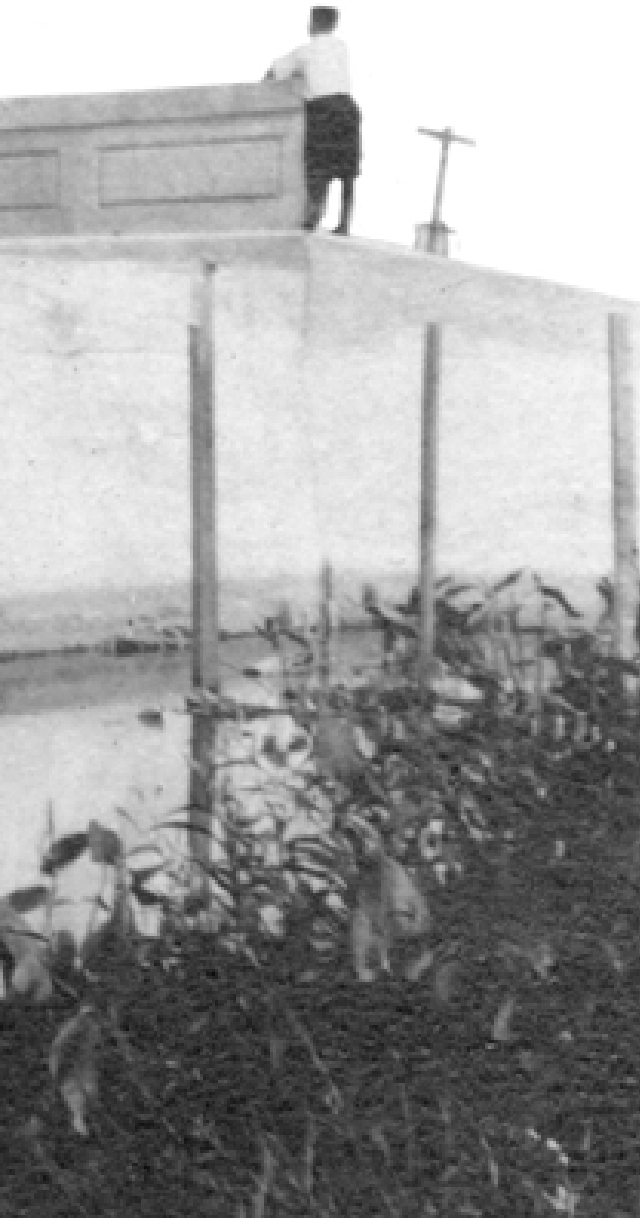
REINFORCED CONCR

ETE BRIDGES

There was an explosion in the use of reinforced concrete by highway bridge builders between 1905 and 1920.



Concrete, composed of sand, gravel, or other aggregate held together by a hardened paste of natural cement and water, has been known since Roman times, but concrete did not come to the fore as a modern building material until after 1813 and the perfection of Portland cement, an artificial hydraulic cement, noted for its strength and abrasion resistance. Initially developed in England, it was expensive, and as result of the cost, its use in this country was very limited until the last quarter of the 19th century. In 1871, David O. Saylor was granted a United States patent for the manufacture of Portland cement and opened a mill at Coplay, Pennsylvania. This breakthrough gave great impetus to experimentation with the material in a variety of building applications. The earliest use of concrete, which has good compressive strength but little tensile strength, was for footings and foundations, but it was soon applied to bridges, especially for the construction of plain concrete arch bridges.

Reinforced concrete proved to be one of the most versatile bridge materials of the 20th century. Large-scale highway improvement campaigns resulted in thousands of standardized, slab, T beam, and arch bridges from the late 1910s to the 1950s. Whether in Delaware or California, the bridges were nearly identical. Dike Bridge, New Castle County, was a two-span reinforced concrete slab bridge erected ca. 1924. This construction photo was taken before the backfill was placed behind the abutments.

Reinforcing plain concrete with internal metal (either rods or mesh) was developed in Europe in the mid-19th century and then experimented with in this country by farsighted engineers like Ernest L. Ransome and Edwin Thacher. While most American engineers were familiar with a combination of concrete and reinforcing`by about 1870, it took another 30 years of experimentation and theoretical and empirical investigations before engineers and builders had a mature understanding of the capabilities and versatility

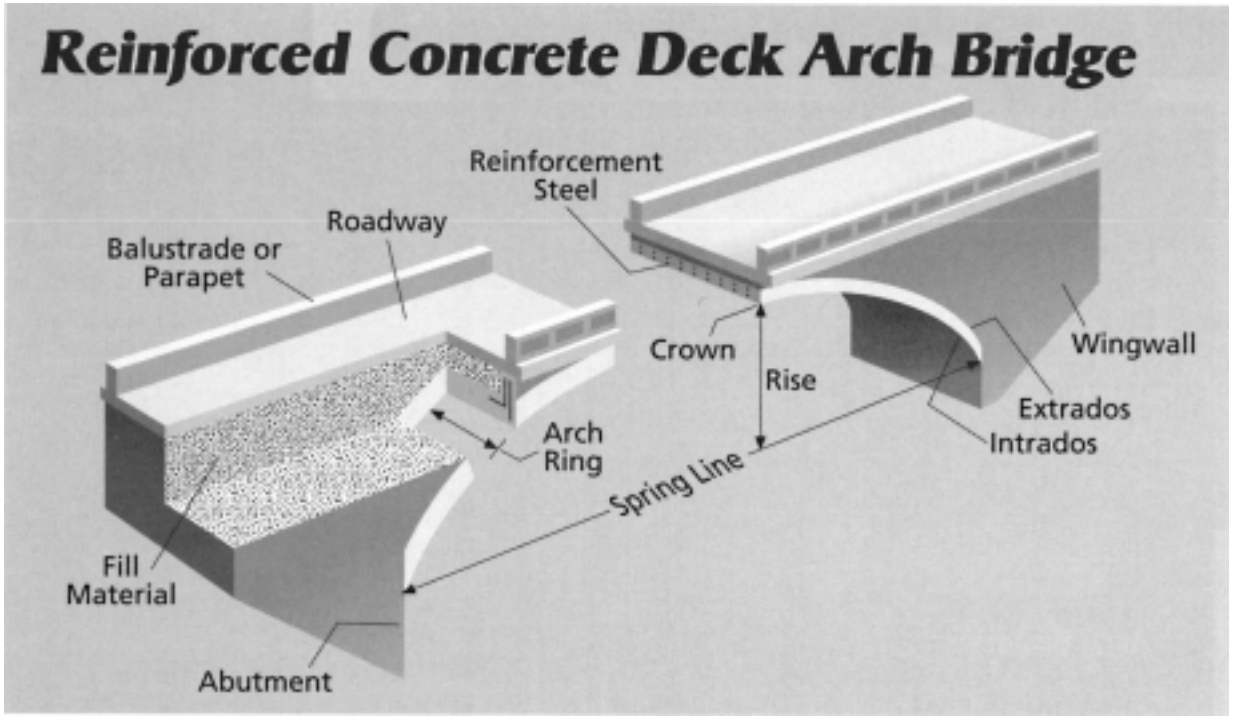
Reinforced Concrete Arch Bridge Construction

Construction photos for 1934 State Bridge K-23A (Lookerman Street over the St. Johns River) illustrate steps in erecting a reinforced concrete arch bridge. First, the falsework is erected (top right) and then the arch ring is poured (top left). Formwork is placed for the spandrel walls (center left), which are then poured (center right). Finally, in this case, a brick veneer is applied to the concrete spandrel walls (bottom right).

of the material. During this period of experimentation, types of reinforcing systems and designs of reinforcing bars were developed. Engineers were even uncertain what to call the new hybrid. Names included ferro-concrete, concrete-steel, and armed-concrete before reinforced concrete became the standardized terminology about 1905.

By the 1910s, reinforced concrete bridges were in widespread use all across the United States. As engineers' understanding of the material matured, it was applied to a variety of bridge types including arches, slabs, T beams, thru girders, and box culverts. The appropriateness of one bridge type over another was predicated on several factors, such as length of span, roadway profile, and economical use of reinforcing steel to accommodate tension and shear.

Reinforcing systems using twisted or textured reinforcing bars became standard. State university engineering schools, state highway departments, the federal Bureau of Public Roads (BPR), and the concrete industry all published literature promoting reinforced concrete to local contractors and municipal governments. Simple instructions



with tables and plans showed county and municipal engineers how to construct economical short-span highway bridges.

Most reinforced concrete bridges are cast in place. Abutments would be placed and then forms, or falsework as it is commonly called, was erected followed by placement of the reinforcing bars. The concrete was then poured into the falsework. Longer spans had to be poured in sections, but shorter spans could usually be completed in one pour. The formwork was gradually released after the concrete had cured sufficiently, usually twenty-eight days depending on conditions. After the formwork was removed, the concrete was finished using a variety of methods. Most often the surface would be rubbed smooth, or alternatively textured with different tools such as a bush hammer. The application of a stone veneer was also common in Delaware.

In Delaware, reinforced concrete bridges did not seriously challenge metal bridges until after 1905. Between 1905 and 1920, however, there was an explosion in the use of the material by highway bridge builders throughout the state. In New Castle County alone, there were already approximately 150 reinforced concrete structures by the late 1920s, accounting for nearly a third of all of that county's highway bridges and culverts. The Delaware State Highway Department, established in 1917, immediately adopted reinforced concrete slab bridges and box culverts for standard use on state highways. The department continued to build the same basic reinforced concrete slab bridges and culverts from the 1920s through the 1950s.

The current survey has identified over 180 reinforced concrete bridges dating from 1906 to 1956. The bridges represent the variety of 20th-century concrete bridge types and designs, including arch, slab, T beam, rigid frame, and box culvert. Thirty-three of the more than 180 DelDOT bridges are significant for their historical association with important early reinforced concrete bridge builders and designers, or for their technological distinction as the earliest, most complete, or innovative in-state examples.

The Locations of Delaware's Historic Reinforced Concrete Bridges

Arch Bridges

1. ***Van Buren Street over Brandywine Creek***
   State Bridge NC-698
   Wilmington, New Castle County
2. ***Jamison Corner Road over Scott Run***
   State Bridge NC-383
   Northwest of Boyd's Corner, New Castle County
3. ***Old Cooch's Bridge Road over Christina River Tributary***
   State Bridge NC-337
   Cooch's Bridge, New Castle County
4. ***Road 46 over Gravelly Branch***
   State Bridge S-237
   Middleford, Sussex County
5. ***Old US 13 over Clear Brook***
   State Bridge S-202
   Hearns Mill, Sussex County
6. ***Washington Street over Brandywine Creek***
   State Bridge NC-576
   Wilmington, New Castle County
7. ***Mount Cuba Road over Red Clay Creek***
   State Bridge NC-120
   Ashland, New Castle County
8. ***Old Baltimore Pike over Christina River***
   State Bridge NC-336
   Cooch's Bridge, New Castle County
9. ***Maryland Avenue over Little Mill Creek***
   State Bridge NC-160
   South of Elsmere, New Castle County
10. ***Lookerman Street over St. Jones River***
    State Bridge K-23A
    Dover, Kent County
11. ***North State Street over Silver Lake***
    State Bridge K-3C
    Dover, Kent County
12. ***Old State Route 7 over White Clay Creek and Mill Creek***
    State Bridge NC-246
    Near Stanton, New Castle County
13. ***Court Street over St. Jones River***
    State Bridge K-67A
    Dover, Kent County

Slab Bridges

14. ***Montchanin Road over Brandywine Creek Tributary***
    State Bridge NC-76
    West of Granogue, New Castle County
15. ***Road 48 over Cow Bridge Branch***
    State Bridge S-673
    North of Millsboro, Sussex County
16. ***Alley Mill Road over Paw-Paw Branch***
    State Bridge NC-476
    Northwest of Clayton, New Castle County
17. ***State Route 1A over Silver Lake***
    State Bridge S-707
    Rehoboth, Sussex County
18. ***Road 54 over Vines Creek***
    State Bridge S-445
    Southeast of Dagsboro, Sussex County
19. ***Kirkwood Highway over Little Mill Creek***
    State Bridge NC-153
    Elsmere, New Castle County
20. ***Market Street over Conrail and Ramp to US Route 13 Southbound***
    State Bridge NC-686
    South of Wilmington, New Castle County
21. ***Silver Lake Road over Silver Lake Spillway***
    State Bridge NC-504
    South of Middletown, New Castle County
22. ***High Street over Conrail (Delaware Railroad)***
    State Bridge S-258
    Seaford, Sussex County
23. ***South Heald Street over Conrail and State Route 9 Ramp***
    State Bridge NC-684
    South Wilmington, New Castle County
24. ***Jefferson Avenue over Chestnut Run***
    State Bridge NC-630
    Willow Run, New Castle County

T Beam Bridges

25. ***Adams Dam Road over Wilson Run***
    State Bridge NC-69
    Rockland, New Castle County
26. ***US Route 13 over St. Jones River***
    State Bridge K-24A
    Dover, Kent County

Box Culverts

27. ***Willow Street over Records Pond Spillway***
    State Bridge S-329
    Laurel, Sussex County
28. ***Road 544B over Hearn's Mill Pond Spillway***
    State Bridge S-200H-1
    Hearn & Rawlins Mill, Sussex County
29. ***Ratledge Road over Barlow Branch Tributary***
    State Bridge NC-430
    Southeast of Townsend, New Castle County
30. ***Brenford Road over Little Duck Creek***
    State Bridge K-42A Massey's Mill Pond, South of Smyrna, Kent County
31. ***State Route 24 over Herring Creek***
    State Bridge S-709
    Southwest of Rehoboth, Sussex County

