it was completed in 1905 the Elizabeth Bridge was the longest suspension bridge in Europe, with a span of 951 feet, a record held for 26 years. It was designed and built by architect M. Nagy and engineer A. Czechelius.



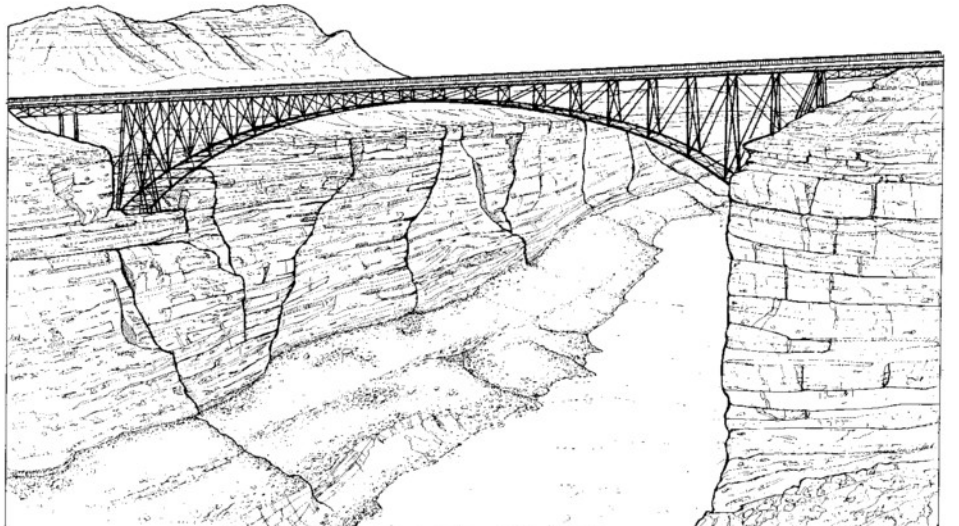
Queensboro Bridge, 1909. The Queensboro Bridge is one of New York City's most ornate and distinctive bridges, as befits its construction in the Edwardian era. The bridge contains 50,000 tons of steel and was the first to use large amounts of high-strength nickel steel. The two cantilever arms crossing the East River are 1,182 feet and 984 feet in length, connected in the middle by a steel truss span 630 feet long. The anchor span to Manhattan measures 469 feet, while the span to Queens is 459 feet long. The bridge was completed in 1909 under the direction of engineer and architect Gustav Lindenthal, who served as New York City's commissioner of bridges from 1902 to 1903.



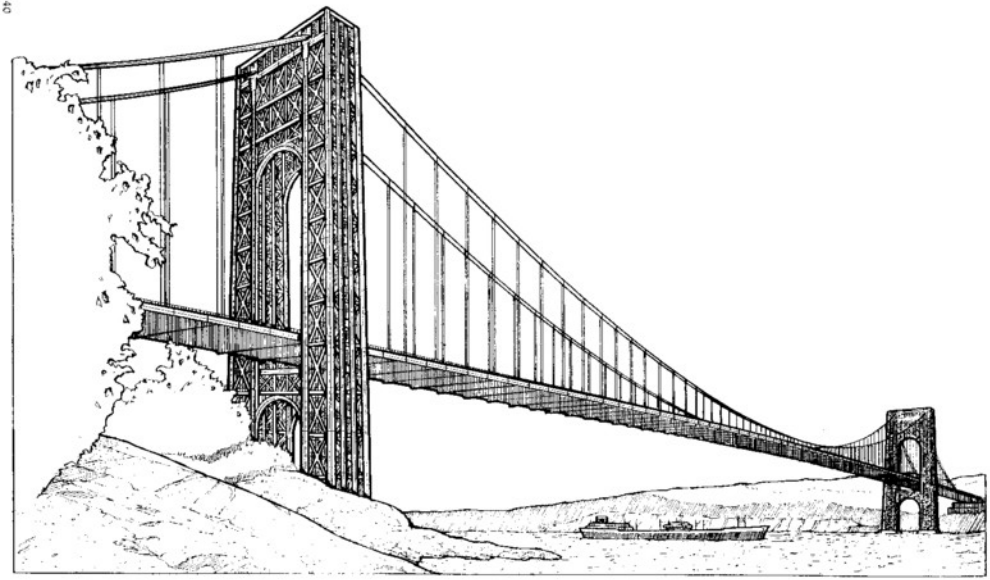
Tunkhannock Creek Railroad Viaduct, built from 1912 to 1915. One of the most massive structures ever built in terms of sheer volume of construction materials is this railroad viaduct crossing the Tunkhannock Creek Valley, near Scranton, Pennsylvania. Its ten arch spans cover 2,375 feet from one end of the valley to the other and contain 162,000 cubic yards of steel-reinforced concrete. The double-track railway is 240 feet above the valley floor. Built from 1912 to 1915 for the Delaware, Lackawanna and Western Railroad, it was designed by architect Meyer Hirschthal and engineer George Ray.



