Recreational Timber Bridges in Pennsylvania State Parks and Forests

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Abstract

This paper reviews three specialty timber bridge projects designed to serve as heritage recreation features on state land in Pennsylvania, including:

(1) twin 16-foot span Kingpost truss bike trail bridges,
(2) a 50-foot span Camelback truss canal bridge;
(3) a 220 foot long three-span Burr arch/truss aqueduct;

All three bridges share the common goal of re-utilizing the best traditional structural timber forms and joinery, in combination with modern timber technologies. These projects demonstrate the importance of heritage reconstruction by incorporating historic details integral to the structures. These bridges are not simple wooden facades applied to concrete or steel stringers, but are true timber structures. The three designs were collaborations between landscape architects, Simone and Jaffe Incorporated (SJ) and structural engineers, DCF Engineering Inc. (DCF.) In each case, the bridges represent similar partnerships which include: project initiation by local citizen organizations; design funding by USDA Forest Service; and construction and ownership by the State of Pennsylvania through the Department of Conservation and Natural Resources. The projects were in various stages of design and construction at the time of this submission.

Keywords: Timber, Historic, Recreation, Bridges, Kingpost, Camelback, Burr Truss, Delaware Canal, State Park, Aqueduct, Forbes State Forest, Pennsylvania, USDA Forest Service.

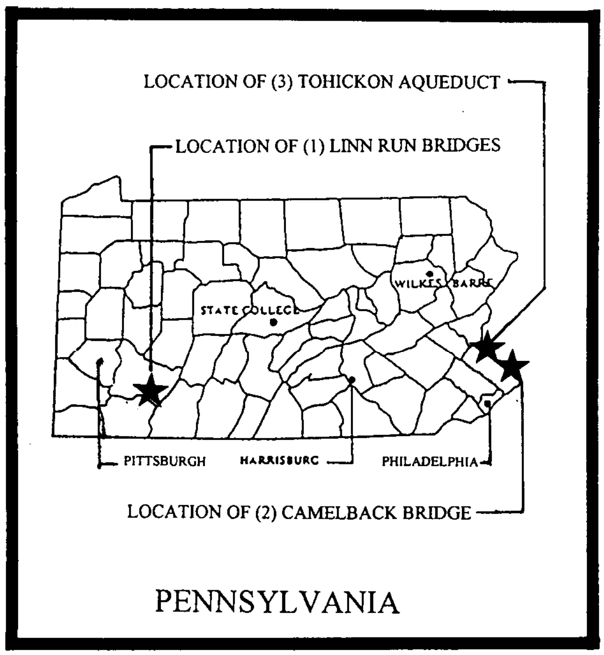

Figure 1-Location of Described Bridges

1. Linn Run Kingpost Truss Bike Trail Bridges

Background

Twin trail bridges were constructed in 1995 over Linn Run, a creek which flows down the western slope of Laurel Hill within Forbes State Forest in Westmoreland County. Laurel Hill is the last, great ridge in Pennsylvania which has historically posed an obstacle to all those traveling to the west.

In 1758, Brigadier General John Forbes built his military road across Pennsylvania as a strategic supply route for the British march on Fort Duquesne (Pittsburgh) during the French and Indian War. Forbes Road, as it is known, included forts constructed 30 miles apart. A dying Forbes was carried over Laurel Hill from Fort Bedford to Fort Ligonier, built at the western foot of Laurel Hill. The French left Fort Duquesne in the fall of 1758 to attack Fort Ligonier, but were turned back by the British in what many consider to be the decisive battle of the war.

The Pittsburgh, Westmoreland and Somerset Railroad (PW&S) grade was constructed over Laurel Hill near the Forbes Road crossing. The PW&S was a short-lived, but significant logging, freight and passenger railroad which was operated between 1900 and 1916 by the Byers-Allen Lumber Company. Lumber was processed at its mill in Ligonier. In less than ten years, Laurel Hill was denuded of trees and declared to be forever barren. The State of Pennsylvania purchased a 9,500 acre tract from Byers-Allen in 1909 and named it after Forbes, as the first State Forest Reserve in the Ohio River basin. Since that time, the forest ecosystem has regenerated and sustained yields based on the PA Bureau of Forestry (Forestry) management plan. Forbes Forest now encompasses over 50,000 acres, mainly along 40 miles of the Laurel Hill ridge.

In 1990, the Loyalhanna Watershed Association (Loyalhanna,) a citizens' environmental organization based in Ligonier, proposed the development of a mountain bike system within the rugged forest to manage the growing sport as part of the state's multi-use management plan. With funding from the federal Southwestern Pennsylvania Heritage Preservation Commission (SPHPC), and a partnership with the local forest district, Loyalhanna commissioned Simone and Jaffe Incorporated (SJ) to develop the PW&S RR Bike Trail Master Plan in 1993. The plan identified the PW&S grade as a significant historic landscape feature within Forbes Forest, noting the integrity of several remaining RR structures, including: the main grade, two runaway grades, several stone drainage culverts, two bridge sites, and a watering pool fed by Linn Run.