Rigid Frame Bridges

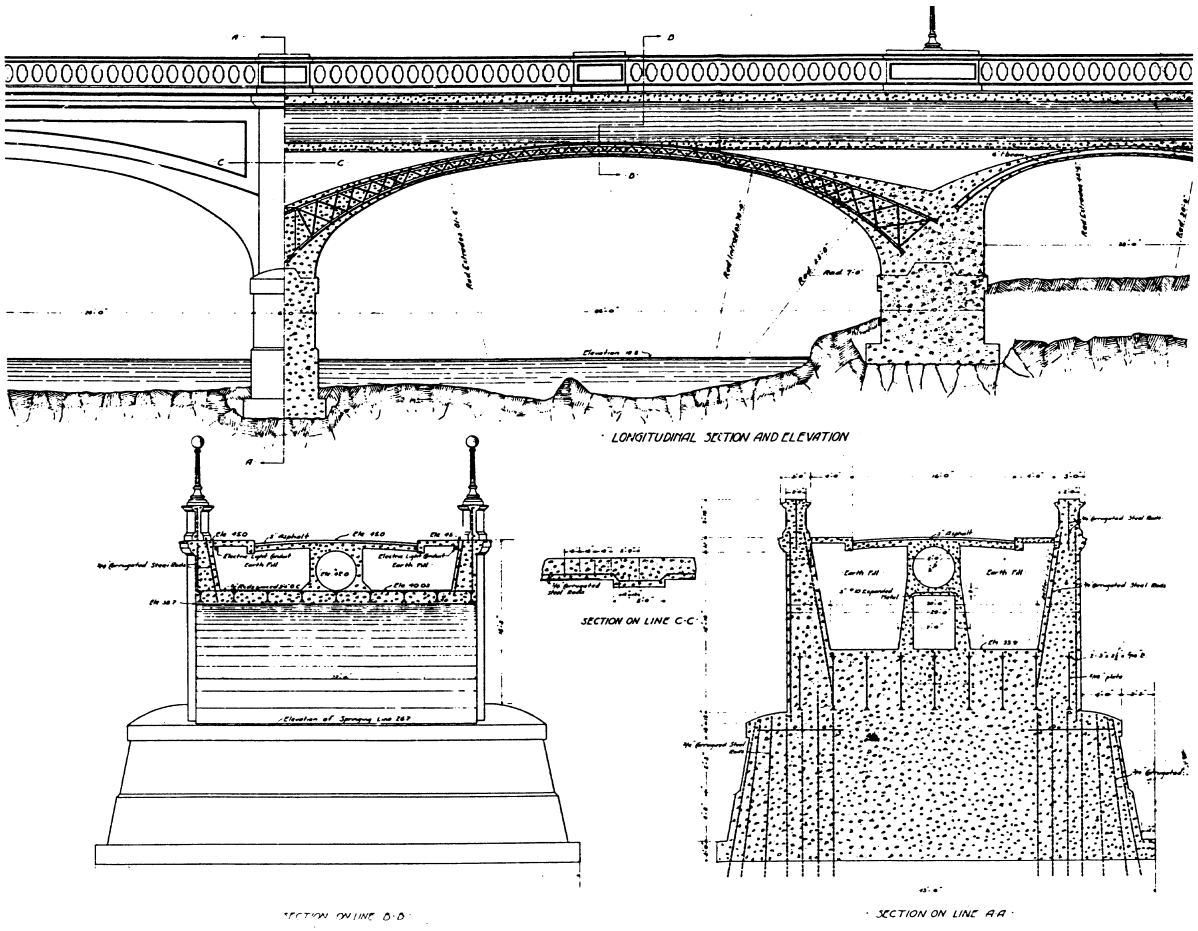
32. ***US Route 13 Northbound over Blackbird Creek***
    State Bridge NC-488N
    North of Blackbird, New Castle County
33. ***Porter Station Road over Red Lion Creek***
    State Bridge NC-300
    Southwest of Red Lion, New Castle County
34. ***Curtis Mill Road over White Clay Creek***
    State Bridge NC-231
    Newark, New Castle County

Arch Bridges

The same principles that govern traditional stone arch construction govern reinforced concrete arch construction, only that rather than shaped blocks compressed together under vertical loads as in a stone arch, reinforced concrete arches are monolithic structures with the reinforcement in the tension zones of the arch ring. In traditional stone arch or plain concrete arch bridges, the sheer mass of material is used to absorb the tensile stresses, but reinforced concrete arches use reinforcing bars to perform the same function. Reinforced concrete arches are in many ways a more efficient design, since a lesser volume of material can do the work formerly done by the additional mass.

One of the earliest reinforcing systems applied to arch bridges was developed in 1861 by a French gardener named Jean Monier. He first used wire mesh nets embedded in the concrete for making stronger pots and tubs. The same principle was

The Luten Bridge Company of York, Pennsylvania, was very active in Delaware in the 1910s and early 1920s. Non-extant Luten bridges from New Castle County included (from top to bottom) a box culvert near Hares Corner, an arch on the Capital Trail over Mill Creek, and another arch over Calf Run.



Details from the 1906 plans for the Van Buren Street bridge (State Bridge NC-698) show the built-up lattice steel beams embedded in the concrete typical of the Melan system.

applied to reinforcing concrete arches at the intrados. His single-net design proved insufficient for handling the tensile stress introduced by live loads, so a second net near the surface of the extrados was added to provide the tensile capacity needed at the outer limits of the arch ring. Over time this system proved less than satisfactory as the mesh was difficult to work with, and the transverse wires of the mesh took no stress making them an expensive but useless detail.

The Melan system, invented in 1892 by Austrian engineer Josef Melan and patented in this country in 1893, utilized steel beams embedded in the concrete. Really more like a steel arch with concrete encasing than a true reinforced concrete structure, the Melan system was able to support greater capacity for longer span lengths than earlier systems, such as the Monier system. The leading proponent of the Melan system in the United States was engineer Edwin Thacher. He designed the first major Melan-type arch, a three-span structure, over the Kansas River at Topeka beginning in 1894. He established the Concrete-Steel Engineering Company of New York City in 1901, and the firm went on to design more than 200 Melan arch bridges prior to 1912, including

Ransome twisted reinforcing bar.

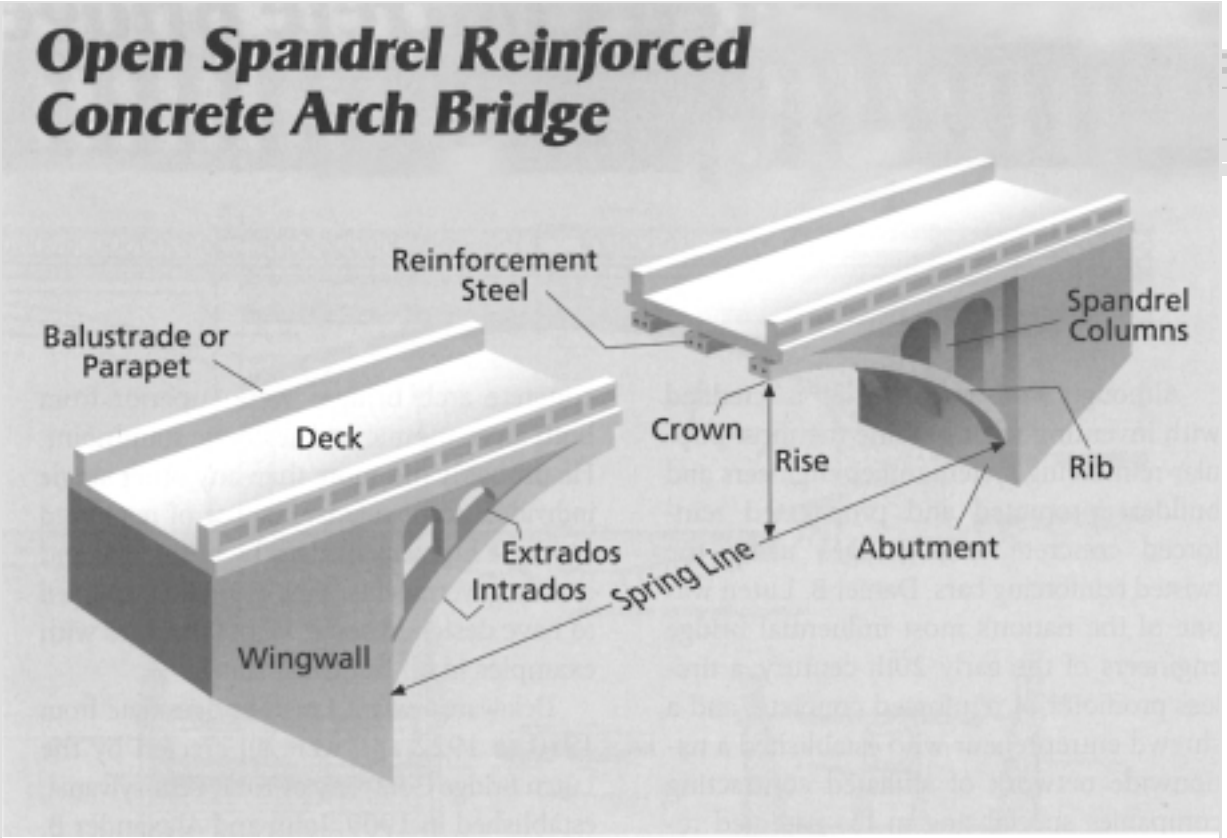
Wilmington's Van Buren Street bridge in 1906 (State Bridge NC-698). It is the state's only example of a Melan arch.

The Melan system was eclipsed during the first decade of the 20th century by versions of the Ransome system of twisted reinforcing bars, first used by Ernest Ransome in the late 1880s. Ransome was a California builder and manufacturer of concrete block who received a patent for the commonly used square twisted reinforcing bar in 1884. He was searching for a factory-building material that offered superior resistance to earthquake, explosion, and fire. He later applied the twisted reinforcing bars to arch bridges, and his 1889 Alvord Lake bridge in San Francisco's Golden Gate Park is considered America's first concrete arch using reinforcing bars. The Ransome system offered important advantages; the twisted bar provided a much better bond between the steel and concrete, and twisting the bar cold raised the steel's yield point considerably. The bars could be offered in a range of sizes, thus providing greater control over the available cross section and eliminating unnecessary metal.

Although Ransome usually is credited with inventing what became the most popular reinforcing system, other engineers and builders promoted and propagated reinforced concrete arch bridges using the twisted reinforcing bars. Daniel B. Luten was one of the nation's most influential bridge engineers of the early 20th century, a tireless promoter of reinforced concrete, and a shrewd entrepreneur who established a nationwide network of affiliated contracting companies specializing in his patented reinforced concrete arch bridges. Between 1899 and 1913, Luten applied for 15 reinforced concrete bridge patents, most for variations of arch design and reinforcing bar placement. In 1902, he organized the National Bridge Company of Indianapolis, and in about 1905, he began making arrangements with other companies from Massachusetts to California to act as agents and contractors for the patented arch bridges. Luten published illustrated catalogues with photographs and plans of his bridges, gave public talks on the virtues of reinforced concrete, and in plain simple terms explained to laymen why reinforced concrete arch bridges were superior from both an economic and aesthetic standpoint. He probably did more than any other single individual to popularize the use of reinforced concrete highway bridges by municipal and county governments. By 1919, Luten claimed to have designed some 17,000 bridges with examples in all but three states.

Delaware's extant Luten bridges date from 1910 to 1922 and were all erected by the Luten Bridge Company of York, Pennsylvania, established in 1909. John and Alexander B. Whittaker operated the firm under a licensing agreement with Daniel Luten and built it into the largest of Luten's affiliated corporations, erecting hundreds of bridges in a market region stretching from New York to Georgia and as far west as Ohio and Tennessee. The firm was very active in Delaware. At least four extant Delaware bridges (State Bridges NC-383, NC-337, S-237, NC-120) are attributed to the company. They are each similar to the "Highway Bridge of Plain Design" described in Luten's catalogues.

In addition to the proprietary arch bridge types and designs like Luten arches, Delaware's county and state highway department



engineering staffs made use of similar plain utilitarian, but non-proprietary arch bridges during the early 20th century. The Delaware State Highway Department, for instance, built a number of reinforced concrete arch bridges during the late 1910s and 1920s, including the 1919 Old US 13 bridge over Clear Brook (State Bridge S-202). The 1922 Old Baltimore Pike bridge over Christina River (Cooch's Bridge/State Bridge NC-336) is a similar example designed by the New Castle County Engineer.

In the first decades of the 20th century, the structural and economic advantages of reinforced concrete became ever more apparent and engineers used the material for other types of arch bridges, most notably open spandrel arches and thru arches.

The development of reinforced concrete technology came to a graceful yet powerful culmination about 1907 in the open spandrel arch bridge that efficiently combines the compressive ability of concrete with the tensile capacity of steel reinforcing. The type can have a continuous arch ring across the width of the bridge or individual ribs, which results in further economy of material. Both designs are finished with spandrel columns to support the deck. Open spandrel arch bridges differ from closed spandrel arch bridges in that spandrel columns are used to support a deck slab rather than walls holding back earth fill. Open spandrel arch bridges were built nationally from about 1907 through the 1950s.

Although they offered economy of material in comparison to closed spandrel arches of similar size and lessening of dead load, open spandrel arch bridges also required more complicated formwork, and they were thus best suited to long-span crossings where an aesthetic bridge was desired. Delaware has one notable open spandrel arch bridge, the 1920-21 Washington Street bridge (State Bridge NC-576) in Wilmington. Like many open spandrel arch bridges nationally, it is in a prominent urban setting where the aesthetics of the design and its architectural features, such as urn-shaped balusters and pylons, are shown off to the best advantage.

