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Design and Construction of the

Pochuck Quagmire Bridge — A Suspension Timber Bridge

Appalachian Trail
Vernon Valley, New Jersey

Acknowledgments

Many individuals have had an integral part in the production of this publication, and we would like to thank everyone who contributed to this effort. Also, we would like to thank the reviewers for their insight and comments.

In addition, we would like to take this opportunity to thank specifically the New Jersey Department of Environmental Protection, Division of Parks and Forestry, for making the plan sheets referenced in the text available for information sharing.

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NEW JERSEY
Division of
Parks and Forestry

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Pochuck Quagmire Bridge — A Suspension Timber Bridge

Appalachian Trail
Vernon Valley, New Jersey

by

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USDA
Forest Service

NORTHEASTERN AREA
State and Private Forestry

Preface

The premise for writing this publication came from a USDA Forest Service Wood In Transportation grant funded in federal fiscal year 1995. This publication documents one of more than 400 projects the Wood In Transportation Program has funded throughout the country. It captures the partnerships developed, the trials and tribulations, and design and construction of a suspension bridge.

This project was administered by the New York-New Jersey Trail Conference and resulted in the construction of a suspension timber pedestrian bridge on the Appalachian Trail. The bridge is a critical link in the realignment of the Appalachian Trail to its designated trail corridor in the State of New Jersey.

Edward T. Cesa
Program Manager
Wood In Transportation Program

Dedication

This publication is dedicated to the memory of Duane Bell and Peter Morrissey, who were instrumental and invaluable in the construction of the Pochuck Quagmire Bridge.

Tibor Latincsicss, P.E.
Project Engineer and Author

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List of Acronyms

AASHTO	American Association of State and Highway Transportation Officials
AITC	American Institute of Timber Construction
ACI	American Concrete Institute
ADA	Americans with Disabilities Act
ATC	Appalachian Trail Conference
BOCA®	Building Officials and Code Administrators
CCA	Cromated Copper Arsenate
CY	Cubic yards
DBC	Division of Building and Construction
E	Modulus of Elasticity
EIP IWRC RRL	Extra Improved Plow Steel, Independent Wire Rope Core, Right Regular Lay
FEMA	Federal Emergency Management Agency
GW & JNF	George Washington and Jefferson National Forest
KDAT	Kiln-dried after Preservative Treatment
KSI	Kips per Square Inch
MC	Moisture Content
MPH	Miles per Hour
NJDEP	New Jersey Department of Environmental Protection
NPS	National Park Service
OSHA	Occupational Safety Health Administration
PCF	Pounds per Cubic Foot
PFC	Pultruded Fiberglass Composite
PISA®	Power Installed Screw Anchors
PQB	Pochuck Quagmire Bridge
PSF	Pounds per Square Foot
PSI	Pounds per Square Inch
REA	Rural Electrification Administration
SYP	Southern Yellow Pine
TECO	Timber Engineering Company
USDA	United States Department of Agriculture
WIT	Wood In Transportation
WMNF	White Mountain National Forest

Executive Summary

This publication provides practical, cost-effective design and construction guidelines for a timber pedestrian suspension bridge. It presents basic engineering design criteria and construction tips as well as material, machinery, and peoplepower costs and needs. This information can be used as a general planning tool by anyone wishing to construct a suspension bridge. However, consultation with a licensed professional engineer (P.E.) with expertise in these structures is needed before undertaking such a project.

Suspension bridges, like the Pochuck Quagmire Bridge (PQB), provide a solution to long-span crossings. Plans and photography of it and other pedestrian suspension bridges are featured throughout this publication. The materials used to build this 146-foot-long bridge cost $36,000. It was constructed by a unique volunteer-driven, public-private partnership between the NY-NJ Trail Conference, the New Jersey Department of Environmental Protection (NJDEP), and the Appalachian Trail Conference. The Pochuck Quagmire Bridge is located on the Appalachian Trail in Vernon Valley, New Jersey, and is a vital link in the Appalachian Trail.

The Pochuck Quagmire Bridge is a vital link in the Appalachian Trail.

Photo 1. The Appalachian Trail Pochuck Quagmire Bridge. *Photo courtesy of Ms. Bernadette Conroy.*

Project Summary

Project Data for The Great Pochuck Quagmire Bridge

- Missing Link #1 of the Appalachian Trail. Timber pedestrian suspension bridge, total length 146 feet with a width of 44 inches and a 110-foot center span. The bridge walkway complies with the Americans With Disabilities Act (ADA);
- Class I southern yellow pine (SYP) transmission pole truss towers, 34 feet above river bank
- #1 southern yellow pine CCA.40 KDAT (kiln-dried after preservative treatment) MC (moisture content) 19% dimension lumber
- Chance® Power Installed Helical Anchors and Helical Piers
- One-inch galvanized 6 x 25 EIP IWRC RRL (extra improved plow steel, independent wire rope core, right regular lay)
- Concrete snowshoe foundation