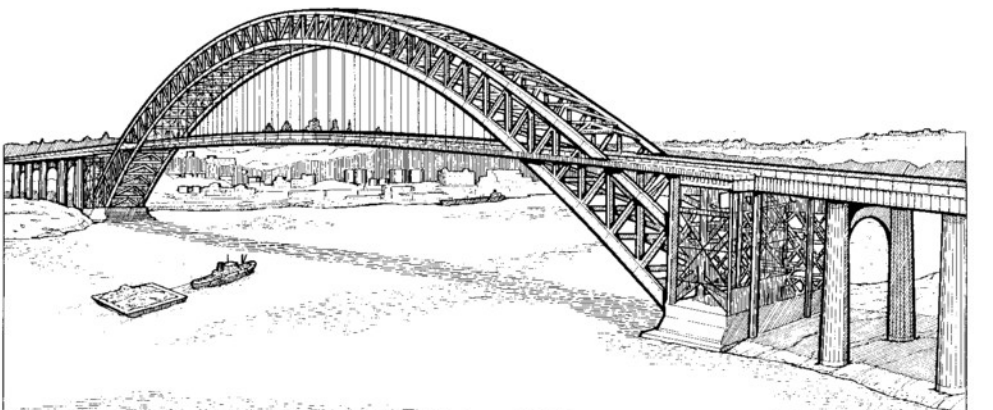
Hell Gate Bridge, 1915–1916. Still considered the strongest steel arch ever constructed, New York's Hell Gate Bridge has been in use since 1916. Its graceful steel arch spans 1,017 feet across the junction of the Harlem and East Rivers. The four railroad tracks on the bridge deck rise 135 feet over the water and the crown of the arch rises to 305 feet; the granite towers at each end are 250 feet high. The bridge contains 40,000,000 pounds of steel and has 1,174,000 rivets in its connecting members. The cantilever method of construction was employed to build the arch, each side erected out to connect in the center. It was designed and constructed under the supervision of Gustav Lindenthal with assistance from engineers Othmar Ammann and David Steinman.



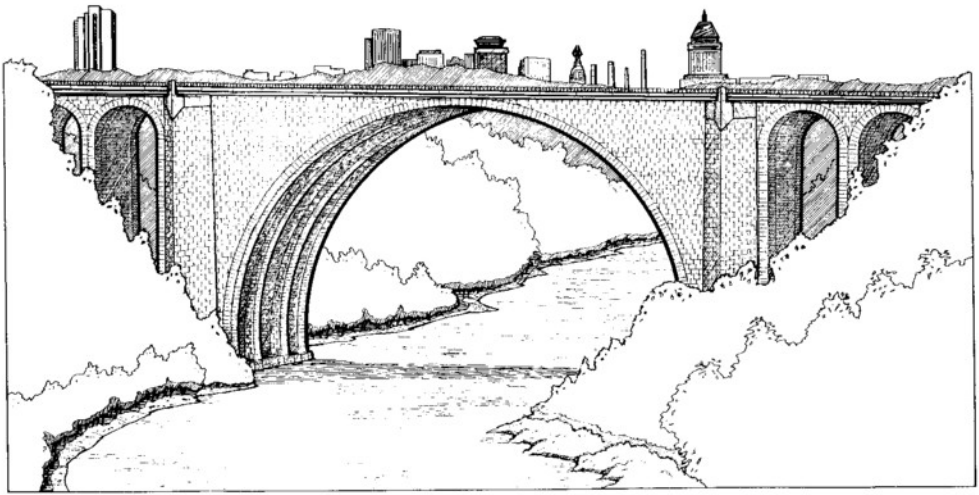
Marble Canyon Bridge, 1928. Crossing the Colorado River at close to 500 feet above the water, the Marble Canyon Bridge looks almost too spindly to support its own weight. But the use of high-tensile strength steel and modern construction techniques for its single arch span provides the bridge with plenty of strength. The steel deck roadway crosses 467 feet above the river and is 616 feet long. Built near Lee's Ferry, Arizona, in 1928, with architect R. A. Hoffman and engineer L. C. Lashmet supervising the project, it is also known as the Navajo Arch Bridge over the Colorado River.