Reinforced concrete thru arch bridges

State Bridge NC-246, a reinforced concrete thru arch over White Clay and Mill creeks near Stanton, New Castle County, erected in 1940-1942.

appeared in the United States during the early 1910s, and they are sometimes referred to as Marsh arches, after engineer James B. Marsh of Des Moine, Iowa, who received a patent for a thru arch design in 1911. The thru arch usually consists of two arch ribs carrying the deck on vertical hangers suspended from the arch. Many thru arches were built throughout the Midwest in the 1910s and 1920s, but they were never greatly popular on the East Coast, and as a class, they were not important to the development of Delaware's highways. The state's only known reinforced concrete thru arch bridge is the old SR 7 bridge over White Clay and Mill creeks near Stanton (State Bridge NC-246). Designed by the Delaware State Highway Department in 1940 and opened to traffic in 1942, it is a late example of the thru arch bridge type.

By the late 1920s, the great era of reinforced concrete arch bridges had ended nationally and in Delaware. After 1929, reinforced concrete arch bridges were built less frequently as plain utilitarian structures because of their comparatively high cost of construction and material in comparison to steel and other reinforced concrete bridge types, such as T beams, slabs, and rigid frames. They did, however, continue to be built in small numbers in urban or park-like settings where an aesthetically pleasing bridge was desired. Among the later reinforced concrete arch bridges in the state are three Colonial Revival-style arch bridges in Dover that were designed to complement the nearby state house complex. The three bridges are the 1934 Loockerman Street bridge over St. Jones River (State Bridge K-23A), the 1937 US 13 Business bridge over Silver Lake (K-3C), and the 1956 Court Street bridge over St. Jones River (K-67A).

LEFT: Wilmington's urban progressive reformers, who led the movement for city parks and an improved water system at the turn-of-the century, wanted to improve city life by merging engineering, architecture, and landscape architecture in a City Beautiful Movement. The neoclassical architectural treatment of the Van Buren Street bridge reflected period tastes and was considered appropriate for its setting in Brandywine Park. This photo shows the bridge in its park setting in 1958.

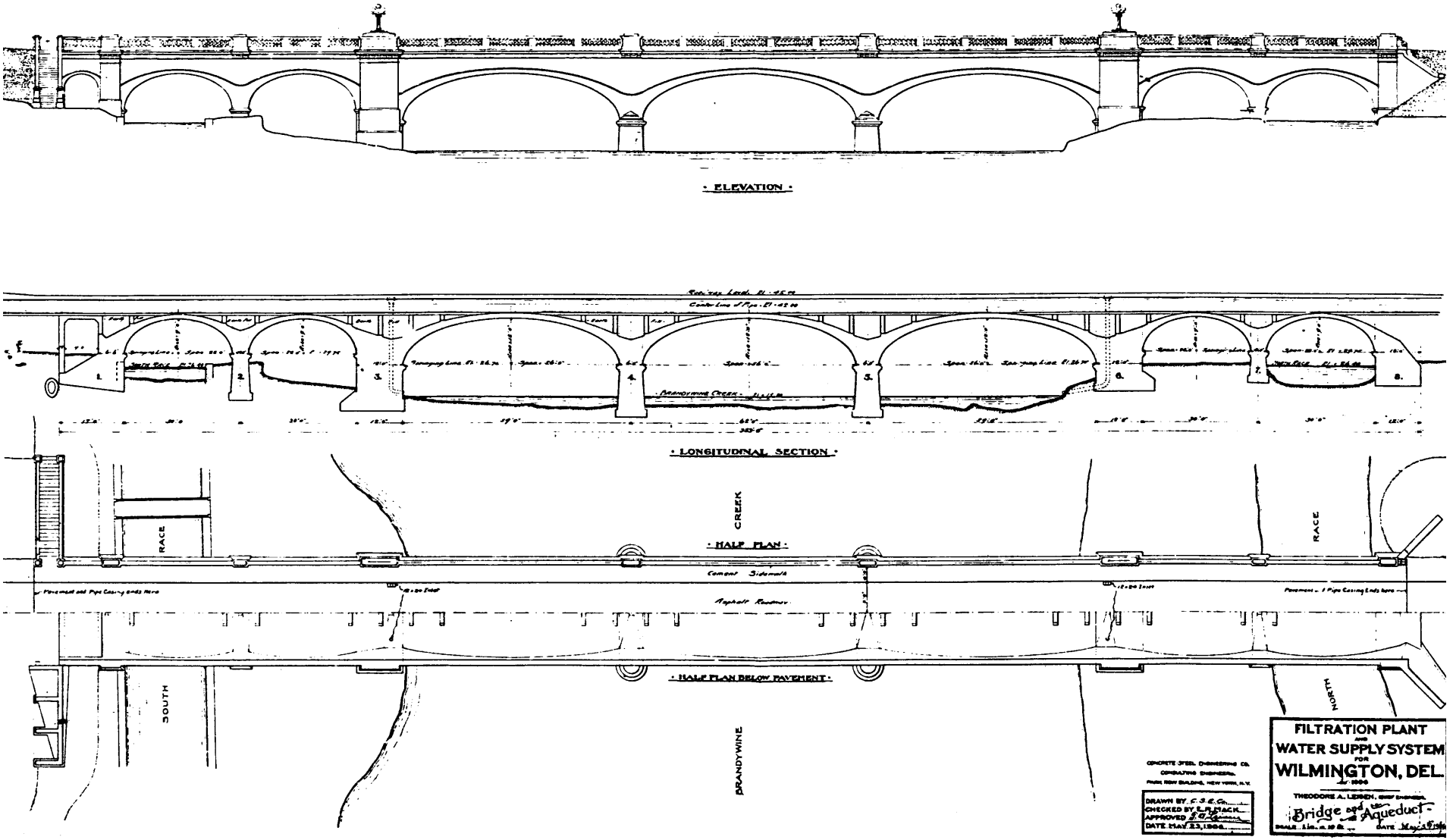
The Van Buren Street bridge built in 1906 is Delaware's only Melan arch.

Van Buren Street over Brandywine Creek

State Bridge NC-698
Wilmington, New Castle County
Designer/Builder: Concrete-Steel Engineering Company

1906

The Van Buren Street bridge is Delaware's only identified example of a Melan arch. Built in 1906 under the joint auspices of Wilmington's water and parks commissions, the bridge was designed by the Concrete-Steel Engineering Company of New York, established by Edwin Thacher

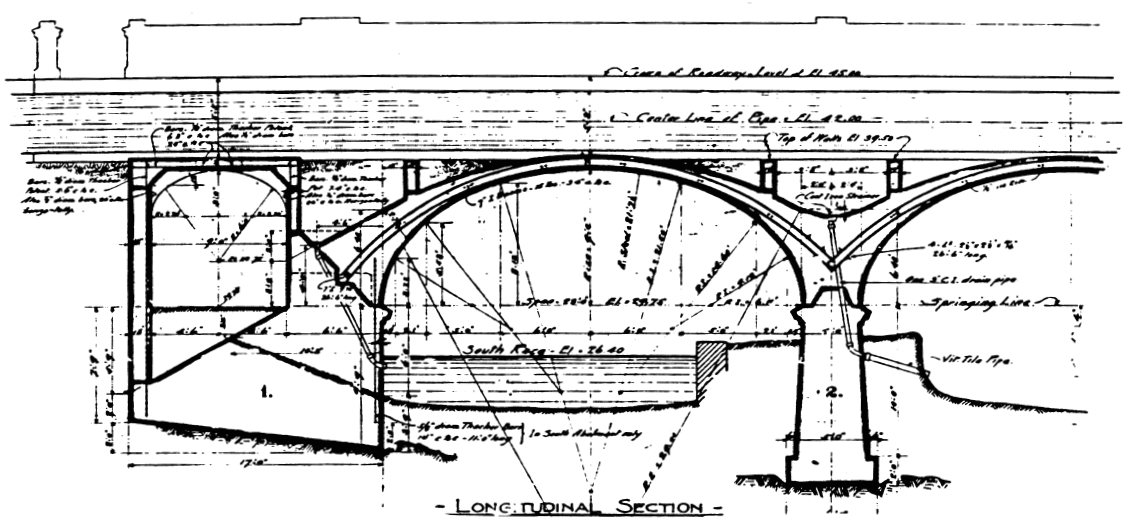


Elevation and plan from the original 1906 drawings for State Bridge NC-698 prepared by the Concrete-Steel Engineering Company. The plans are for "a bridge and aqueduct" for the Wilmington water supply system, indicating the bridge's dual function as a vehicular bridge and an aqueduct for a water main pipe buried in the arch's fill.

DelDOT recently completed a rehabilitation of the Van Buren Street bridge. Although much of the concrete in the spandrels was in an advanced state of deterioration and had to be removed, extraordinary efforts were made to replicate the architectural features and maintain the historic character of the bridge.

in 1901. The 353'-long Van Buren Street bridge has eight arch spans with the longest spans measuring 56' and spanning the creek. The shorter western spans cross over a park walkway and the Brandywine canal raceway. The Melan system consists of metal beams embedded in the concrete. In the 56'-long spans, the curved beams are built-up riveted lattice girders, and in the shorter spans they are rolled I-beams. In actual structural action, Melan arches are more like steel arches encased in concrete than true reinforced concrete arch structures. The spandrel walls and west wingwall staircases are reinforced with twisted reinforcing bars with a textured finish that were patented by Thacher in 1899.

The Van Buren Street bridge is one of Wilmington's finest examples of the influences of the City Beautiful Movement. The Progressive-era, nationwide, urban reform movement merged engineering, architecture, and landscape architecture in an at-



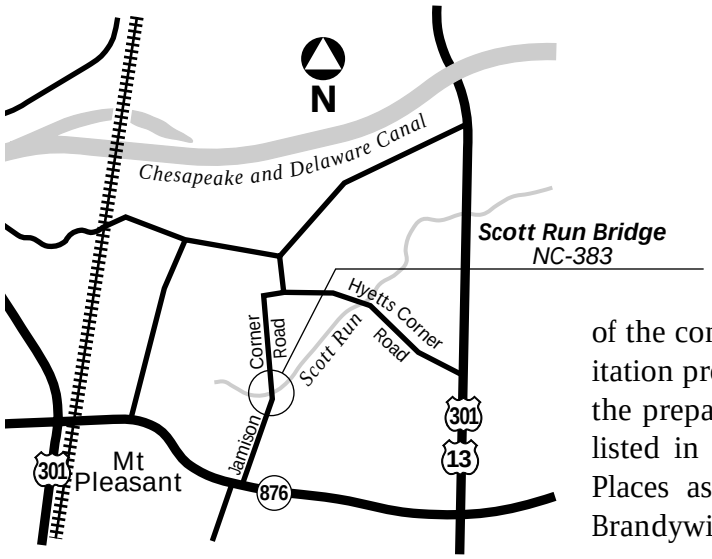
Plans for the Melan arch show the embedded steel beams characteristic of the Melan system.

tempt to improve city life by planning cities with parks and parkways, as well as laying out to a master plan all sewers, water systems, public transit and other public improvements. The Van Buren Street bridge was an integral part of a major project undertaken to improve Wilmington's water supply by carrying water across the Brandywine River from Porter Reservoir to the filter station at 16th and Market streets. The Water Commission first suggested submerging the 48"-diameter water main in the Brandywine River, but planners finally decided in consultation with the Parks Commission to afford the pipe better protection in an aqueduct that would also carry vehicles and pedestrians between the east and west sides of Brandywine Park. The water main was supported on a concrete pedestal built on top of the arch ring and buried in the arch backfill. Brandywine Park was established in 1886 with the original design by Samuel Canby, city parks engineer, in collaboration with America's leading late-19th-century landscape architect, Frederick Law Olmsted.

The neoclassical architectural treatment of the Van Buren Street bridge reflects the period taste of urban progressive reformers. The bridge is finished with ornate concrete balustrades with urn-shaped balusters. The balustrade posts are adorned with dentils, and the end posts have decorative scrolls. The arches are accented by scored arch rings. The piers have rounded ends, and every other pier has a plain pilaster extending upward to form a balustrade post. The west wingwalls serve as the base for parapeted staircases leading to the park.

The Van Buren Street bridge cost $40,000, one-third paid by the Parks Commission and two-thirds by the Water Commission, according to a 1900 agreement. The two commissions shared maintenance of the bridge until 1958.

The bridge has been transferred to state ownership. In 1970, the roadway was widened by 3' by removing the curb and sidewalk on one side. Over time, the bridge has developed numerous spalls and deteriorated and cracked concrete, caused in part by moisture trapped inside the fill. In 1996, DelDOT began a project to rehabilitate the structure, saving as much of the historic fabric as possible given the advanced state



ABOVE: The Jamison Corner Road bridge as it appeared in 1921.

RIGHT: State Bridge NC-383 is Delaware's oldest Luten arch bridge, built in 1910.

of the concrete's deterioration. The rehabilitation project was completed at the time of the preparation of this book. The bridge is listed in the National Register of Historic Places as a contributing resource to the Brandywine Park Historic District.