Project Location

- Appalachian Trail Corridor
- Township of Vernon, Sussex County, New Jersey
- East of Route 517, west of Canal Road
- Lots 10.01 & 11, Block 31
- Wawayanda Quad Sheet
- N 875,000; E 2,053,600
- Hudson River Watershed

Project Partners

- ***Project Owner*** — New Jersey Department of Environmental Protection (NJDEP), Division of Parks and Forestry, 5 Station Plaza, 501 East State Street, Trenton, NJ 08625
- ***Project Construction Manager*** — Wes Powers, New Jersey State Park Service, Region III Office, R.D. #1 Box 999, Franklin, NJ 07416
- ***Project Engineer and Author of this Publication*** — Tibor Latincsics, P.E., Conklin Associates, P.O. Box 282, Ramsey, NJ 07446
- ***NY-NJ Trail Conference*** — Anne Lutkenhouse, 232 Madison Avenue, Room 802, New York, NY 10016
- ***NJ Appalachian Trail Management Committee of the NY-NJ Trail Conference*** — Paul DeCoste, P.O. Box 37, Highland Lakes, NJ 07422
- ***GPU Energy, formerly known as Jersey Central Power and Light Company*** — John Karcher, P.E. and Peter Morrissey, 300 Madison Avenue, Morristown, NJ 07962

- ***Paul Bell*** — P.O. Box 189, Pottersville, NJ 07979
- ***USDA Forest Service, Wood In Transportation Program*** — Ed Cesa, 180 Canfield Street, Morgantown, WV 26505

Project Construction Material Budget

- $10,000 USDA Forest Service Wood In Transportation Grant
- $20,000 NJDEP Matching Funds
- $6,000 Cash Donations
- $36,000 Total Budget
- Significant In-Kind Donations by the Volunteer Sector

Project Work Force

- NY-NJ Trail Conference and Appalachian Trail Conference Volunteers
- GPU Energy Volunteers
- New Jersey State Park Service
- New Jersey Corrections Work Detail

Project Administration, Survey, Engineering, and Environmental Permits

- $26,000 Funding by NJDEP Division of Parks and Forestry
- Significant In-Kind Donations by the Volunteer Sector

Dean Shemenski, Bev Shuppon, John Siebert, Steve Steele, William Stoltzfus, Jim Walsh, Dick Warner, and St.

Photo 1a. The Appalachian Trail Pochuck Quagmire Bridge. *Photo courtesy of Mr. Stephen Klein, Jr.*

Introduction

The Appalachian Trail is a continuous, marked, national scenic trail meandering 2,160 miles from Georgia to Maine. More than 73 miles of it runs through New Jersey — from the Delaware Water Gap to Greenwood Lake. In 1978, the Appalachian Trail Amendment to the National Trails System Act authorized the United States Department of the Interior to establish a 1,000-foot-wide protective corridor around the Trail for portions that are outside State or Federal Parkland. The State of New Jersey took the lead to acquire a continuous protective trail corridor. This was announced with great fanfare in 1980, by then-Governor Thomas Kean.

However, because of wetlands and river crossings, the Appalachian Trail departs from the corridor in two locations — Wallkill River and Pochuck Creek (Figure 1). Constructing bridges over these two waterways to place the trail within the corridor remains the number one priority of the Appalachian Trail project partners in New Jersey. This goal is outlined in the New Jersey Appalachian Trail Management Plan.

Figure 1. The Appalachian Trail map indicating the 2.1 mile detour outside the trail corridor that will eventually be eliminated as a result of completing the Pochuck Quagmire Bridge. *Map Courtesy of the NY-NJ Trail Conference.*

Site Description

To provide a trail corridor from Pochuck Mountain to Wawayanda Mountain, within Vernon Valley, the New Jersey State Park Service and the National Park Service acquired 141.1 acres between Sussex County Route 517 and Canal Road. The cost of this land was $399,050.

Unfortunately, the Appalachian Trail could not be placed practically within this trail corridor until the 60-foot-wide Pochuck Creek could be crossed safely by hikers. The creek is up to eight feet deep, with steep, slick clay banks, and a deceptive current. A 3,000-foot-wide floodplain wetland covers both sides of Pochuck Creek. Crisscrossed with tributaries and ditches, this floodplain has poor soil conditions and is normally inundated.

The quagmire has been described as a "sea of dark, oozing, quivering, leg-sucking black muck with rank weeds and lush, slimy water plants."

The wetland approach on either side of the creek is a quagmire into which a hiker can sink waist deep even during the dry summer months. The quagmire has been described as a "sea of dark, oozing, quivering, leg-sucking black muck with rank weeds and lush, slimy water plants."

This area is classified as an Exceptional Resource Value Wetland because of the habitat it provides for a variety of threatened and endangered species. In flood conditions, the creek returns the valley to the prehistoric 3,000-foot wide lake it once was.