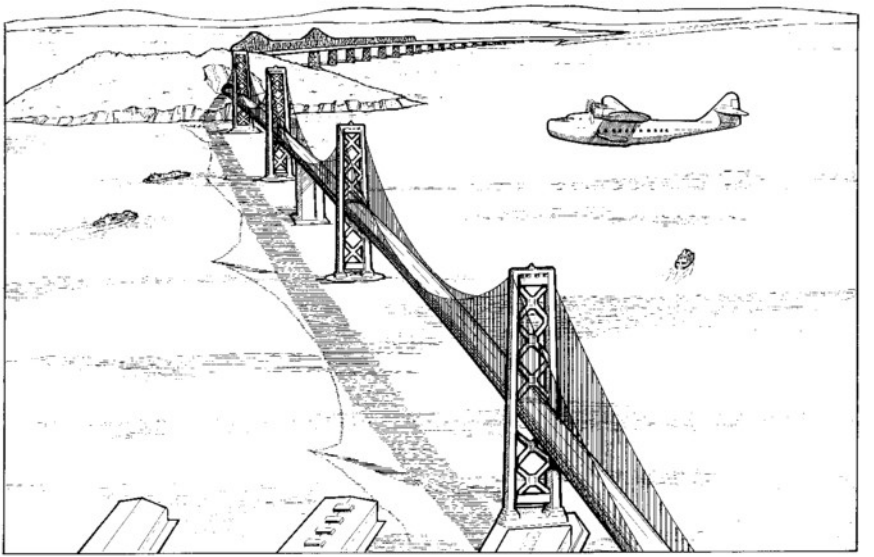
George Washington Bridge, 1931. The George Washington Bridge across the Hudson River was New York City's longest suspension bridge for over 30 years, until the completion of the Verrazano-Narrows Bridge in 1964. The bridge's open span length of 3,500 feet is double that of its nineteenth-century cousin, the Brooklyn Bridge. Crossing over the Hudson River from the New Jersey Palisades to New York City, it was designed by famed bridge engineer and architect Othmar Ammann. This bridge is one of the most distinctive-looking suspension bridges in the world due to the appearance of its towers, which were left uncovered to expose the intricate pattern of steelwork that forms their structure. Originally designed to be covered with concrete and granite, they were left open for the reasons of both reduced cost and aesthetic appeal. The two great towers are each 635 feet high and weigh 20,000 tons. Considered by engineers to be the strongest suspension bridge ever constructed, its four main suspension cables are each 36 inches thick, over 5,000 feet long, and constructed from 26,474 individual steel wires. The saddles that sit atop the towers and support the great weight of these cables weigh 180 tons apiece. The bridge is anchored 160 feet deep into solid rock on the New Jersey side, and on the New York side it is supported by a specially constructed concrete anchorage that measures 200 feet by 290 feet by 130 feet. Still ranked as the fourth longest suspension bridge in the world, the George Washington is one of New York's truly great bridges.



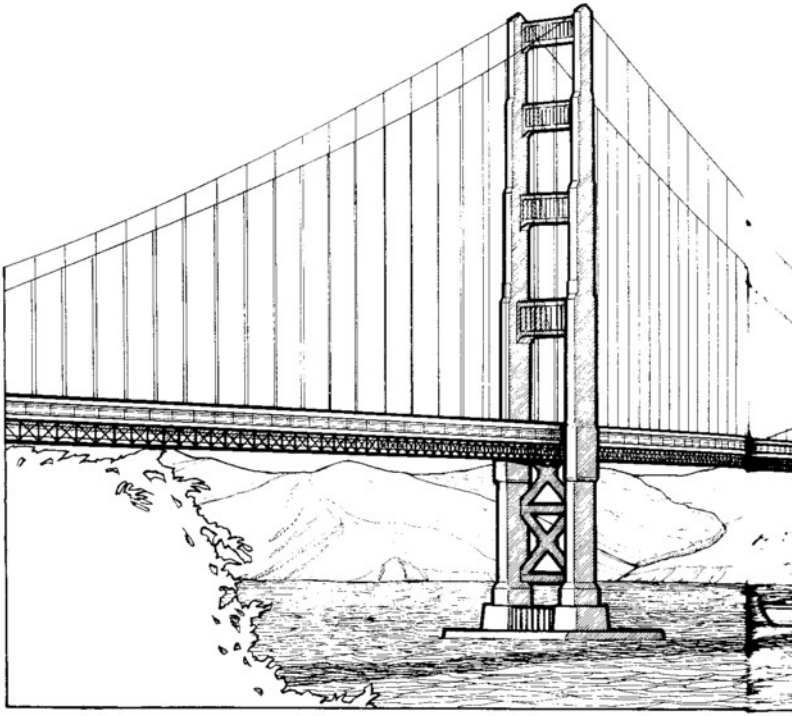
Bayonne Bridge, 1931. Although San Francisco had two famous suspension bridges constructed during the 1930s (the Golden Gate Bridge and the San Francisco-Oakland Bay Bridge), in New York City a record-breaking steel arch was built, the Bayonne Bridge. Crossing over a waterway known as the Kill van Kull, it connects the city of Bayonne, New Jersey, with New York City's Staten Island. The Kill van Kull is an estuary that carries a great deal of shipping traffic to and from the New York City area. When it was completed in 1931, the Bayonne Bridge was the longest steel-arch bridge in the world—with a span of 1,652 feet—and it remains so today. The bridge barely edged out its rival, Australia's Sydney Harbor Bridge, which opened in 1932 with a span of 1,650 feet (a difference of only 25 inches!). The Bayonne Bridge rises to a height of 266 feet at the crown of its arch and was the first bridge to use the newly developed high-strength carbon-manganese steel in its structure. The bridge was designed by Othmar Ammann and Allston Dana.