Jamison Corner Road *(Road 413)* over Scott Run

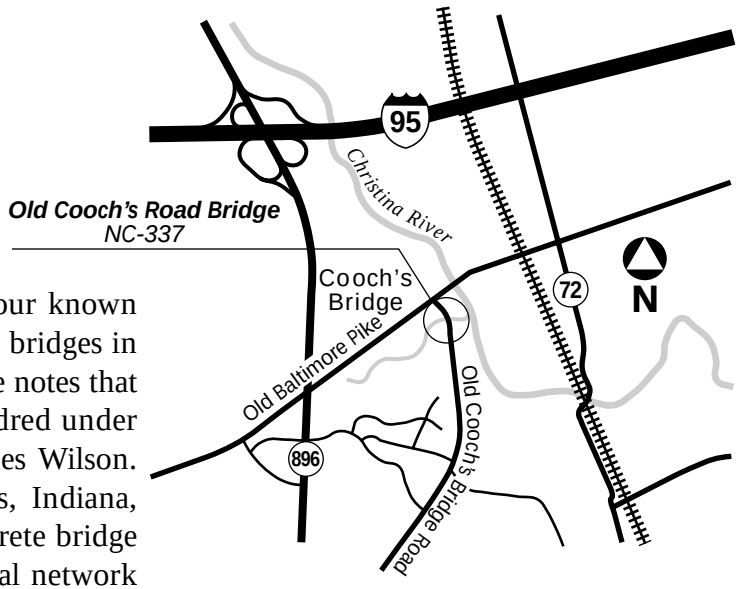
State Bridge NC-383

Northwest of Boyd's Corner, New Castle County

Designer/Builder: Luten Bridge Company of York

1910

The Jamison Corner Road bridge is a one-span, 14'-long, closed spandrel reinforced concrete arch bridge built in 1910 by the Luten Bridge Company of York, Pennsylvania. The 18'-wide bridge has paneled concrete parapets and is supported on concrete abutments with flared wingwalls.



State Bridge NC-337 (1912) is one of four Luten arch bridges in the state historic bridge inventory.

The bridge is the oldest of four known examples of Luten highway arch bridges in Delaware. A plaque on the bridge notes that it was built for St. Georges Hundred under the supervision of engineer James Wilson. Daniel B. Luten of Indianapolis, Indiana, began patenting reinforced concrete bridge designs in 1899, and his national network of companies, established after 1905, was important to the popularization of reinforced concrete bridges throughout the United States. The Luten Bridge Company of York was founded about 1909 by John and Alexander Whittaker who worked under a licensing agreement with Luten. The company sought bridge building contracts throughout many Mid-Atlantic states, including Delaware. The 1910 Jamison Corner Road bridge may well be one of the oldest examples of the firm's work in the region. The bridge is similar to bridges pictured and described as "Highway Bridge of Plain Design" in Luten's catalogue of reinforced concrete bridges, published in 1907.

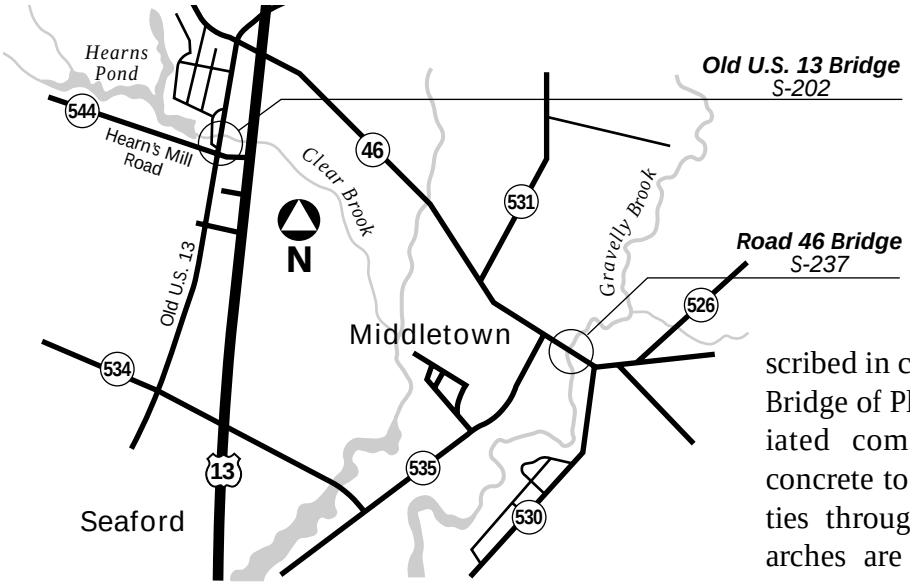
Old Cooch's Bridge Road *(Road 408)* over Christina River Tributary

State Bridge NC-337
Cooch's Bridge, New Castle County
Designer/Builder: Luten Bridge Company of York

1912

The Old Cooch's Bridge Road bridge is a single-span, 12'-long, closed spandrel reinforced concrete arch bridge built in 1912 by the Luten Bridge Company of York, Pennsylvania. The bridge was widened on the upstream (west) side by a 7'-6" wide reinforced concrete slab addition in 1932. It is finished with concrete parapets with incised panels and is supported on concrete abutments with wingwalls. Although widened, the bridge still retains its original appearance on the east elevation. The west side parapet was replaced in kind.

The bridge is the second oldest of four extant Luten arch bridges built between 1910 and 1922. The bridge plaque identifies the builder and date of construction, but no original plans survive in DelDOT records. The Old Cooch's Bridge Road bridge is a representative short-span example of



State Bridge S-237 (1919) is an example of the standard arch bridge type that the Luten Bridge Company of York, Pennsylvania, built by the hundreds throughout the eastern United States.

the standard Luten arch described in company catalogues as "Highway Bridge of Plain Design." Luten and his affiliated companies introduced reinforced concrete to many municipalities and counties throughout the United States. Luten arches are among the earliest reinforced concrete arch bridges surviving in Delaware. The bridge is contributing to the Cooch's Bridge Historic District.

Road 46 over Gravelly Branch

State Bridge S-237
Middleford, Sussex County
Designer/Builder: Luten Bridge Company of York

1919

The Road 46 bridge is a one-span, 62'-long, reinforced concrete, closed spandrel arch bridge. Like the other four extant Luten arch bridges built between 1910 and 1922, it is finished with concrete parapets with incised panels. It is supported on concrete abutments with U-shaped concrete wingwalls. Flared timber wingwalls have been added in an effort to arrest erosion of the embankments.

According to state records, the Road 46 bridge was built in 1919 by the Luten Bridge

Company of York, Pennsylvania, under the supervision of Sussex County Engineer W. E. Hawkins. Construction plans do not survive, but the bridge is similar to the "Highway Bridge of Plain Design" advertised in Luten company catalogues. Daniel B. Luten's first bridge company was the National Bridge Company of Indianapolis, Indiana, established in 1902, but after 1905 Luten expanded his business by establishing licensing relationships with bridge contractors all across the United States. The companies, such as the York concern founded in 1909 by John and Alexander Whittaker, were instrumental in promoting reinforced concrete highway bridges to local municipalities and counties, especially throughout many rural regions of the country. The 1919 Road 46 bridge is a later example of the arch bridge type that the Luten Bridge Company of York had been building in Delaware for nearly 10 years. It is the only surviving Luten arch bridge in Sussex County.

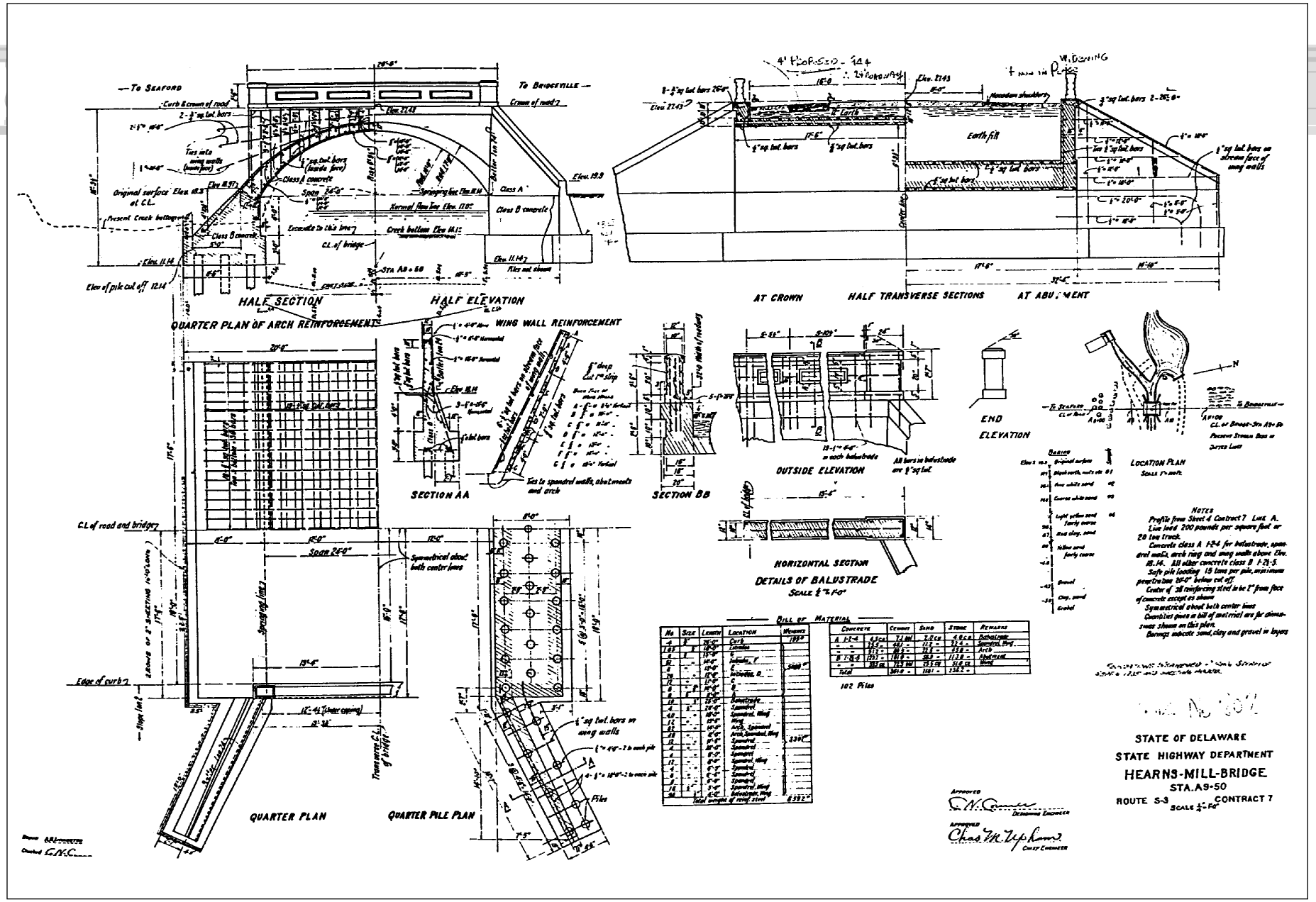
State Bridge S-202 (1919) on Old US 13 is a plain, utilitarian arch bridge of a type that was very common from the 1910s to the 1930s.

Old US 13 *(Road 13)* over Clear Brook

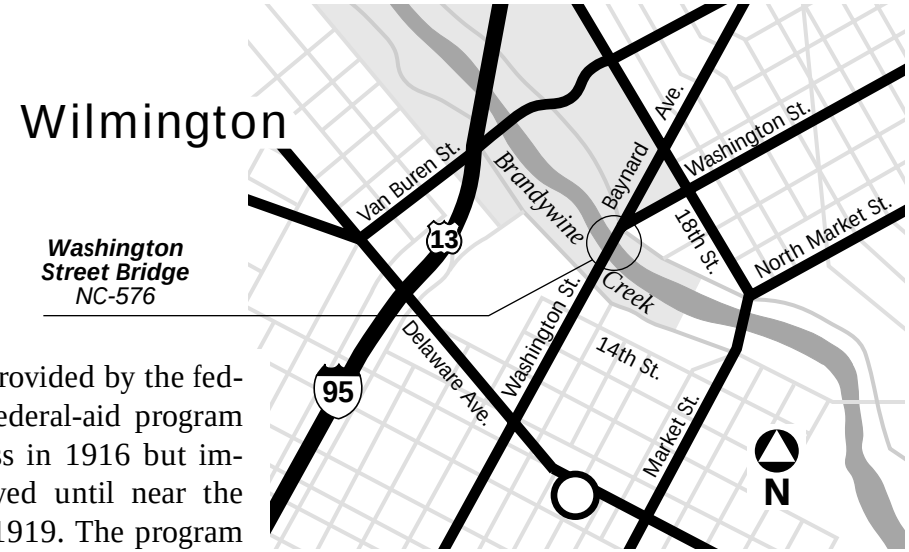
State Bridge S-202
Hearns Mill, Sussex County
Designer/Builder: Delaware State Highway Department/Kaufman & Garcey
1919

The Old US 13 bridge is a 28'-long, 35'-wide, reinforced concrete, closed spandrel arch bridge. The bridge is finished with paneled concrete parapets with corbeled bases and caps. It is supported on concrete abutments with flared wingwalls.

The bridge is historically significant as one of the oldest identified arch bridges designed in-house by the state highway department as part of one of the state's first federal-aid projects (FAP 2) in 1919. The project was for the construction of a 6.6-mile concrete road from Seaford to Bridgeville, and included all bridges and culverts,



State Bridge S-202 was one of the first bridges designed in-house by the Delaware State Highway Department, established in 1917. The department led a centralized program of road and bridge improvements designed to upgrade the state's highways for motorized vehicular traffic.



with $20,000 funding provided by the federal government. The federal-aid program was created by Congress in 1916 but implementation was delayed until near the end of World War I in 1919. The program marked a major shift in national highway policy and spurred the creation of state highway departments, including Delaware's in 1917, to manage and maintain state highway systems and administer federal aid. The state and federal highway programs led to an accelerated and centralized program of road and bridge improvements designed to upgrade the state's primary roads for automobile and truck traffic.

Plans for the arch bridge over Clear Creek were prepared by the state highway department in April 1918. It is representative of the type of plain, utilitarian structures advocated by the federal highway bureau and state highway departments.