Before the Pochuck Quagmire Bridge was built, hikers wishing to continue on the Appalachian Trail, were forced to detour the quagmire by following a dangerous 2.1 mile circuitous roadwalk along Sussex County Route 517 and Maple Grange Road to Canal Road. The detour along the heavily traveled county roadway with poor sight distances is shown in Figure 1, the Appalachian Trail map, on the preceding page.

The Great Pochuck Quagmire Bridge project was initiated to address this problem. The primary goal of the project was to provide a safe, practical, cost-effective creek crossing that would place the Appalachian Trail within the corridor and eliminate the hazardous roadwalk. Phase 1 of this objective has been accomplished through the construction of the Pochuck Quagmire Pedestrian Suspension Bridge.

Project Background

Before deciding to build a suspension bridge, the project partners rejected several other structural design alternatives. The various alternatives were either too expensive or impractical. The following section provides the decision process of the project partners in selecting the suspension bridge alternative.

Project Design History

The Pochuck Creek Bridge had three design phases:

1. Department of Treasury, Division of Building and Construction (DBC) Project No. P375 - Phase 1 Pre-Design Study

2. CCA.60 Light Frame Construction Suspension Bridge
3. Completed Timber Suspension Bridge

Phase I Pre-Design

In 1985, the New Jersey Department of Treasury, DBC of the performed a phase I pre-design study of the Pochuck Creek crossing. The study recommended a 4-foot-wide by 80-foot-long prefabricated steel truss bridge, set one-foot above the top of the creek bank. The pre-design study recommendation did not take into account the serious, frequent flooding and logjams of Pochuck Creek. The estimated construction cost of bridge alternatives varied from $114,000 to $208,000 in 1985 dollars. Construction of a truss bridge would require a bulldozed access road, pile driving equipment, and a crane. The cost estimates did not include these expenses. Also, the Pochuck Quagmire is an Exceptional Resource Value Wetland, and under the 1987 New Jersey Freshwater Wetlands Protection Act, construction with such an impact is prohibited in an Exceptional Resource Value Wetland.

The pre-design study identified the need for a “catwalk” approach on 550 piles (timber posts) across the west side wetlands. The 22-inch-wide, 2-foot-tall, no-guard rail west side catwalk was estimated to cost an additional $235,000 in 1985 dollars.

The phase I study provided basic hydrology, hydraulic, soils, and environmental information. Taking the access and total site work costs into consideration, the project cost ran into hundreds of thousands of dollars. Because of the more stringent wetlands regulations and the cost of the project, the State of New Jersey, Division of Parks and Forestry, made a decision to proceed with an alternative bridge design or system.

CCA.60 Light Frame Construction Suspension Bridge

Because of the importance of the Pochuck Creek crossing for hiker safety, the NY-NJ Trail Conference and the NJ Division of Parks and Forestry seriously committed to this project in 1991. The NY-NJ Trail Conference provided the administrative and engineering leadership on the project, via the private volunteer sector. Several criteria were identified. These are as follows:

- Original project construction budget was $10,000.
- Foundation design must address poor soil and riverbank conditions.
- Because of flood-driven logjams, the bridge must provide adequate clearance to debris carried by the 100-year flood level.
- Design must assume that all construction material and equipment would be hand-carried to the site. As a result, only hand tools would be available for construction.
- Design employed light frame construction techniques with CCA.60 SYP foundation grade dimension lumber.
- To provide for high clearance and a wide span, a suspension bridge was identified as the best type of bridge for the difficult site conditions.   This type of bridge is also the most efficient from a weight-strength perspective.

A suspension design, utilizing CCA .60 southern yellow pine dimension lumber for the foundation and towers, was prepared, permits obtained, and in September of 1993, construction was initiated by a correctional facility work crew, supervised by State Park staff.

Final Project — Completed Timber Suspension Bridge

In the fall of 1994, the scope of the project was radically redefined because of the following:

- GPU Energy, a regional utility company, came "on-board" as a project volunteer, making people, material, heavy equipment, and expertise available to the project.
- Project partners made handicap accessibility from Route 517, across the quagmire, over the creek, and through the woods to Canal Road, a project goal. The bridge was no longer just for the agile, intrepid hiker, but for all segments of the population, including school children and senior citizens. The design standards were redefined with an enhanced emphasis on public safety.
- The NY-NJ Trail Conference applied for and received a $10,000 grant from the USDA Forest Service Wood In Transportation Program. The State of New Jersey matched this grant 2:1 with $22,323. Private donations added $6,000. The project construction budget was set at $36,000. The NJDEP Division of Parks and Forestry provided $26,000 in funding for the project administration, survey, engineering, and environmental permits.

A unique public-private partnership consisting of a volunteer nonprofit group, State Park Service, a corporate volunteer, and even correctional facility workcrews was born.

During the planning phase, the primary project goal remained the same — eliminate the dangerous 2.1 mile roadwalk via placement of the Appalachian Trail within the designated and previously purchased trail corridor. This would require the construction of a safe, practical, cost-effective, and durable bridge over the Pochuck Creek.