Linn Run Bridge Program

Reconstruction of two Linn Run trail bridges were determined as priorities to improve the RR grade as the main "spine" of the mountain bike trail system. New bridges would allow mountain bikes to safely cross the creek and discourage fording, as well as establish emergency and maintenance vehicular access to previously inaccessible parts of the trail. Loyalhanna's goal to develop a trail, included adding integrity to the site by constructing new timber bridges in a historic form that would also meet modern design requirements. Forestry was concerned with bridge construction, safety, and long term maintenance. Loyalhanna commissioned the team of SJ/DCF for a design and heritage construction workshop demonstration project using a USDA Forest Service Timber Bridge Initiative grant. Traditional timber joinery techniques would be taught to Forestry personnel and local volunteers in a week-long fabrication workshop. Loyalhanna, SJ/DCF, and Forestry jointly developed an aesthetic and practical design program to ensure that the bridges respected the historic period of significance (1901 to 1916,) and were capable of handling modern demands. A single bridge design was developed to economically serve both short spans of approximately 14 feet.

Linn Run Bridge Partnership

Loyalhanna managed the entire project including; grant writing, material procurement, and publicity. SJ worked with Loyalhanna and DCF on technical design details, developed milling and treatment schedules, and coordinated workshop details with Forestry. DCF produced the final design and construction documents from the SJ concept. Members of the Timber Framers Guild of North America, were recruited by a fellow

Figure 2-Previous Footbridge at Linn Run

guild member at SJ to serve as fabrication workshop teachers. A lead timber framer and landscape architect provided technical support during installation. Forestry provided the labor and equipment for the installation of both bridges. The PA Youth Conservation Corps also helped by adding riprap to stream channel structures and installing the new timber bridge sills.

Existing Conditions at Linn Run

Two narrow foot bridges without handrails previously existed on top of WPA-era concrete stream channel structures. The structures were considered unsound as abutment foundations for the new bridges, but needed to remain undisturbed to avoid additional construction costs and time for stream encroachment permits.

With no original documentation available, the period of significance was used to select a "King Post" truss as the best representative historic timber structure for its strength, simplicity of construction, and aesthetics. A 45 degree top chord angle was chosen for the short spans so the top chords would create a strong vertical element above the required 54" high bike railing.

Engineering - Traditional Kingpost trusses had few iron elements until builders found that the addition of keeper bolts at the heel connection and tie straps at the kingpost greatly increased the load capacity. At Linn Run, members and connections were designed to meet AASHTO HS-8 (eight ton) loading. The steel connections were designed to mimic early iron connections. Field installed 2 5/8 inch diameter shear plates provided the needed capacity at the kingpost connection. Lateral stability of the trusses was secured by extending the transverse beam beyond the floor of the bridge to accept diagonal braces to the sides. Some of the DCF engineering details were altered slightly to suit field construction. Field test loading by an eight-ton backhoe with driver showed no deflection in the transverse beam to the naked eye.