Washington Street (Road 43) over Brandywine Creek

State Bridge NC-576
Wilmington, New Castle County
Designer/Builder: Benjamin H. Davis & Vance W. Torbert/Walsh Construction Company

1920-21

The skewed, five-span, 720'-long Washington Street bridge consists of a 250'-long, ribbed open spandrel arch main span, flanked to each side by two closed spandrel arches of 85' and 75'. The roadway is 40'-wide from curb to curb with 14'-wide sidewalks on either side. The bridge is the only open spandrel arch bridge in Delaware, and it is noteworthy for its elaborate architectural treatment. The arch ribs of the main span are scored to appear as stone voussoirs. Pilasters with dentils rise from the piers to form pylons. The spandrel

New York architect Vance W. Torbert designed the Washington Street bridge's architectural features, including the pylons pictured here, as a fitting memorial to Delaware's veterans.

The Washington Street bridge (1920-21) is the only open spandrel arch bridge in Delaware. The high-level crossing of Brandywine Creek provided an ideal location to show the handsome open spandrel arch design.

The view from below the Washington Street bridge.

columns are arcaded, and the balustrades have urn-shaped balusters. The bridge has eight pylons: four, 40'-high pylons over the piers of the main span, and four 23'-high pylons at the portals. The bridge is supported on concrete abutments and piers; a stairway at the southwest corner of the bridge leads to the river walk and Brandywine Park below. It is located in the Brandywine Park Historic District and is rated as a contributing resource to the district.

The Washington Street bridge was designed as a memorial to Delaware's war veterans. Four, 40'-tall, pylons of the main span carry bronze tablets commemorating the Revolutionary War, the War of 1812, the Mexican War, the Civil War, and the Spanish-American War. Two tablets commemorate World War I, one with the names of battles in which Delaware troops fought, and the other inscribed with the names of men from Delaware killed in the war. The pylons are further embellished by carved stone eagles and shields, ornamental bronze lanterns, and inscribed quotes from famous Americans.

Open spandrel arch bridges were first built in the United States in the last half of the first decade of the 20th century, and the technology remained popular through the 1950s, especially for bridges that were at prominent locations or park settings where an aesthetic design was desirable. The Washington Street bridge is a classic example of the bridge type, designed by Benjamin H. Davis, one of America's foremost engineers of open spandrel arch bridges, with the assistance of architect Vance W. Torbert. From 1906 to 1910, Davis gained his reputation as a bridge engineer for the Delaware, Lackawanna & Western Railroad (DL&W),

assisting with the design of open spandrel arch bridges for the line's New Jersey Cut-off between Hopatcong, New Jersey, and Slateford, Pennsylvania. The DL&W was the first railroad in the United States to turn to the use of reinforced concrete for all of the structures on a major section of its main line, earning it the name "The Concrete Railroad." The DL&W's decision to use reinforced concrete won the material widespread acceptance and popularized the open spandrel arch design. Davis went on to design a number of other monumental open spandrel arch bridges in the region, including bridges in Conshohocken, Wilkes-Barre, and Allentown, Pennsylvania; Richmond, Virginia; Chattanooga, Tennessee; and Lawrence, Massachusetts.

Architect Vance W. Torbert was a graduate of Drexel Institute, Philadelphia, and a former member of the prominent architectural firm of Carrere & Hastings in New York, specializing in Beaux-Arts designs. In the early 1910s, Torbert established his own practice and was noteworthy for his work on the residences of the exclusive suburb of Tuxedo Park, New York, and the annex to the Aura Grata Cathedral of the Ancient Accepted Scottish Rite, Brooklyn (1915). Torbert worked with Davis on more than a half-dozen bridges in the 1910s and 1920s.

The Washington Street bridge replaced a metal deck truss bridge fabricated in 1893 by the Edge Moor Bridge Works of Wilmington and erected by the Wilmington Construction Company. The North Side Improvement Company, incorporated in 1891 as a development corporation for suburban residences on the highlands north of the Brandywine River, influenced the county Levy Court to build the 1893 truss bridge. By 1919, increased traffic associated with suburban development had rendered the old bridge obsolete because of its narrow width. Plans were made to replace it with a wider structure that would accommodate a double streetcar track, automobile and truck traffic, and pedestrians.

Early in the planning for the replacement bridge, it was decided that the new bridge would be dedicated as a memorial to war veterans and that its prominent location over Brandywine Park required an aesthetic

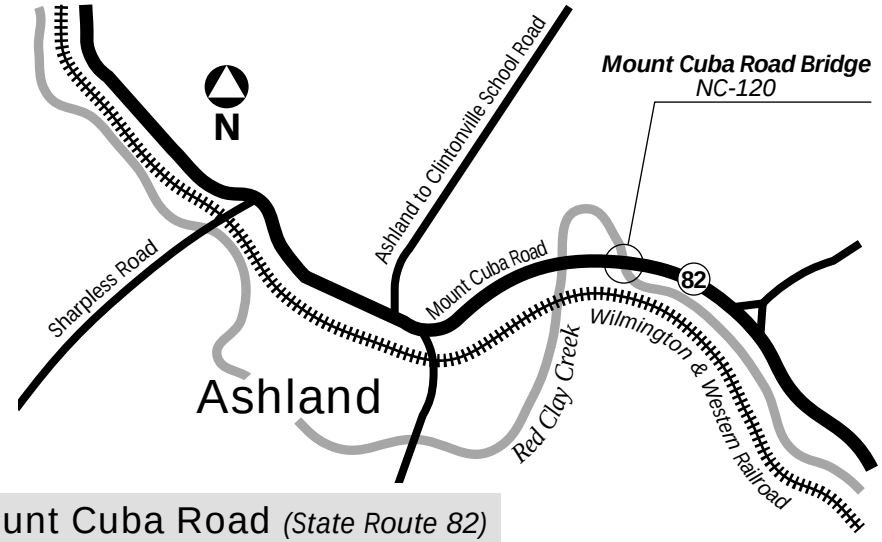
The Washington Street bridge has arch ribs, which result in economy of material in comparison with a continuous arch ring.

design. In order to raise the estimated half-million dollars for construction, the Delaware General Assembly authorized the creation of a Washington Street Bridge Commission in March 1919 to issue bonds backed by the credit of New Castle County and the state. Preliminary surveys and designs were prepared by Charles E. Grubb, New Castle County Engineer, and John E. Greiner of Baltimore. The local newspaper called the Washington Street bridge project the city's "first successful effort to combine an artistic treatment of a municipal bridge with structural solidity and dignity."

A competition was held for the final design; the commission's invitation to bid was sent to a preselected list of nationally prominent candidates in May 1919 and stipulated: "A substantial, durable bridge is essential, but the location and the desire to give the structure or its surroundings a memorial character make imperative careful consideration of the aesthetic features of the design." Davis responded enthusiastically by telegram two days later: "very much interested in your proposition just rec'd... bridge site magnificent; possibilities great; am delighted to receive your invitation and accept it with pleasure." A number of prominent engineers, including Daniel Luten, presented designs, but the final choice of the commission was the collaborative effort of Davis and Torbert based on their submission's aesthetic value and price.

In February 1920, the commission chose the Walsh Construction Company of Davenport, Iowa, and Syracuse, New York, as the general contractor for a price of $747,700. Worked commenced in August 1920. The personal finances of bridge commission chairman Alfred I. duPont were placed at the disposal of the commission at several different junctures. He advanced $90,000 to cover architectural and engineering fees to avert a delay of up to 18 months caused by a slow bond market, and he guaranteed the payment of $300,000 to the contractor when the estimated cost exceeded the $500,000 authorized by the county and state. DuPont also underwrote the additional cost of executing the balustrades and pylons in Litholite cast stone rather than concrete to achieve better appearance.

The bridge opened to traffic on November 24, 1921, but cosmetic work continued through the early part of 1922. The formal opening was deferred until Memorial Day, 1922. The opening ceremonies were a major city event with an invocation, speeches, and a pagent depicting the history of the Brandywine Valley in allegory. At the close of the ceremonies, the bridge was formally handed over to New Castle County by the bridge commission, and the memorial tablets were unveiled. This was followed by a parade of 1,200 girls, strewing flowers on the waters of the Brandywine River. In 1924, *Scientific American* featured the Washington Street bridge in a one-page article stressing the appropriateness of the bridge as a veterans' memorial and a practical transportation improvement.



State Bridge NC-120 (1922) was built by the Luten Bridge Company of York, Pennsylvania.

Mount Cuba Road *(State Route 82)* over Red Clay Creek

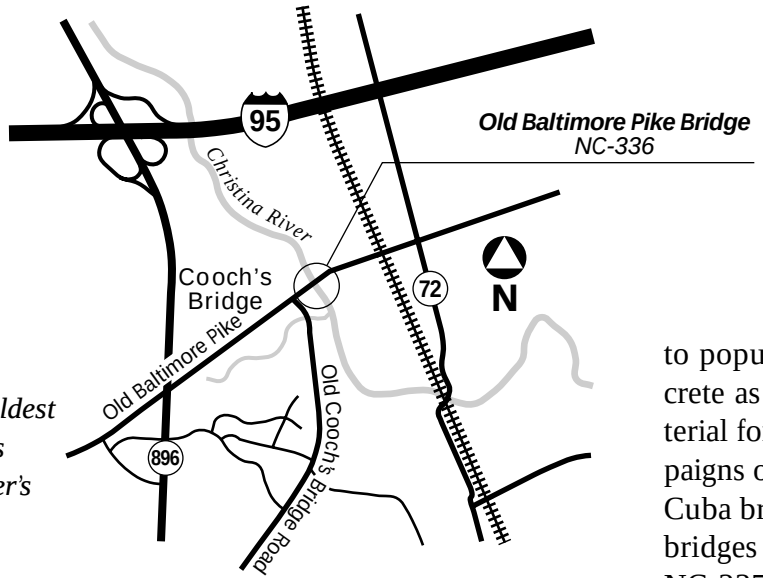
State Bridge NC-120
Ashland, New Castle County
Designer/Builder: Luten Bridge Company of York

1922

The skewed, one-span, 87'-long and 27'-wide reinforced concrete closed spandrel arch bridge is supported on concrete abutments with wingwalls. It is finished by concrete parapets with incised panels. Built in 1922, by the Luten Bridge Company of York, Pennsylvania, the Mount Cuba Road bridge is the latest of four extant Luten arch bridges from 1910 to 1922 in Delaware. Established by John and Alexander Whittaker in 1909, the Luten Bridge Company of York was one of several companies throughout the United States specializing in the patented reinforced concrete bridge designs of Daniel B. Luten. All four of Delaware's Luten arches were constructed by the company and are representative of Luten's "Highway Bridge of Plain Design," illustrated in company catalogues.

Daniel Luten was one of America's foremost builders and promoters of reinforced concrete arch bridges in the early 20th century. An 1894 engineering graduate of the University of Michigan, Luten early recognized the potential of reinforced concrete and secured himself in the bridge-building business by taking out more than 15 patents from 1899 to 1911. After founding his own National Bridge Company in Indianapolis in 1902, he went on to aggressively seek out business partners, like the Whittakers, to market and build Luten arch bridges throughout the country. By 1920, he claimed that more than 17,000 Luten bridges had been built nationwide. Luten did as much as any other single individual

The arch bridge replaced a Pratt pony truss bridge in 1922.



State Bridge NC-336 (1922) is among the oldest and longest reinforced concrete arch bridges designed by the New Castle County Engineer's Office. It is located in the Cooch's Bridge Historic District.

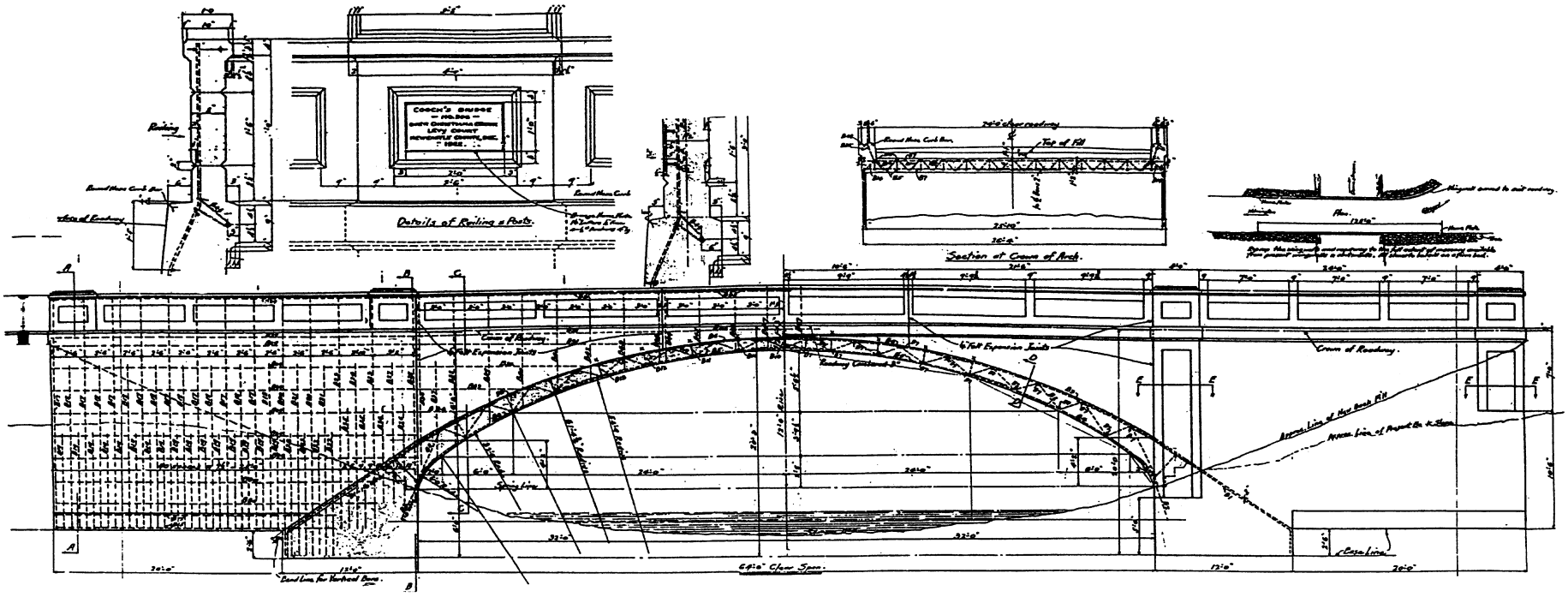
to popularize and promote reinforced concrete as the most appropriate building material for the highway bridge building campaigns of the early 20th century. The Mount Cuba bridge and the other three Luten arch bridges in the state (State Bridges NC-383, NC-337 and S-237) are historically and technologically significant bridges documenting the influence of Luten.