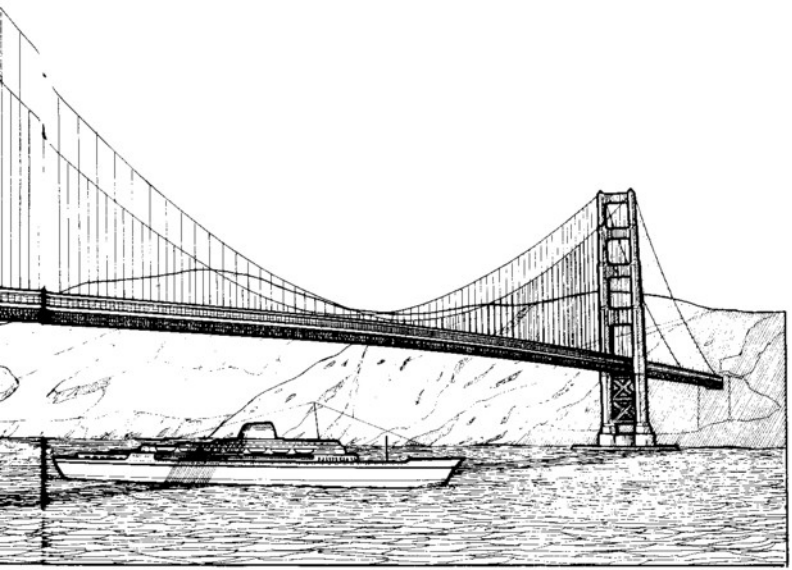
Veterans Memorial Bridge, 1930–1931. A modern concrete arch bridge of classical design, the Veterans Memorial Bridge crosses the Genesee River gorge at Rochester, New York. It was constructed using steel-reinforced concrete and then completely covered with a facade of four-and eight-ton granite blocks. The bridge has one large arch with a span of 300 feet and six smaller arches, three on each side, with spans of 58 feet each. The total length of the bridge is 972 feet and it rises 197 feet above the river. A total of 60,000 cubic yards of reinforced concrete and 130,000 cubic feet of Massachusetts granite were used in the structure. Construction of the bridge, which was designed by renowned bridge architect Frank P. McKibben and engineered by W. H. Roberts, lasted just over one year, from November 1930 to December 1931.