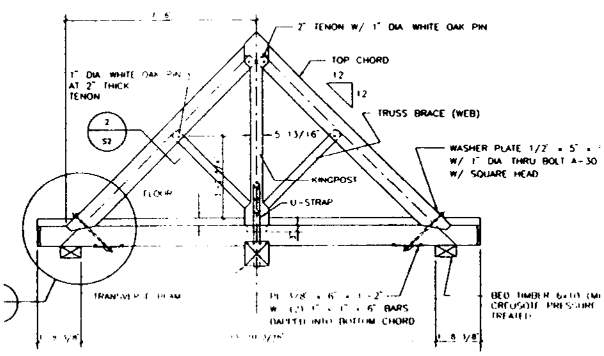

Figure 3-Side Elevation - Kingpost Truss

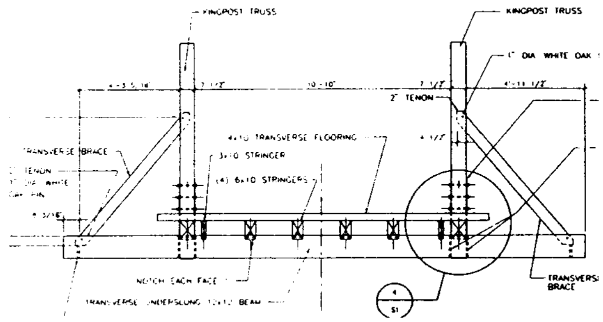

Figure 4-Transverse Section - Kingpost Truss

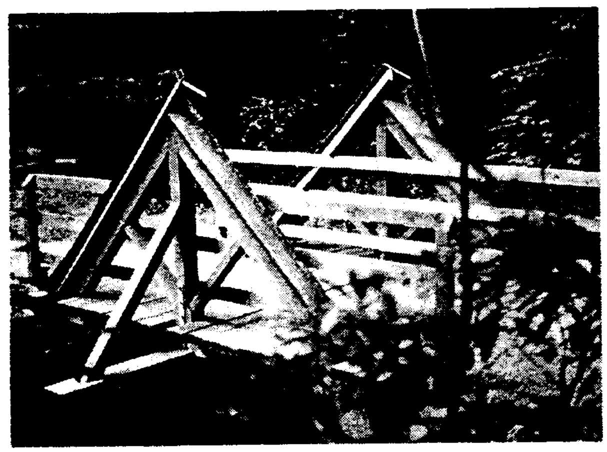

Figure 5-Completed Kingpost Truss Bridge

Species Selection - Hemlock and White Pine were the major species harvested during the peak of the timbering era. Local barns and other structures made of hemlock have historically shown little signs of checking or twisting - an important consideration for posts. Hemlock was selected for the entire bridge. The timbers were air dried for a month before fabrication.

Timber Protection - Modern techniques were selected which would improve safety and efficiency, but not sacrifice the integrity of the original structure type. The finished bridge members were returned to the mill for CCA preservative treatment after joinery fabrication. This ensured that framers did not breath treated dust during joinery, and that the treatment "shell" of protection would not be perforated during construction. The treatment process left a subtle green hue to the finished timbers after they were left to dry for two weeks between treatment and installation. Every mortise, tenon, pin hole, and nail hole was executed before treatment. Every joint was designed with weep holes or sloped bottoms to prevent standing water. A "flitch cut" cap was installed to protect truss top chord from weather and to discourage people from climbing.

Table 1 - Linn Run Bridges • Project Costs

Consultant fees	$8,096
Materials	$7,158
Equipment	$ 645
Personnel	$6,811
Overhead	$ 406
CASH EXPENSE TOTAL	$23,116
Bureau of Forestry - labor	$9,801
Bureau of Forestry - equipment	$ 480
Youth Conservation Corps	$3,750
LWA	$ 525
Americorps	$ 420
Construction Volunteers	$1,400
White Oak Pins	$ 200
Accommodations	$ 450
IN-KIND EXPENSE TOTAL	$17,026
TOTAL PROJECT COST	$40,142

Hardware - A local blacksmith was found to fabricate and galvanize antique style hardware for the bridges.

Foundations - The new bridges were designed to bear on new creosoted RR tie sills set in gravel behind the existing concrete walls.

Kingpost Bridge Construction

Fabrication was performed in the Forestry workshop during a week-long training session with approximately 20 people in May, 1995. Modern tools such as a portable bandsaw and chain mortiser were used to rough out joinery for most bridge members. Forestry staff and PA Youth Conservation Corps workers installed the new bridges during a week in June, 1995.

Project Significance - Linn Run Bridges

Building the Linn Run Bridges was a symbolic and tangible way of involving the entire community in environmental, cultural, historic and economic issues of the region, (such as stewardship of natural resources, timber management, forest renewal, railroad history, modern milling, and judicial use of preservative treatments.) The new bridges physically demonstrate new business opportunities between today's local timber industry and the region's growing recreation industry.

The workshop helped perpetuate the historic craft of timber framing, and showcase a highly successful partnership between: federal and state governments, public utilities, private foundations, and local citizens organizations. A professional video documentary of the project, produced by a local television station, has aired on public television. The Linn Run site is scheduled for additional heritage/interpretive improvements in 1997.

2. Delaware Canal Camelback Bridges

Background

The Delaware Canal is a 60-mile long by 60-foot wide state park in Pennsylvania which parallels the Delaware River from the Lehigh Canal at Easton to the historic seaport of Bristol. The canal began operation in 1831, and the "Camelback" truss was the original bridge designed to span the waterway at local roads and farm lanes. The bridge approaches were raised to allow mules and drivers on the towpath, and canal boats on the waterway to pass below. The average bridge span was 48 feet between stone abutments. From a distance, the Camelback profile was similar to Palladio's design for a framed truss, dated about 1550. Today, the Delaware Canal is a National Historic Landmark, National Recreation Trail and part of the Delaware and Lehigh Canal National Heritage Corridor. Camelback bridges are an enduring symbol of the Delaware Canal. Three original design Camelbacks still exist, but are closed to vehicular traffic or weight restricted to three tons. In 1993, the Friends of the Delaware Canal (Friends,) in partnership with PA Bureau of State Parks (Parks,) received a Timber Bridge Initiative grant from the USDA Forest Service to study existing bridges over the canal and to design a "modern" timber Camelback truss bridge capable of carrying an HS-20 AASHTO design load. Parks projected constructing five camelback replacements over the next five years. SJ/DCF was retained to produce three optional designs, including:

a modern HS-20 Camelback truss;
a facade truss for existing canal stringer bridges and;
a documentation of the original bridge design.