Old Baltimore Pike *(Road 336/ Cooch's Bridge)* over Christina River

State Bridge NC-336
Cooch's Bridge, New Castle County
Designer/Builder: Charles E. Grubb, New Castle County Engineer/Charles P. Witsil

1922

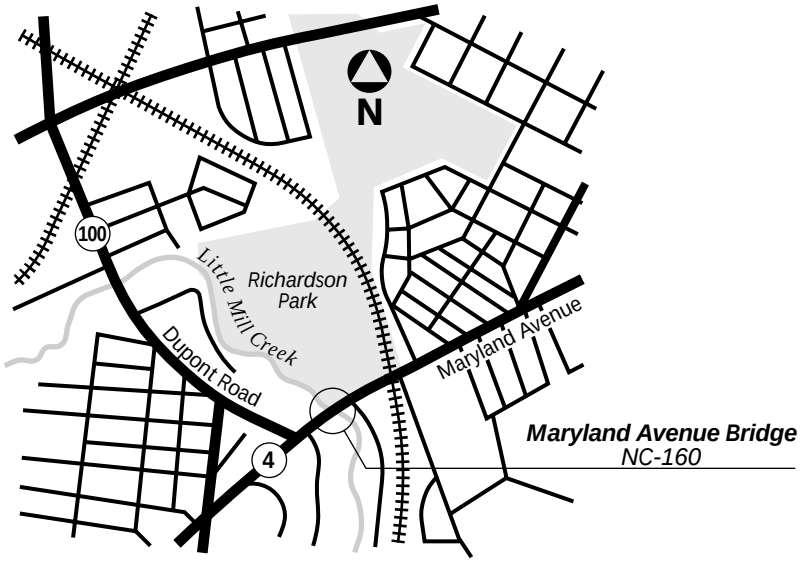
The Old Baltimore Pike bridge, Cooch's Bridge, is a one-span, 88'-long, reinforced concrete arch bridge built in 1922. It is finished with incised paneled parapets



Excerpts from the original 1922 drawings for State Bridge NC-336 show the reinforcing bar plan and a detail of the paneled parapets.

and is supported on concrete abutments with wingwalls. Paneled pilasters are located at the abutment corners and rise to form the parapet posts. The bridge is historically significant as a well-detailed, aesthetic, and long-span example of its bridge type, designed by the county engineering department and built by a local Wilmington contractor, Charles P. Witsil. It is among the oldest and longest surviving county-designed reinforced concrete arch bridges in New Castle County. According to Levy Court records, the 1922 bridge replaced a pony truss bridge placed in 1881. The truss was dismantled with the members match-marked so it could be reassembled elsewhere.

The bridge is rated a contributing resource in the Cooch's Bridge Historic District. The district, which extends along the Christina River up and downstream of the bridge, includes Dayett's Mill, on the east bank of the river and one of only two remaining operable flour mills in Delaware, and the Cooch Mansion, located on the property northwest of the bridge. The bridge is at the site of the Battle of Cooch's Bridge, a Revolutionary War battle. A monument commemorating the event is located beside the road west of the bridge.



State Bridge NC-160 was built in 1931 as a replacement structure as part of improvements to widen Maryland Avenue for four lanes of traffic.

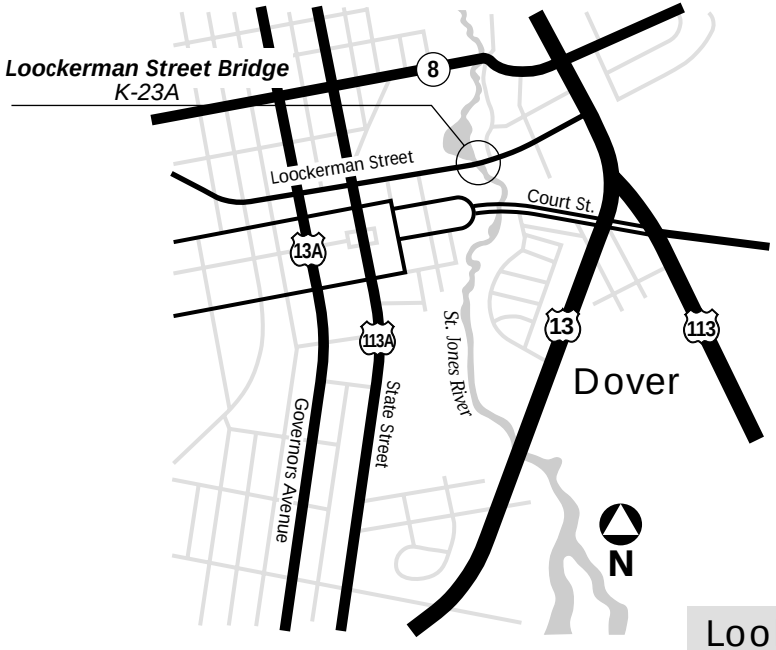
Maryland Avenue *(Road 336)* over Little Mill Creek

State Bridge NC-160
South of Elsmere, New Castle County
Designer/Builder: County Engineer/Ed Daylor

1931

The one-span, 58'-long, 62'-wide, reinforced concrete closed spandrel arch bridge, built in 1931, is historically significant as an example of its type. It is finished with concrete balustrades. Sections of the upstream balustrade were lost and replaced in kind in 1983. Original luminaires have been removed. The bridge is supported on concrete abutments with U-shaped wingwalls. It was designed by the New Castle County Engineer and built by contractor Ed Daylor of Coatesville, Pennsylvania.

According to Levy Court records, the bridge was a replacement structure built as part of improvements to widen Maryland Avenue for four lanes of traffic. The project



State Bridge K-23A has Colonial Revival detailing in keeping with the style of the nearby statehouse complex in Dover.

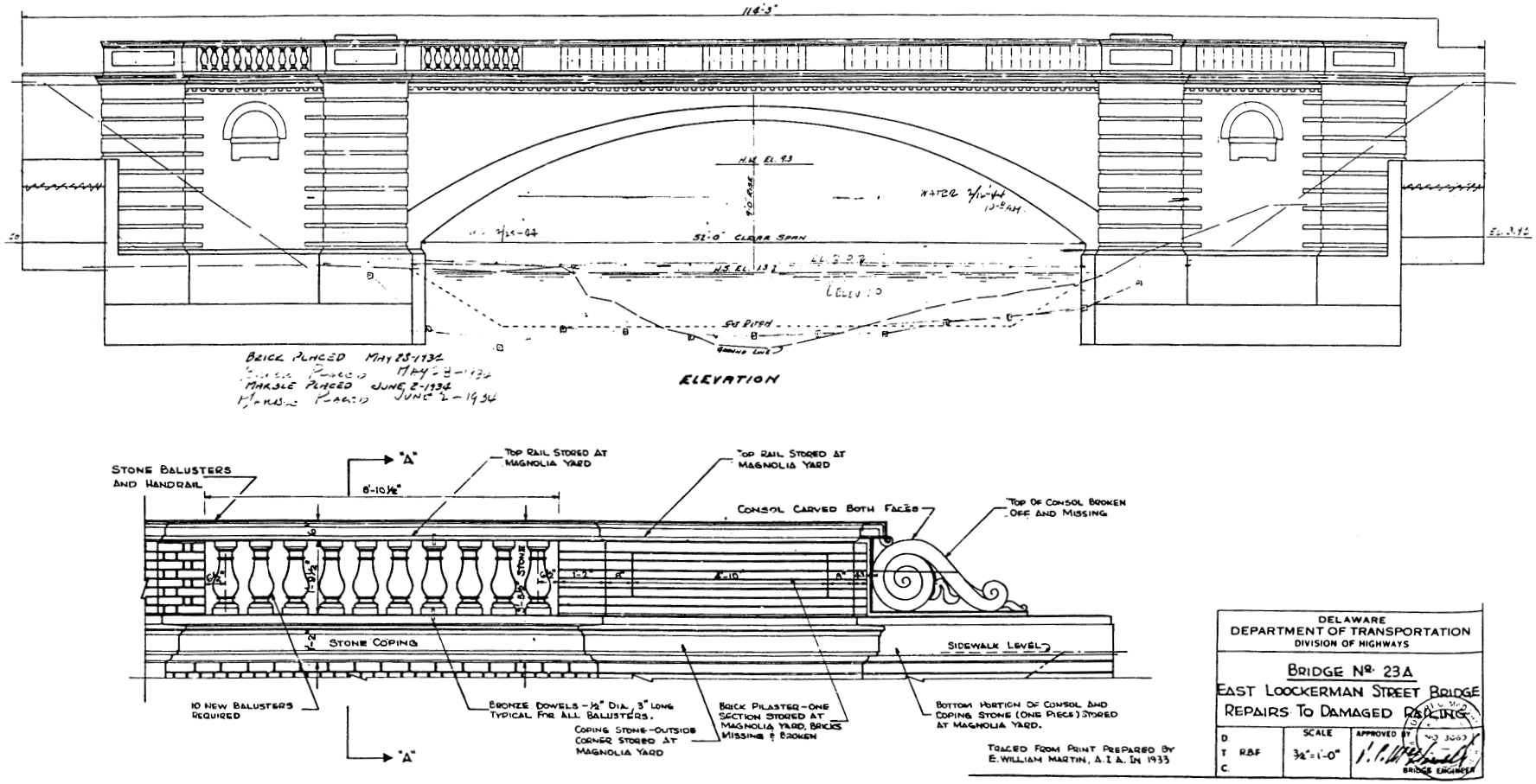
coincided with the development of the adjacent Richardson Park, a recreation area of picnic tables, fields, and playgrounds, on the north side of the avenue. The opening of the park and bridge were celebrated by speakers and a parade on November 21, 1931. During the first half of the 20th century, arches were usually considered one of the most appropriate bridge types for park settings because of their aesthetic value.

Lookerman Street *(Road 23)* over St. Jones River

State Bridge K-23A
Dover, Kent County
Designer/Builder: E. William Martin/Snyder Engineering Company
1934

The Lookerman Street bridge is a one-span, 57'-long, 43'-wide, reinforced concrete, closed spandrel arch bridge noteworthy for its Colonial-Revival detailing which is in keeping with the nearby statehouse complex. The bridge has brick veneer spandrel walls and wingwalls, an arch ring emphasized by a white marble veneer, brick and white marble balustrades with urn-shaped balusters and consoles, ornamental wrought-iron lamp posts, and brick pilasters with niches accenting the wingwalls.

The bridge is historically significant for its association with prominent Delaware architect E. William Martin, who designed it for the state highway department. In 1932,

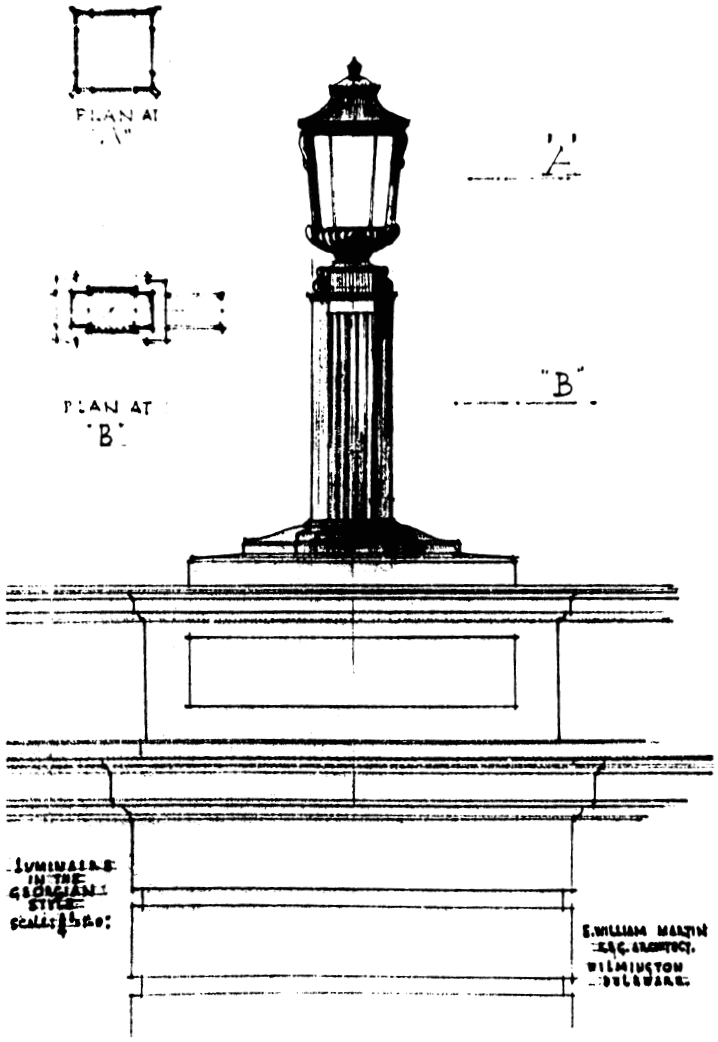


Railing details for the Lookerman Street bridge. Traced from the original 1933 drawings for 1979 repairs.