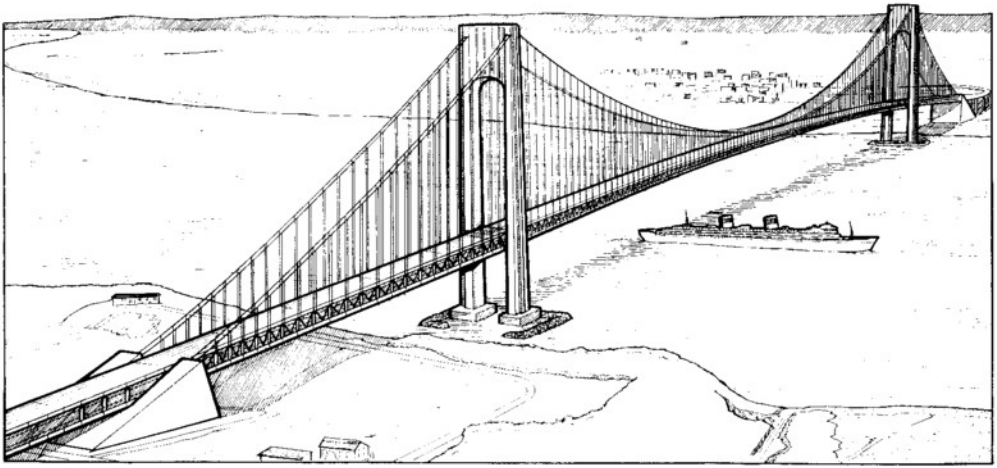
San Francisco-Oakland Bay Bridge, built from 1933 to 1936. One of the most remarkable bridges ever constructed is the eight-and-one-half-mile-long San Francisco-Oakland Bay Bridge system shown above. Its tremendous span length stretches from San Francisco out into the open bay to Yerba Buena Island, then through a tunnel on the island, and out over the rest of the bay to the Oakland side. To accomplish this span, a series of different types of bridges was constructed to form one long, continuous roadway, beginning on the San Francisco side with a steel-wire suspension bridge with two main spans (each 2,310 feet long) and four side spans (each 1,160 feet long). This suspension span is supported by five piers within the bay and four towers that rise 475 feet above the water. At the center of the span, the height of the roadway above the bay is a dizzying 281 feet. The roadway continues on to reach hilly Yerba Buena Island, where it then goes through a 540-foot-long tunnel, emerging to connect with a steel-cantilever bridge that is 1,400 feet long. The bridge then continues across the bay as a steel-truss span with five sections, and then as a causeway onto the Oakland shore—totaling a stupendous 43,500 feet, or eight and one-half miles. This innovative engineering project, designed by C. H. Purcell, was begun in 1933 and completed in 1936.



Golden Gate Bridge, built from 1933 to 1937. If the Brooklyn Bridge is considered the engineering marvel of the nineteenth century, then its twentieth-century counterpart would have to be the Golden Gate Bridge, at the entrance to San Francisco Bay. Enormous technical difficulties had to be overcome to construct such a long open span across frequently rough ocean water. When completed in 1937, the Golden Gate Bridge was the longest suspension bridge in the world and held that record for 27 years. (It was bested by New York's Verrazano-Narrows Bridge in 1964 by just 60 feet.) The bridge connects the city of San Francisco with neighboring towns in Marin County, across the bay. The center span is 4,200 feet long and the total length of the bridge, including

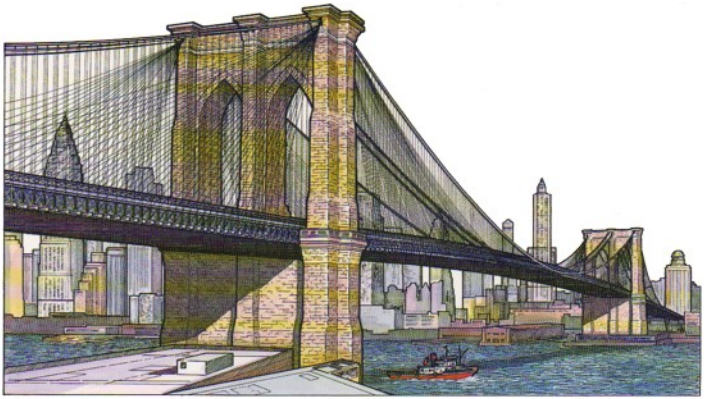


its approaches, is 8,981 feet. The towers rise to an impressive 746 feet (the tallest bridge towers in the world), and at midpoint, the bridge roadway is 265 feet above the water. The bridge's two main cables are each 36½ inches in diameter, over 7,000 feet long, and made from 27,572 individual steel wires. Many people are surprised when they see that the Golden Gate Bridge is not "golden" at all, but has a reddish-orange hue derived from a coating of anti-rust paint. The name comes from the fact that San Francisco Bay is one of the entry points, or "gates," into California, the "Golden State," hence the name Golden Gate Bridge. The bridge was constructed over a four-year period from 1933 to 1937 and its architect and chief engineer was Joseph B. Strauss.



Verrazano-Narrows Bridge, built from 1959 to 1964. The current record holder for longest suspension bridge in the world is the Verrazano-Narrows Bridge at the mouth of New York Harbor. It was constructed over a five-year period from 1959 to 1964 and was designed by engineer Othmar Ammann. It stretches for a total length of 13,700 feet from Brooklyn to Staten Island; its clear center span is a record-holding 4,260 feet. The towers are 690 feet high with the bridge deck rising 228 feet above the water. Its four main suspension cables are each 36 inches thick and composed of 26,108 individual wires. Each main cable is 7,205 feet long and the total length of all the wire used to support the bridge is an astounding *142,500 miles*. The Verrazano-Narrows Bridge represents a high point in the 2,000-year history of bridge design and engineering.

Chinese "camel-back" arched bridge



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