Description of Original Camelback Structure

The original Camelback bridges were elegant in their simple appearance, but complex in operation. The main truss included a horizontal top chord between two sloping top chords. Two posts were joined into the top chord and notched into a composite transverse beam below. A wrought iron rod was slung over a cast iron saddle on the chord above each post to suspend the transverse beams. These rods were inclined slightly away from the post into the cartway and toward the outside of the bridge to also serve as lateral bracing for the trusses. The transverse beams divided the span approximately into thirds. The three bays were bridged by stringers which simply overlapped side by side on

Figure 6-Original Camelback Truss Bridge

the transverse beams. Transverse decking extended slightly past the outside of the truss. Lower chords were constructed of two wrought iron rods located on both sides of each truss and connected to a cast iron "shoe," or heel connector, which also received the foot of the sloping top chord and sat unanchored on the bearing shelf of the stone abutment. Three wrought "links" or sections of chord were connected by forged interlinking eyes to form a full bridge-length rod. The cast shoe was formed to accept the foot of the rafter chord, and to cradle a transverse wrought iron pin on the outside end. The pin was slipped through eyes at the end of the chord rods and nested in a cove behind the shoe. The wrought pin was fabricated with a head on one end and a slot for a wedged pin to lock the other end from working free from the chord eyes. The weight of the bridge placed the rods in tension by pushing the sloping top chords in the longitudinal direction. As the chords stretched, the unanchored shoes were free to move. The lower chords actually rested on the transverse beams which were set at a slightly higher elevation than the level of the abutment shoes. As the lower chords were stretched by loading the bridge, they placed additional pressure into the transverse beams in an effort to straighten - creating a completely flexed structure.

Modern HS-20 Camelback Design

The demands on the Camelback bridges have increased since 1831. The simple canal crossings to farms and houses are now expected to serve heavy oil delivery and refuse trucks.

Team Responsibilities - SJ/DCF designed and documented the new timber superstructure. Parks engineered the foundation, approaches and site.

Design Program - As the owner, Parks required the SJ/DFC design to meet certain design standards including: HS-20 capacity, a l2-foot wide clear cartway, a redundant design for safety, and low maintenance materials. The USDA Forest Service grant required a demonstration of hardwood glued lamination with preservation technology at a highly visible site, in partnership with state and local organizations. Friends' design requirements included: maintaining or reinstating towpath headroom under the new bridge, and aesthetic considerations such as - bridge scale, local stone abutments, and traditional color finish.

Design Improvements - SJ/DCF chose to recreate a true Camelback truss at a slightly larger scale and replace overlapping stringers with single span curved glulam stringers that bear on both abutments and transverse beams. Cast iron hardware was replaced by simplified galvanized steel saddles and shoes. Wrought iron tension rods were replaced by galvanized steel rods with turnbuckle tensioning. Transverse members were increased in depth to handle the increased bending moment demanded by the 20-ton truck design load and the widening of the original cartway by two feet. The transverse suspension rods were housed on the inside post faces to remove the old obstruction to the cartway. The glulam stringers were designed with different radii for top and bottom curves, which permitted a 16 1/12

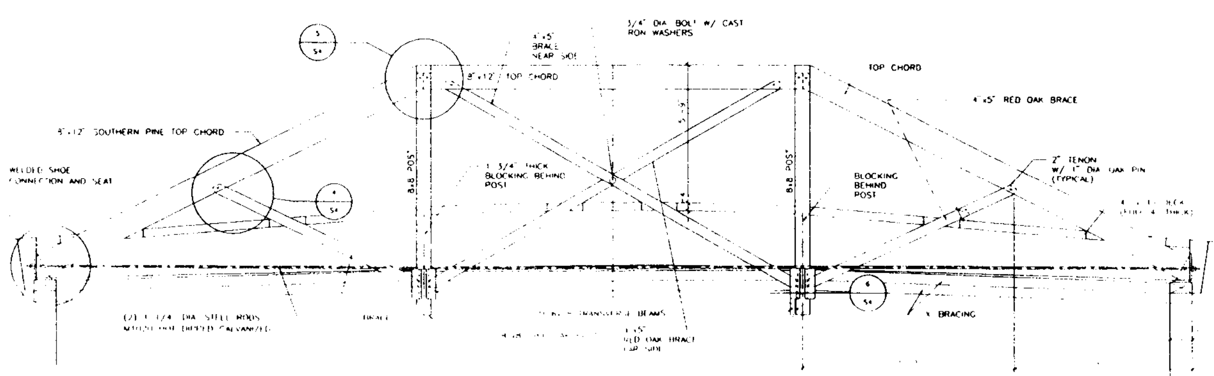

Figure 7-Side Elevation - Modern Camelback Truss Bridge

inch member depth at the abutment bearings and a 27 l/2 inch member depth at center span. The new design included bolting stringers to the transverse beams to ensure that they work in concert with the trusses. Top chords were designed with the traditional gable cap boards.