Additional project goals established by the project partners were as follows:

- Preserve the primitive trail experience by constructing a bridge with a rustic appearance.
- Comply with the Appalachian Trail Conference policy on stream crossings.
- Utilize previously purchased material and/or donated material.
- Comply with the NJDEP wetlands and flood hazard area rules and regulations.
- Take advantage of GPU Energy expertise and standard practice, where practical, when developing the bridge design.
- Provide a handicap accessible section of the Appalachian Trail.
- Provide a site for environmental and floodplain education as well as wildlife and bird observation, while keeping visitors off the fragile flora.

Engineering Challenges to Overcome

Review of the pre-design study, various literature searches, numerous site inspections, and discussions with project partners defined the critical design problems. The problems were as follows:

- Low budget.
- Meandering 60-foot-wide stream channel.
- Steep, undercut, and unstable banks.
- Extremely poor soil conditions consisting of alluvial silt, clay, organic muck, and a high water table.

- Frequent overbank flooding; however, the Pochuck Creek is a non-delineated river, so the various frequency flood levels were not accurately identified.
- Serious logjam problems.
- Remote site with poor access.
- The entire area is a NJDEP designated Exceptional Resource Value Wetland, with extensive habitat for a variety of threatened and endangered species.
- No survey or elevation benchmark.
- Design and construction methods would have to be consistent with the ability level of a mainly volunteer, layperson work force. While some machinery would be available for construction, the premise of hand carrying all material to the site and utilization of hand tools was still valid.

In short, spanning the Pochuck Creek presented a unique and peculiar challenge!

In short, spanning the Pochuck Creek presented a unique and peculiar challenge!

The answer to the referenced problems was to utilize a suspension bridge. Other bridge designs were investigated, but these alternatives failed to address some or all of the critical design criteria. The other designs considered before the suspension bridge were as follows:

- Center pier bridge
- Simple beam bridge of timber, steel, or concrete
- Arch bridge
- Truss bridge

Bridge Design Alternatives

Center Pier Bridge

A center pier bridge was totally unacceptable from both hydraulic and environmental perspectives. A mid-stream channel pier would be a major obstruction to normal and flood flows. It could easily turn into a dam by collecting debris or ice. The heavy construction methods required to build a durable mid-channel pier were beyond the resources of the project partners and would have had unacceptable environmental impacts. Finally, NJDEP regulations strongly discourage a center pier bridge.

Simple Beam Bridge

A simple, single-span beam of various material could span the Pochuck Creek from a structural perspective; however, practical limitations quickly arise. The steep, undercut, and unstable streambanks dictate that any abutments be set back from the banks. This requires that a beam be at least 82 feet long. The abutments would also have to be tall enough to provide proper clearance to floodwaters.

These requirements, in addition to the exceedingly poor soil conditions, quickly result in the bridge abutments needing pile driving and reinforced concrete. These methods are not allowed in an Exceptional Resource Value Wetland. Nor were they within the project budget, the ability of the project partners, or the philosophy of the Appalachian Trail.

Assuming the use of a pair of twin beams for the bridge, a comparison of various materials is very interesting. To span 82 feet, a steel beam would be required to have a 20.8-inch web, with 6-inch flanges, weighing 50 pounds per linear foot (American Institute of Steel Construction Designation is a 21 by 50 section). A southern pine glulam beam would have to be 37-1/3 inches deep by 6-3/4 inches wide, weighing 87 pounds per foot. A precast concrete beam would be 43-1/2 inches deep by 16 inches wide, weighing 623 pounds per foot. Each of the alternatives would be a custom fabricated item.

How does one transport an 82-foot-long beam weighing anywhere from 4,100 pounds to 51,000 pounds down the Appalachian Trail and across a “sea of dark, oozing, quivering, leg-sucking black muck?” A simple beam bridge was not a simple solution.

Arch Bridge

Glulam wood arch bridges are often used for “showcase” facilities, such as the arch bridge at Crab Tree Falls within the George Washington and Jefferson National Forest (GW & JNF) adjacent to the Blue Ridge Parkway in Virginia. The combination of the natural wood grain and pleasing architectural lines of an arch make such structures beautiful. Glulam arch bridges have been used for pedestrian bridges spanning 85 feet or more. While an arch provides additional clearance to floodwaters, the foundation and transportation problems are even more difficult than those of a simple beam. Placing an 82-foot arch would require a crane, which was not an option in this situation.

Truss Bridge

A prefabricated truss bridge of Corten® steel, pressure treated lumber, Prestek® Systems, or Extren® Fiberglass was considered. Each of these materials is utilized for pedestrian truss bridges throughout the nation. Continental Bridge Company of Alexandria, Minnesota, is a well-known manufacturer of prefabricated, self-weathering Corten® steel truss bridges. Over 5,000 Continental bridges are in use in the United States. Steadfast Bridges of Fort Payne, Alabama, and Big R Manufacturing in Greeley, Colorado, are additional manufacturers. These firms provide bridges from 10 to 250 feet in length and 4 to 12 feet in width. A prefabricated Corten® steel truss bridge offers many advantages: the manufacturer often provides the structural design, they come prefabricated, bridges up to 75 feet in length can be shipped completely assembled, and they are virtually maintenance free and vandal-proof. An 80-foot span, self-weathering, steel pedestrian truss bridge carries the Appalachian Trail across the City Stream in Green Mountain National Forest, Vermont.