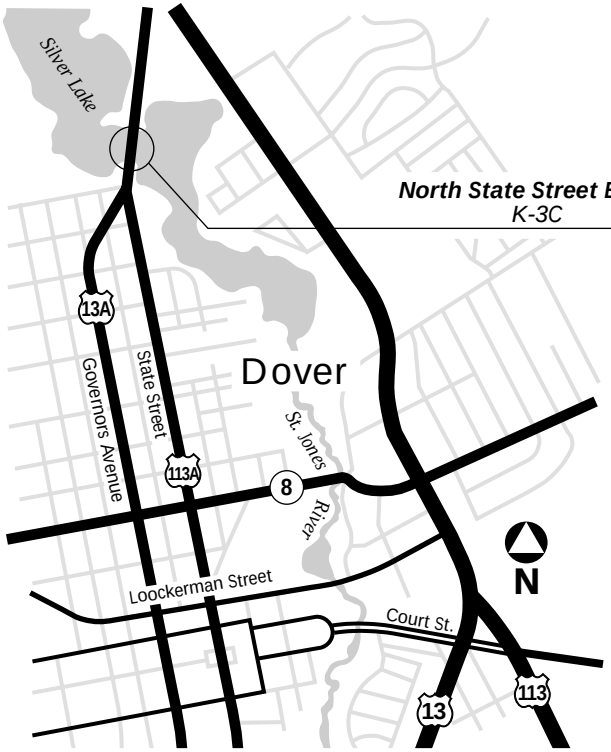
the department began planning for a new bridge at East Lookerman Street to improve access to the statehouse complex. The department noted that the structure required "special attention...to secure a design which will be in harmony with its surrounding and setting," especially the new Georgian-Revival State Legislative Building on the state capital grounds immediately to the west. To achieve this harmony, the department developed five alternative designs with the final decision for a traditional Colonial-Revival appearance. Martin also designed the State Legislative Building. He was among Delaware's most prominent architects of the period. A graduate of the University of Delaware and the School of Architecture of the University of Liverpool, England, he began practicing in Philadelphia and was admitted to the American Institute of Architects in 1923. He moved to

Wilmington and opened an office in the DuPont Building in 1926. Martin quickly rose to statewide prominence in the profession, becoming a charter member (and later President) of the Delaware Chapter of the AIA, which was organized in 1931, a leader in the movement to support state legislation requiring the registration of architects, and a winner of numerous state and national architectural awards. Among his commissions were a number of large residences for leading Delawareans, the federal court and post office buildings in Wilmington, several buildings for the University of Pennsylvania, and a number of the buildings at Longwood Gardens.

For the Lookerman Street bridge, Martin detailed the red brick fascia and white marble trim; the result proved very satisfactory to the state highway department. In its 1933 *Annual Report* the department called it "one of the beautiful small bridges in America. It is...finished with colonial brick and white marble, the motif being suggested by that of the nearby new State Legislative Building. The completion of the bridge...will transform this formerly ugly locality into one of undeniable attraction." The marble consoles on the parapets were modeled by Edward Ardolino, Inc., architectural sculptors of Philadelphia, and the decorative stonework executed by the Vermont Marble Company of Proctor, Vermont. General contractor Snyder Engineering Company of Middlesex, New Jersey, built the bridge. The Lookerman Street bridge earned Martin another commission from the state highway department, this one for the similarly detailed 1937 North State Street Bridge over Silver Lake in Dover (State Bridge K-3C). The 1956-57 Court Street Bridge (K-67A) was also patterned after the Lookerman Street bridge, although Martin was not directly involved with the design.



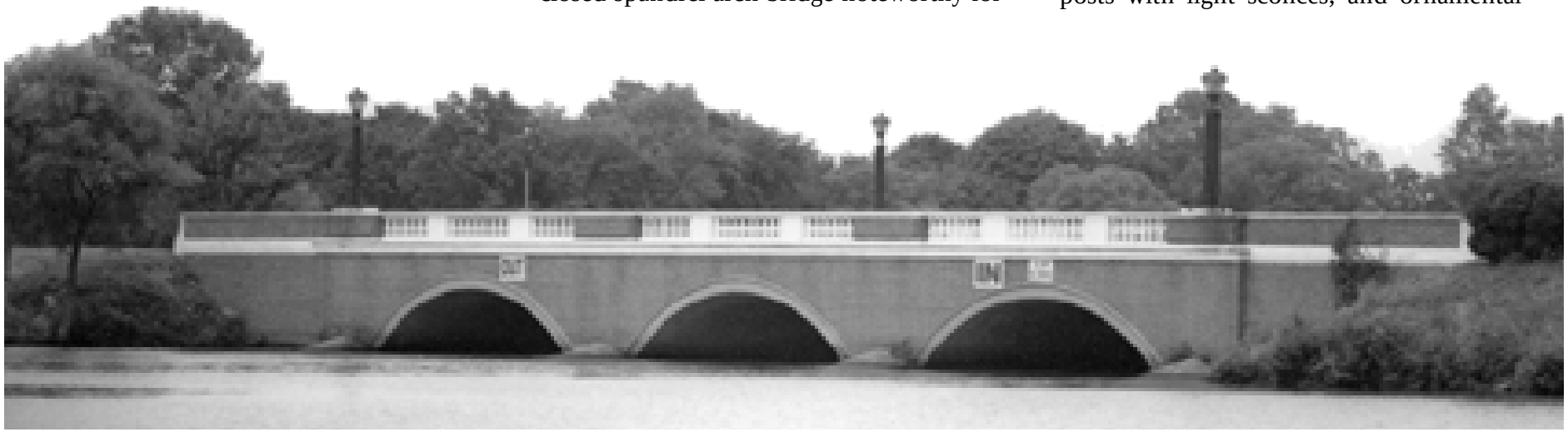
"Luminaire in the Georgian Style" designed by Wilmington architect E. William Martin for the Lookerman Street bridge.



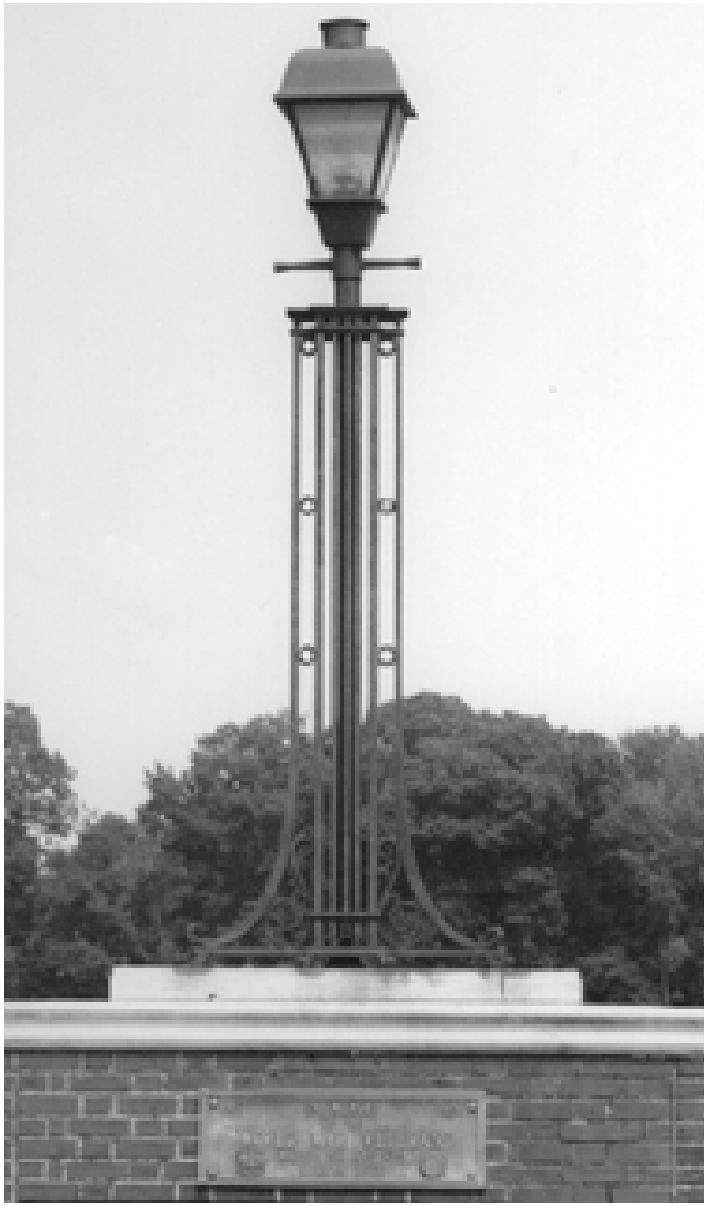
North State Street *(US Route 13A)* over Silver Lake *(St. Jones River)*

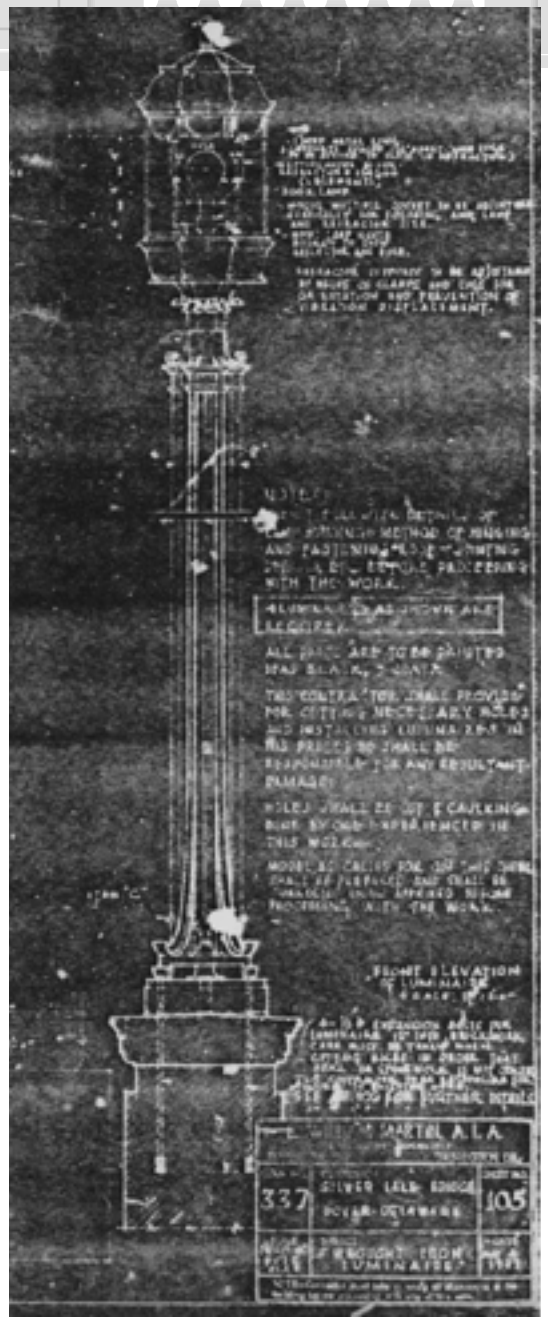
State Bridge K-3C
Dover, Kent County
Designer/Builder: E. William Martin/Spear-Jones Company
1937

The North State Street bridge is a three-span, 155'-long, reinforced concrete, closed spandrel arch bridge noteworthy for its Colonial-Revival detailing and association with prominent Delaware architect E. William Martin. The bridge has brick veneer spandrel walls and wingwalls, an arch ring emphasized by a white marble veneer, brick and white marble balustrades with urn-shaped balusters and paneled brick posts with light sconces, and ornamental



State Bridge K-3C (North State Street over Silver Lake) in Dover is the second of two similar spans with architectural details by E. William Martin.



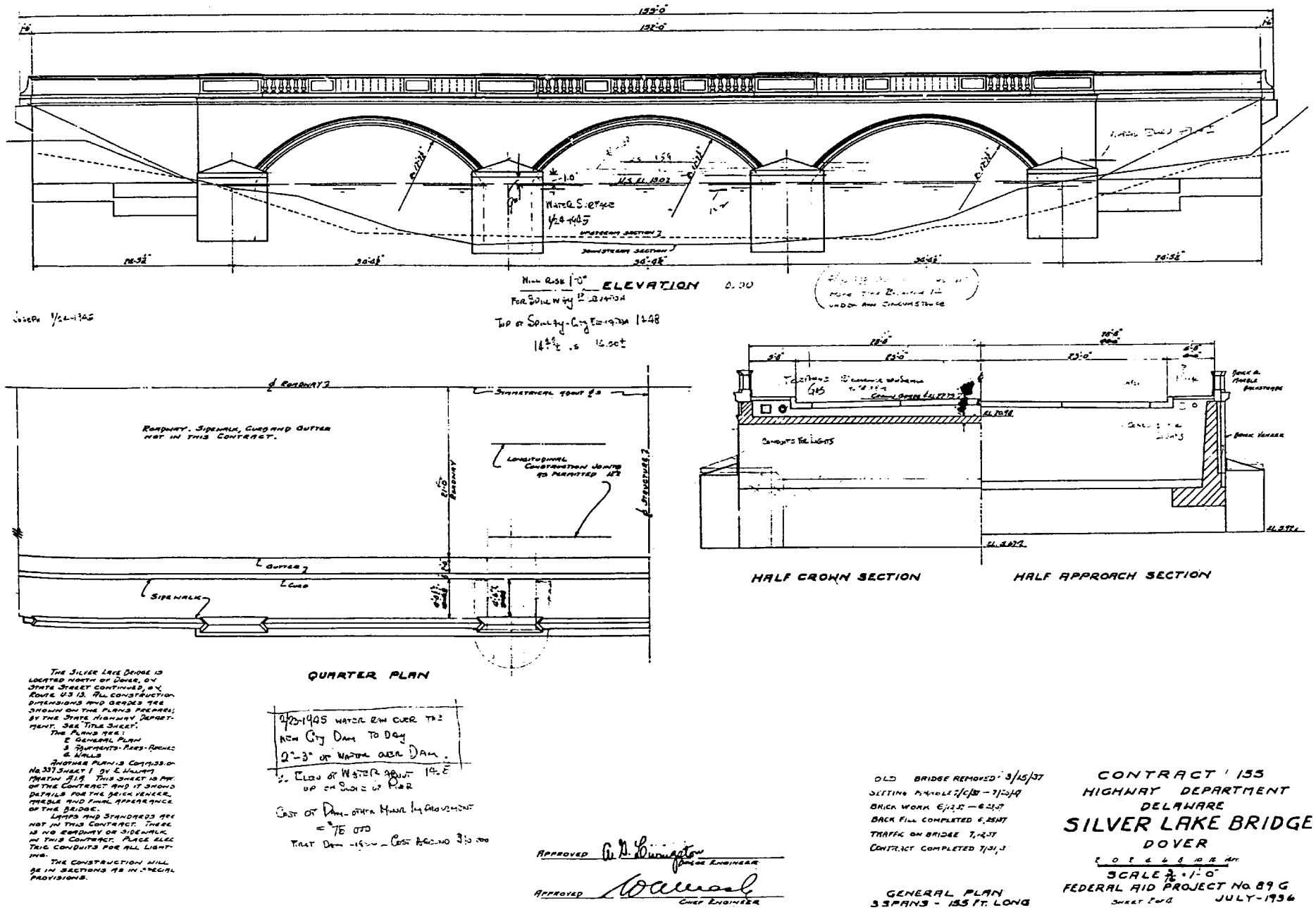


The ornamental wrought-iron lamp posts for the Silver Lake bridge were custom designed by the Frederick Gundy Ironworks of Philadelphia. Original drawing (right) and as they appear today (left).