Modern Camelback Engineering

Trusses were designed to support an HS-20 load through suspension of the floor at the posts - which creates compression in the truss chords and tension in the rods. Parks required a redundant design in the event that a large vehicle were to strike the trusses, causing them to fail. The trusses were designed with 8” x 12” Southern Pine top chords and 1 l/2 inch diameter bottom chord ties. Diagonal 4” x 8” red oak braces completed the truss profile. The floor stringers were designed using glued laminated red oak 10 3/4 inches wide as the redundant structural elements. The floor beams are tapered and curved to simulate the original “hump” as closely as possible.

Camelback Timber Treatment

The traditional Camelback bridges were painted red to protect the timber and for identity. Penta in light oil was selected as the preservative treatment for the truss members, to allow the new bridge to also be painted.

Significant Camelback Location

Several locations were contemplated by Parks for the prototype site. The Virginia Forrest Picnic Area was selected as a major state park access location - directly adjacent to PA Scenic Highway Route 32, and approximately 3 miles north of New Hope. The new HS-20 Camelback prototype will replace a ten year old, 10-ton weathering steel prefabricated pony truss removed due to extensive rusting. The bridge site is visible from heavily traveled River Road, and the new ramped approach will re-establish a useable towpath below. The new bridge will allow mule-drawn tour boats, which were previously forced to stop at the old bridge, to now continue an additional mile north, connecting the tourist towns of New Hope and Lumberville via canal.

3. Tohickon Aqueduct, Delaware Canal State Park, Point Pleasant, PA

Brief History

The Tohickon Aqueduct, in Point Pleasant, PA was originally built in 1831, over the largest Delaware River tributary along the 60 miles of Delaware Canal. The waterway served as an active commercial transportation route for 100 years. Point Pleasant, located at mile 30, was well known for its accommodations within Bucks County. Historic survey notes indicate that the original timber aqueduct in Point Pleasant consisted of seven spans. Unfortunately, no original construction documents remain.

Previous Tohickon Aqueducts - Several old photographs show a subsequent 3-span iron truss version of the aqueduct with wooden waterway or “trunk.” The structure was built on stone abutments and two concrete covered stone masonry piers. Each span was approximately 60 feet. The old photos show the iron aqueduct brimming over with sheets of water spilling into the Tohickon and people swimming in the “old swimmin’ hole” as it was called. Two days after a Labor Day community swim in 1932, the iron aqueduct failed catastrophically. Fortunately, no one was injured.

Commercial operation ceased after the aqueduct failure. The canal was acquired by the Commonwealth as a state park and, after World War II, a reinforced concrete and steel flume was built atop the existing abutments and two reconstructed stone piers. The concrete aqueduct served until the mid 1980’s, when concrete buttresses on the outside of the walls began to lose integrity and no longer support the water pressure. By 1993, the structure was empty, condemned and the towpath closed to foot traffic.

Creating an Aqueduct Partnership - In 1991, the Point Pleasant Community Association (PPCA) began discussing the reconstruction of a historic aqueduct using timber. A concept design was developed within the association and proposed to Parks, which in turn proposed a challenge: if PPCA could deliver the timber superstructure engineering documents, Parks would provide all foundation and sitework engineering. The agreement was endorsed by local legislators. A $10,000 grant from the USDA Forest Service Rural Development Program funded preliminary engineering of the timber superstructure, through a local township. A similar grant funded prefinal engineering. Both grants were matched by equal amounts of Parks engineering time. A third Forest Service grant from the

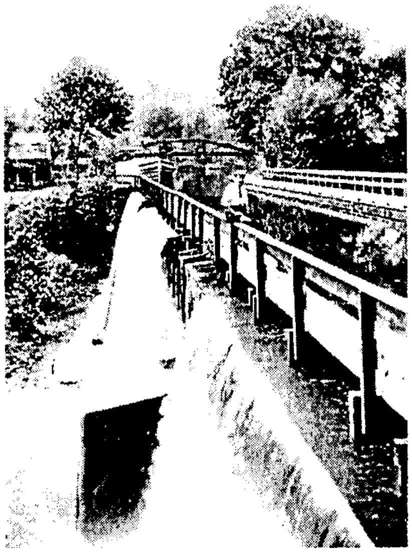

Figure 8-Tohickon Iron Truss Aqueduct, 1932.

Timber Bridge Initiative grant was awarded to PPCA for final construction documentation and partial construction observation. Again the match had an equal Parks commitment. Parks enlisted engineering expertise of the PA Bureau of Flood Protection (BFP) for foundation design. SJ/DCF was retained by the community to perform the superstructure design.