Truss bridges of wood are also very common. Trusses utilizing timbers (5 inches by 5 inches or larger) provide for spans of up to 140 feet. Trusses utilizing dimension lumber (2 to 4 inches thick) have been used for exterior pedestrian spans of up to 85 feet.

It would appear that a prefabricated truss would be the preferred solution. However, the inaccessibility of the site, span and clearance requirements, poor soils, environmental restrictions in combination with the heavy equipment required to handle a prefabricated bridge, and the extensive conventional foundation required all decision-makers to eliminate a truss bridge as an option.

Suspension Bridge Proves to be the Most Viable Solution

The solution to the unique and peculiar challenges presented by the Pochuck Quagmire was to utilize a suspension bridge. A suspension bridge can be defined in its simplest form as a bridge where the primary structural member is a flexible cable or wire rope. In their most recognizable form, suspension bridges consist of a rigid floor system hung by suspender cables from main catenary cables. The main catenary cables pass over the support towers via cable saddles and are connected to subsurface anchorages. From Lackawaxen to the Brooklyn Bridge, from the Golden Gate to the Verazzano Narrows, and now the diminutive Pochuck, the suspension bridge has provided the answer for challenging long-span crossings. For heavy-loaded vehicular bridges, the suspension bridge is the exclusive bridge type when the clear span exceeds 1,800 feet. For remote pedestrian trail locations that are inaccessible by heavy equipment, suspension bridge engineering provides a solution for clear spans ranging from 75 to 400 feet in length.

For the Pochuck Quagmire, the suspension bridge concept provided the following advantages.

- By their inherent geometry, suspension bridges lend themselves to tall, high clearance, and wide-span situations. This addressed the unstable stream banks and floodwater clearance problems.
- For a given span and loading, they are the lightest bridge system. Suspension bridges are an “efficient” structural solution because of the predominance of tensile stresses and the direct stress paths from the load to the support points. This assisted in addressing the dead load foundation requirements for the extremely poor soil conditions. This also resulted in economic and practical advantages in terms of material, transportation, and workforce costs.
- A structure is the sum of its parts. In this case, all of the material utilized was common construction material, available on relatively short notice.
- The design centered around the off-site prefabrication of the suspended truss walkway by volunteers of the NY-NJ Trail Conference. Common carpentry skills were sufficient to complete the project.
- All the material and prefabricated elements were transportable to the remote site.
- The towers provided support for an overhead erection cableway which, in turn, doubled as guy lines.

Historical Significance of Suspension Bridges to the Appalachian Trail

Interestingly, there is a direct historical parallel in the use of a suspension bridge for the Appalachian Trail route in the metropolitan New York area. Benton MacKaye presented his concept of the Appapachian Trail in 1921, when the NY-NJ Trail Conference was a fledgling one-year-old organization. In 1923, the NY-NJ Trail Conference built the first section of the Appalachian Trail in Bear Mountain-Harriman State Park, beginning at the west bank of the Hudson River and working southwestward toward New Jersey.

The next year, 1924, the Bear Mountain Vehicular Suspension Bridge, the longest suspension span in the world at the time, opened across the Hudson River. The bridge provided for passage of the Appalachian Trail over the mighty Hudson River as well as being the first roadway over the Hudson between New York City and Albany. The cablewire and steel rope for the bridge were manufactured by John A. Roebling & Sons Company of Trenton, New Jersey, as were the wire rope used on almost every major suspension bridge in the 19th and 20th centuries. John Roebling is revered as the father of modern suspension bridges.

The offices of the NJDEP Division of Parks and Forestry are also located in Trenton, a stones throw from the former Roebling Mills. The NJDEP acquired the first of its recreational pedestrian suspension bridges in the same era. The 350-foot long Cranberry Lake Pedestrian Suspension Bridge located in Allamuchy State Forest was constructed in 1928. It seemed appropriate that the NY-NJ Trail Conference would be utilizing a suspension bridge to provide a critical “Missing Link” of the Appalachian Trail in its 75th anniversary year.

The Pochuck Quagmire Bridge design contains all the classic components of a suspension bridge: diagonally braced towers, main catenary cables, deep anchorages, vertical suspenders, cable saddles, stiffening trusses, and the deck system. A comprehensive approach was employed in the design of this bridge.

The first step was to research the literature from the Grand Era of Suspension Bridges (1924 Bear Mountain Bridge to 10:30 a.m., November 7, 1940, Tacoma Narrows Dance of Death). This included review of classic texts, transactions of the American Society of Civil Engineers, the Roebling Papers at Rutgers University, and numerous other sources. A listing is provided in Appendix F and G.