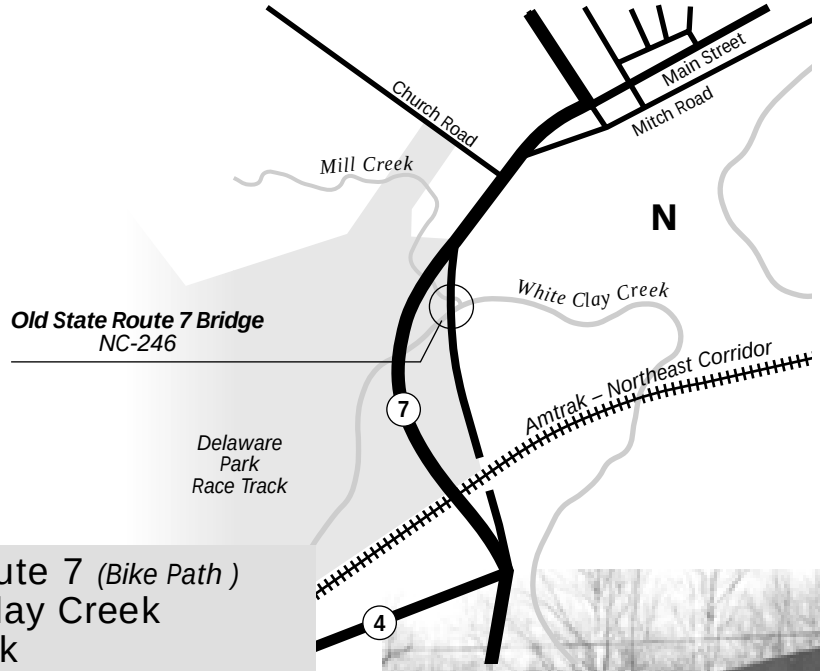
wrought-iron lamp posts. It is supported on concrete abutments and bullnose piers.

The North State Street bridge is the second of two similar spans in Dover designed by Martin under commissions from the Delaware State Highway Department. The other earlier span is the 1934 Lookerman Street bridge (see State Bridge K-23A for more on Martin). Both bridges were designed to blend with Dover's Colonial-Revival surroundings, and were patterned after the State Legislative Building.

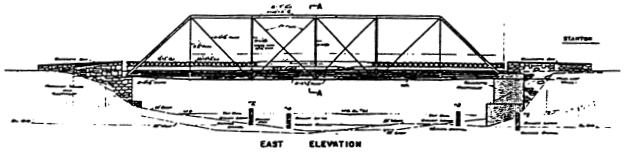
The North State Street Bridge was built in 1937 to replace a one-span stone arch-bridge constructed in 1907. The contractor was the Spear-Jones Company of Dover commending a price of $48,350. The lamps were fabricated by the Frederick Gundy Ironworks of Philadelphia and the marble work done by the Vermont Marble Company of Proctor, Vermont.



Plan and elevation from the original 1936 drawings for State Bridge K-3C in Dover. The Delaware State Highway Department went to extra efforts to design bridges that would be appropriate to the setting in the state's capital.



The old SR 7 thru arch bridge replaced a Pratt thru truss bridge, shown here in preliminary drawings for the current bridge, and as seen in photo archives for New Castle County.



Old State Route 7 *(Bike Path)* over White Clay Creek and Mill Creek

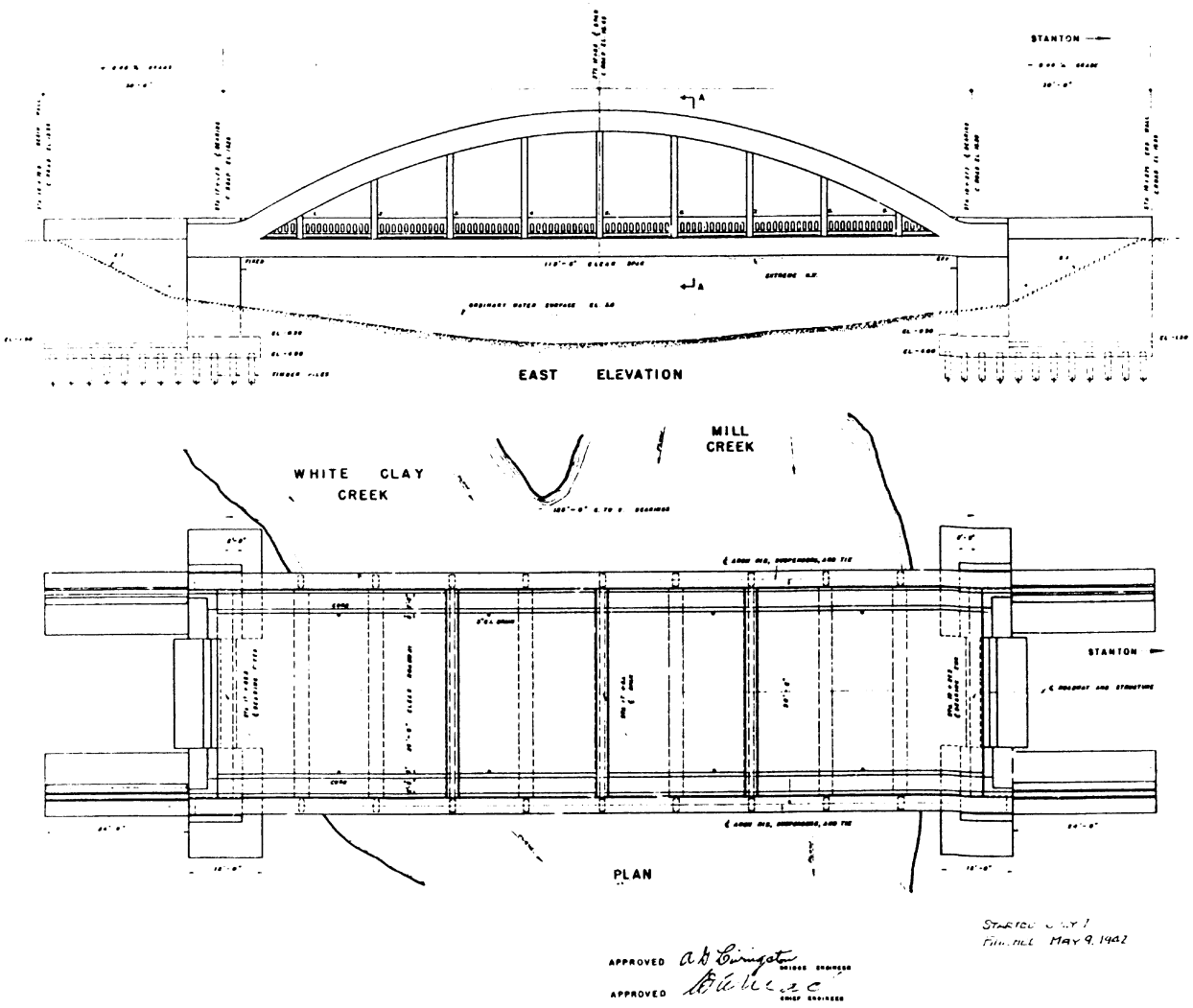
State Bridge NC-246
Near Stanton, New Castle County
Designer/Builder: Delaware State Highway Department/J. A. Bader Company

1941-42

The Old State Route 7 bridge is a reinforced concrete tied thru arch. The arch consists of two parallel ribs that are tied by reinforced concrete girders, which resist the thrust of the arch. The structural action of the arch is similar to an archer's bow, and the bridge type is sometimes also called a

State Bridge NC-246 (1940-42) is Delaware's only reinforced concrete thru arch bridge.

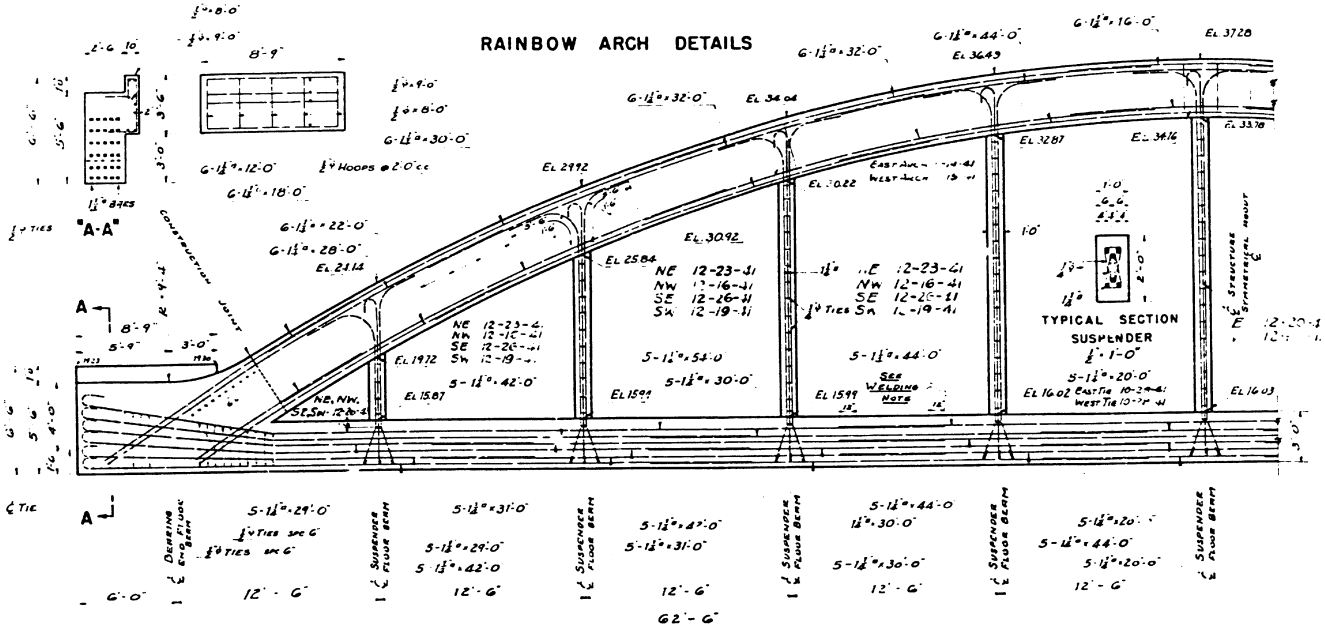
Construction photos for State Bridge NC-246.



Elevation and plan from original 1940 drawings for State Bridge NC-246.

bowstring arch for that reason. Vertical suspenders support floorbeams and a concrete slab deck. Upper lateral ties brace the arch ribs. The roadway is enclosed by concrete balustrades inside the line of the suspenders. The bridge is supported on concrete abutments with wingwalls.

The bridge is Delaware's only example of a reinforced concrete tied thru arch. The Delaware State Highway Department's *Annual Report* (1941-42) reported that it "was the first bridge of its type to be constructed in Delaware," however, the bridge type had been used in other parts of the country for over 30 years. The reinforced concrete tied thru arch bridge type was developed in the early 1910s, with the best-known variation a patented design by German-born engineer James B. Marsh of Des Moine, Iowa. State Bridge Engineer Arthur G. Livingston did not state in any of his reports why the bridge type was chosen for this location, but often tied thru arch bridges are built in locations where an aesthetic arch bridge is desired, but substructure conditions do not permit massive abutments or piers. The tied arch design reduces the size of the required substructure by resisting the horizontal thrust of the arch by the tie girders rather than massive abutments.



The plans for State Bridge NC-246 clearly show the concentration of reinforcing bars in the tie girders (bottom), which primarily act in tension to resist the thrust of the arch.

The thru arch bridge replaced a 102'-long steel Pratt thru truss bridge, which had been built in 1904. The contractor for the thru arch was the J. A. Bader Company of Wilmington. Construction began in July 1941 and was completed in January 1942, except for the final rubbing of the concrete and placement of the bituminous wearing surface, which was suspended due to cold weather. Work on the final details resumed in April 1942 and was completed a few weeks later.