By 1993, the aqueduct was deemed the highest priority state park capital project in Pennsylvania. Two million dollars were allocated in the state budget for the reconstruction. However, design proceeded slowly. The typical competitive bidding for state-funded design contracts was waived when Parks elected to perform the foundation design in-house and use the community's design team produce the superstructure. Funding for the design team needed to be raised entirely by the local community, in phases. Coordination between SJ/DCF and state engineers was fruitful, but complex with each working on different schedules and interdependent parts of the project. Early

Figure 9-Tohickon Aqueduct Failure, 1932.

design phases included consultation from timber bridge builder Jan Lewandoski, of Greensboro Bend, VT. The Pennsylvania Flood of 1996 also delayed state engineers for several months. Technical aspects of the project however, were the greatest challenge.

Aqueduct Program Requirements

The project program included: preserving and reusing the original stone abutments and piers; designing a new heritage superstructure; creating a new trunk waterway for future tour boats; and maintaining the existing canal invert and water level elevations. Two existing stone piers created three spans of approximately 60 feet each. The piers were in excellent condition and reuse was required for financial, historic and aesthetic reasons. The new superstructure design therefore, needed to span those distances and maintain the original canal depth, but not restrict the highwater clearance in the creek below. The width of the new superstructure needed to bear on existing piers which could not be substantially widened. Finally, the entire superstructure needed to be retrofitted into existing stone masonry at a 60 degree skewed alignment.

As a National Historic Landmark, project review by the state historic preservation officer was required. A universally accessible towpath which could serve pedestrians, bicyclists, and horses was required to cross the three spans. The USDA Forest Service required the project to demonstrate timber as a modern construction material. A team goal was a modular timber structure in which members could replaced or repaired in place.

Aqueduct Design Development

Concept plans by the landscape architect employed a Town Lattice truss design with arches, similar to ten Town truss bridges still existing in Bucks County. DCF completed an analysis of the Town truss, but the results, coupled with early historical references pointed to the need for a stiffer truss. DCF chose a Burr Truss Arch for preliminary design analysis. Historic research turned up two existing versions of aqueducts; Duck Creek Aqueduct State Park in Metamora, Indiana; and the Roebling Aqueduct, a historic suspension structure across the Delaware River near the confluence of the Lackawaxen River in New York. The Duck Creek is a single span, Burr Truss Arch with a recently reconstructed simple timber trunk suspended below the bottom chords. The Roebling Aqueduct has been preserved and converted to a single lane vehicular bridge by the National Park Service. The new Tohickon Aqueduct could not be designed as a suspension structure; and a truss constructed above the trunk would create a series of new problems. SJ/DCF

Figure 10-Tohickon Aqueduct, 1994.

determined to place the trunk between the two trusses, and borrow the slanted wall trunk design from the Roebling Aqueduct. This configuration served two purposes: the sloped walls reduced the volume of water to be carried; and also served as lateral bracing for the trusses.

Protecting the superstructure was a primary concern. State engineers and SJ/DCF both believed that the new trunk could not depend upon historical timber construction to hold water. Inevitable leaks in a wooden trunk would directly compromise the new superstructure. A waterproof liner was selected as the best means to protect the investment in the timber superstructure - essentially creating a “covered bridge.”

Aqueduct Engineering

Design Loads - The aqueduct design is based upon a uniform load of 4,000 PLF consisting mostly of water in the trunkway. The superimposed towpath loading was 100 PSF.

Redundant Design - Double Truss/Double Arch
Based upon design load estimates and computer modeling, DCF engineered an interlocking truss/arch system that would work in concert under loading, but was capable of carrying the entire load by either trusses or arches independently. The truss was designed with structural timber posts and braces, and glued laminated upper and lower chords. The arches were designed to be a four leaf, laminated structural timber, two-hinged arch; stitch bolted together at regular intervals. The posts were notched to receive the arch.

Species Selection - Species selection varied for each member, depending upon exposure to weather, required preservative treatment, required precision tolerances, or direct contact with the public.

Truss Chords and Transverse Beams were specified as red oak, treated with Penta-WR. *Truss Braces, Longitudinal Sleepers, Trunk Posts, and Structural Trunk Decking* were specified as red oak, creosote treated. *Truss posts* were specified as creosote treated, recycled southern pine, due to anticipated exposure to weather and need for dry material to accept preservative treatment. Also, the diagonal brace seats cut into the posts were required to remain stable in the cross grain dimension to prevent shrinking and possible loosening of braces. *Truss Arches* were specified as white oak, untreated, except *bearing end laminations* against masonry foundations which were specified as red oak, creosote treated. *Towpath Decking, Railing and Trunk Facade Liner* were all specified as Southern Yellow pine, CCA treated. All joinery was specified to be performed before treatment.

Transverse Beams - The transverse beams were specified as glued laminated members due to load and span requirements. The beams bear upon lower chords and are suspended by rods from the arches. The ends of the beams fall within the structure’s envelope and where exposed, are capped with copper.