The second step was to inspect similar pedestrian structures. Upon discussion with the project partners it became evident that there was no available data or material on similar structures.

Over a period of one year, a field reconnaissance of pedestrian suspension bridges from North Carolina to Maine was performed by the author of this publication. The purpose was to establish de facto design standards as well as to learn from the successes and problems of others. Six of the bridges are on the Appalachian Trail.

Following is a brief listing of the inventoried bridges. Those appearing in bold print are "good" examples of bridges built using USDA Forest Service design and construction methods.

- *Bear Mountain Bridge:* Hudson River, Appalachian Trail, Bear Mountain, New York
- *Bemis Bridge:* Saco River, White Mountain National Forest, New Hampshire
- *Brooklyn, George Washington, Verazzano Narrows, & Golden Gate Bridges*
- *Bull's Island Suspension Bridge:* Delaware River, D & R Canal State Park, New Jersey
- *Clarendon Gorge:* (Robert Brugman Memorial Bridge) Appalachian Trail, Vermont
- *Cranberry Lake Suspension Bridge:* Allamuchy State Forest, New Jersey
- *Deerfield Creek Bridges I & II:* Green Mountain National Forest, Vermont
- *Dry River Bridge:* White Mountain National Forest, New Hampshire
- *Grandfather Mountain Swing Bridge:* North Carolina
- ***Great Gulf Wilderness Bridge**:* Appalachian Trail, White Mountain National Forest, New Hampshire
- ***Hastings Trail Bridge**:* Wild River, White Mountain National Forest, New Hampshire
- ***Jackson River Bridge**:* George Washington and Jefferson National Forest, Virginia
- ***Kimberly Creek Bridge**:* Appalachian Trail, George Washington and Jefferson National Forest, Virginia
- *Libby Bridge:* Peabody River, White Mountain National Forest, New Hampshire
- ***Lincoln Woods Trail Bridge**:* White Mountain National Forest, New Hampshire
- *Mackinaw River Bridge at Parkland:* Bloomington, Illinois
- *Muray River Swing Bridges I & II:* Virginia
- *Northville - Lake Placid Trail Bridge:* West Branch Sacandaga River, Adirondacks, New York
- *Old Job Trail Bridge:* Lake Brook, Green Mountain National Forest, Vermont
- *Orange County Golf Course Bridge:* Orange County, New York
- *Rattle River Bridge:* Appalachian Trail, White Mountain National Forest, New Hampshire

- *Roebling Aqueduct:* Delaware River at Lackawaxen
- *Saxton River Bridge at Bellow Falls:* Vermont Association of Snow Travelers (VAST), Vermont
- *Saxton River Bridge at Grafton:* Vermont Association of Snow Travelers (VAST), Vermont
- *School House Road Bridge:* Chester, Vermont
- *Smokey Angel Bridge:* Hartland, Maine
- ***Tye River Bridge**:* Appalachian Trail, George Washington and Jefferson National Forest, Virginia
- ***Wallace Tract Trail Bridge**:* George Washington and Jefferson National Forest, Virginia
- ***Wilderness Trail Bridge**:* White Mountain National Forest, New Hampshire
- *Winooski Wonder Bridge:* Vermont Association of Snow Travelers (VAST), Waterbury, Vermont

The difference between the Pochuck Quagmire Bridge and the pedestrian bridges listed above became readily apparent in this inventory. Almost all of the bridge sites were easily accessible by a paved roadway. All of the bridges were located on solid rock outcrops or had similar good foundation conditions and crossed a well-defined river in a gorge or sheltered valley. The Pochuck Quagmire site did not have any of these benefits. In addition, the majority of the bridges were located in out-of-the-way rural locations as opposed to the Pochuck site, which is on the fringe of the New York City Metropolitan area. This necessitates a greater emphasis on public safety and anticipation of misuse.

USDA Forest Service's Use of Suspension Bridges

With this inventory it became apparent that USDA Forest Service bridges were the only pedestrian suspension bridges that were built to a consistent, identifiable standard. The USDA Forest Service appears to use the same basic plans for its trail suspension bridges with regional variations. It seems that these plans originated in the 1930s.

During the development of this publication, the author learned of an additional 31 USDA Forest Service suspension bridges in Idaho and Montana. Photographs of a few of these bridges are included in Appendix H. The Appalachian Trail Tye River Bridge was originally built in 1972 and reconstructed in 1992. The Kimberly Creek Appalachian Trail Bridge is the most recent USDA Forest Service Suspension Bridge on the Appalachian Trail, having been built in 1992. The Pochuck Quagmire Bridge design incorporates some of the proven features of the Forest Service bridges and provides alternatives to other elements. The author acknowledges the valuable input of the USDA Forest Service. The Pochuck Quagmire Bridge upgrades structural and public safety elements to Building Officials and Code Administrators® International (BOCA®), American Association of State and Highway Transportation Officials (AASHTO), and the Americans With Disabilities Act (ADA) standards where practical. Based on the field inventory by the author, the Pochuck Quagmire Bridge meets or exceeds the standards utilized for the USDA Forest Service Suspension Bridges on the Appalachian Trail.

Suspension Bridge Nomenclature

Following are some definitions and simple sketches (Figure 2, page 15) of suspension bridge components. These are provided at this time to give the reader an overview. Greater detail is provided later in this case study. As stated previously, suspension bridges consist of a rigid flooring system hung by suspender cables from main catenary cables. The main catenary cables pass over the support towers via cable saddles and are connected to subsurface anchorages.

***Main Catenary Cables*:** These cables provide for the distinctive parabolic silhouette. Cables are in tension. To be correct in a technical sense, what are generally called the cables are more properly called wire rope. Groups of individual wires make up a strand. Groups of strands make up a wire rope. When a wire rope reaches a large diameter, it is generally called a cable. There does not appear to be a common consensus as to the threshold diameter that differentiates between a wire rope and a cable.

***Backstays*:** That portion of the main tension catenary cables (wire rope) that extends from the tower top saddles to the subsurface anchorages.

***Suspenders*:** The vertical wire ropes that run from the main cables to the rigid floor system. Normally these are significantly smaller in diameter than the main cables, and these are equally spaced. They distribute the roadway load to the main cable.

***Center Span*:** The horizontal distance between the towers.

***Towers*:** Also called piers or pylons. The towers support the main cables. They must address wind, temperature, and live and dead loads.

***Sag*:** Also known as dip. The vertical distance between the high and low points of the main cable.

***Sag-Span Ratio*:** The ratio of the cable sag to the span. A critical design element.

***Cradle*:** The horizontal offset distance between the midpoint of the main cable to the straight line established by the cable saddles.

***Flare*:** The horizontal offset distance between the straight line established by the cable saddles and connection of the main cable to the anchorage.

***Stiffening Trusses*:** These act to distribute a concentrated live load over a length on the main cable by loading several suspenders. They provide support for the floor system.

***Camber*:** The arch of the walkway. The vertical distance from the underside of the truss chords at the bridge midpoint to the straight line drawn between the tower walkway support points.

***Tower Footing*:** This component transfers the axial load of the bridge towers to suitable bearing subsurface stratum. It is designed to address uplift, overturning, and sliding.

***Anchorages*:** Mechanisms that counter-act the inclined tension load of the backstays.

Design Standards

A problem that presented itself during the 1994 design phase of this project is that no formal design criteria for any type of pedestrian bridge had ever been addressed by any of the major recognized design codes. Pedestrian bridges seem to have "fallen through the cracks." This was verified by a review of the literature and discussion with engineers nationwide. In order to address this void, in 1997, AASHTO published the "Guide Specifications for Design of Pedestrian Bridges." Excerpts of this guide specifications are provided in Appendix B. Liability by not meeting recognized "design standards" on the part of project partners in the event of an accident or misuse on the bridge became a major concern.