Lateral Bracing/Trunk Construction - The slanted trunk posts are fastened to the transverse beams and the inside face of the upper truss chord. The trunk was designed to permit a twelve foot wide clear waterway inside the trunk facade at a depth of one foot. Channel design depth for water level was 4’-9”, plus an additional foot to the top of abutment flume walls.

Membrane Liner - The membrane liner was specified as a reinforced, 45 mil polypropelene polymer geomembrane, with a non-woven polyester fiber geotextile bonded onto both sides. The liner was designed to cover inside the structural trunk walls and floor in a continuous length and seal to abutments. The design secured the liner to the structural trunk above the canal water level and lapped under the truss cap. A facade trunk liner was designed to protect the membrane liner and retain the timber appearance. The facade was designed as removable pallets, with wall sections that locked down floor sections, without fasteners perforating the membrane below water level.

Towpath - Similar to all previous versions, the towpath was cantilevered to the downstream side. Joists were designed to suspend out from the bottom of the top chord, braced by inclined posts from the bottom chord. The walkway was designed with a five-foot clear width. The top rail was sloped to the outside to drain and to discourage walking, sitting, or resting objects on the handrail.

Truss Siding and Caps - A vertical board siding was chosen to relate to other covered bridges in the county. The siding was designed to be cut concentrically to cover the arches while exposing the structure of treated trusses to view. The accentuated arches relate to the two-span concrete arch of the River Road Scenic Highway bridge within view, 150 yards up Tohickon Creek. Truss caps were specified as painted steel roofing.

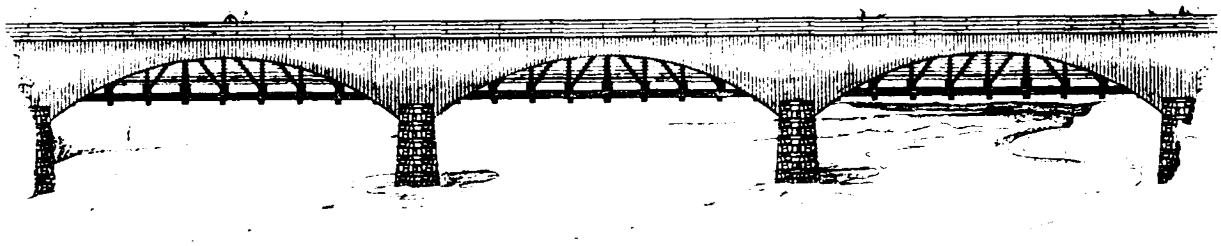

Figure 11-Elevation -Tohickon Burr Arch Aqueduct

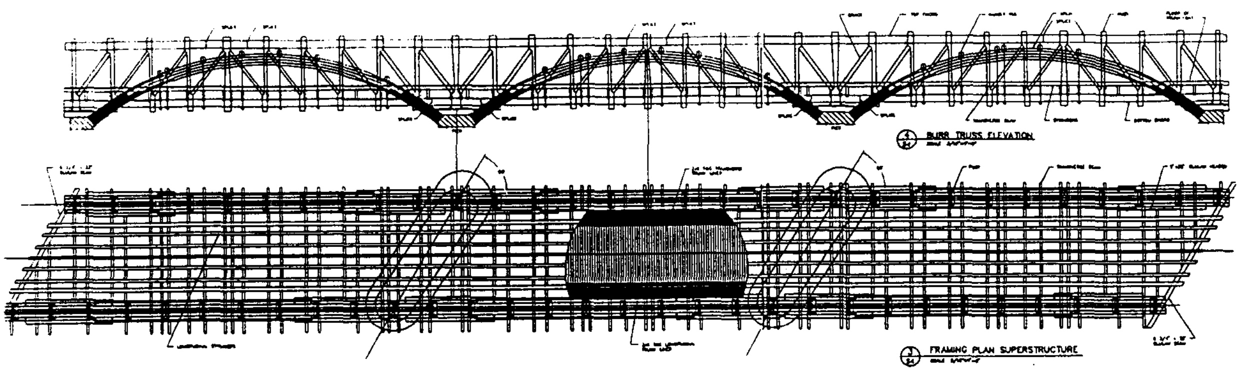

Figure 12-Profile/Plan - Tohickon Burr Arch Aqueduct

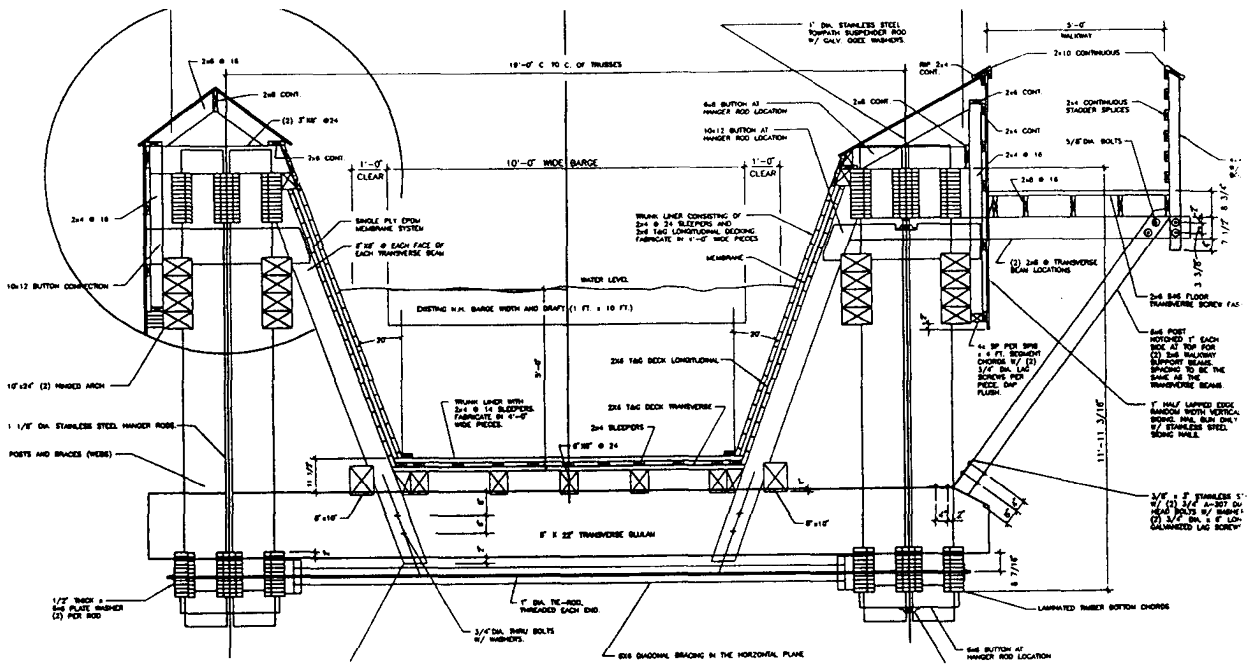

Figure 13-Transverse Section - Tohickon Burr Arch Aqueduct

Hardware - All hardware was specified as either hot dipped galvanized or stainless steel.

Foundations - BFP determined that portions of both stone abutments required reconstruction to bedrock, using a new concrete leveling pad to rebuild native argillite stone walls. BFP designed new concrete sills to bear the new timber trusses and arches within the rebuilt stone walls. Similar sills were redesigned to top the two piers. BFP resolved to remove the top three courses of existing stone and replace them with a formed concrete sill/cap designed to accept the loads of both offset trusses and arches.

Hydraulic Controls - SJ recommended combining overflow and waste gates and locating the hydraulic controls in the abutments rather than historically in the trunk. This design keeps the trunk liner unperforated, and directs water releases away from the superstructure. The overflow/waste gate wells in both abutment flumes drain through piped outlets in the abutment wing walls.

Sitework - BFP redesigned canal approaches to the aqueduct, specifying a geosynthetic clay liner where the earth and the concrete abutment apron meet.

Construction Access - BFP determined that access would be required in the creek bed for both demolition of the existing concrete and steel flume, and construction of the new superstructure.

Maintenance - A primary design consideration was long term maintenance. Species selection, joint detailing, preservative treatment, periodic inspection and cleaning all serve to reduce maintenance, but repair or replacement of members will eventually be required. SJ/DCF attempted to anticipate those future needs and provide a system where members can be exchanged in place. Such a modular design provides a significant advantage of timber over concrete. Perforations in the plastic liner are easily repaired, while repairs in concrete are ultimately futile.

Flexibility - Another advantage is flexibility of a timber structure - even for a supposed uniform load. The new aqueduct may face repeated waterings and dewaterings due to frequent canal breaches and repairs scheduled in the upcoming years. After the initial test loading and unloading an aqueduct rebuilt several years ago as a reinforced concrete structure produced several hairline cracks a near the tops of the walls where reversals in stress are maximized. When the aqueduct is loaded these joints seep. Unloaded, these openings increase and will be on-going maintenance problems which require patching on a regular basis.

Conclusion

Although the Tohickon Aqueduct is certainly the largest and most complex, its development parallels the other two bridges. Each of the three bridges is a special, human-oriented structure, designed specifically for its special environment, by employing the best traditional forms, details, craftwork and modern timber technology. Not all bridge sites warrant this attention. But at special sites, which are subjected to increased expectations of a more sophisticated user population, the integrity of true truss bridges help to create a sense of place and add to tomorrow’s engineering landmarks. The projects re-establish the partnership between landscape architect and structural engineer as designers of significant structures in the context of historic landscapes. The bridges help define a practical and conservative heritage reconstruction philosophy. Community interaction with government at every stage of a project means that the structures will have many stewards in their future.

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