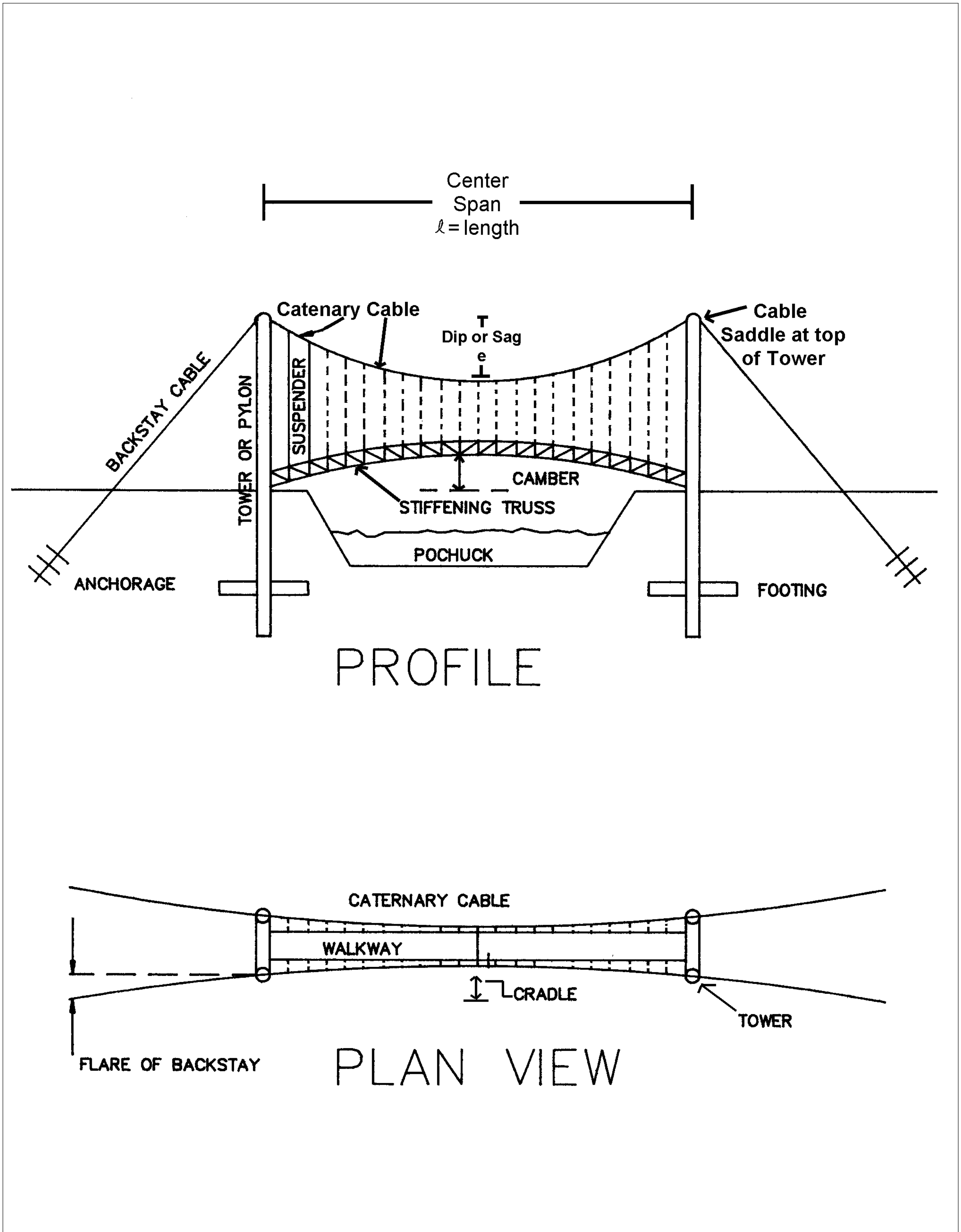


Figure 2. Sketch of Suspension Bridge Components.

The project engineer applied design standards from various codes in effect at the time of design and construction as good judgment dictated. A list of references is provided in Appendix F. The results of the bridge inventory defined what is standard or customary in the field. Examples of the appropriate application of design standards are as follows:

- Utilization of braced-guyed transmission pole standards in concert with BOCA® Loading and Timber Construction Standards for the Trussed Tower Design. The design of the bridge walkway rail system as a Howe Truss, so that the walkway would act as a live load and wind load distribution member, consistent with civil engineering practice. The layout of the rail system horizontal members meets the 1992 AASHTO standard 2.7, 2.2.1, and 2.2 for Pedestrian Walkways. The rail system at the platform at either end was upgraded to meet BOCA® standards for swimming pool enclosures 421.10.1.2, 1.4 by the addition of 1-inch by 1-inch poly coated galvanized wire mesh. The rail system and handrail also meet ADA requirements.
- A common-sense practical approach was utilized in recognition of the resources of the project partners, public safety, long-term maintenance, and appropriate design for a wilderness footbridge. The combination of dead load, live load (20,800 pounds or 110 people at 189 pounds each spaced 1-foot apart), and snow load became the primary design load. Although checked independently, these loads were not combined with wind load or seismic loads, recognizing the improbable occurrence of 110 people on the bridge during a snowstorm with 70 miles per hour (MPH) winds and a simultaneous earthquake.
- A live load of 60 pounds per square foot (PSF) was used. This is consistent with BOCA® standard 1606.1 which specifies 60 PSF for exterior decks. In the early 1990s, well-known bridge manufacturers also used 60 PSF live load for bridges longer than 50 feet.
- The snow load for the Pochuck Quagmire Bridge is relatively low. The reader is advised that in some parts of the country the snow load will be the primary design load.

The bridge was designed and constructed to comply with applicable portions of the following codes and standards as identified in the design calculations:

- 1993 BOCA® National Building Code
- American Institute of Timber Construction (AITC) Timber Construction Manual
- National Design Specifications and Load Factors for Southern Yellow Pine
- Building Code Requirements for Reinforced Concrete, American Concrete Institute (ACI) 318
- Uniform Construction Code — State of New Jersey
- Transmission Line Design, U.S. Department of Agriculture
- Federal Emergency Management Agency (FEMA) Floodproofing Non-Residential Structures
- Title III of the Americans With Disabilities Act
- New Jersey N.J.A.C. 5:23-7 Barrier Free Subcode
- 1992 AASHTO Hand Rail Standard 2.7, 2.2.1, and 2.2 for the walkway

The bridge was constructed to meet or exceed the following:

1. Live load of 60 PSF in combination with a walkway dead load of 9,550 pounds, which results in a design load of 39,400 pounds across the 110-foot span. Dead, live, and snow load translates to maximum cable tension load of 23,455 pounds, and a column load of 21,698 pounds.

2. A ground snow load of 30 PSF, which translates to 18 PSF on an elevated suspension bridge.
3. A 50-year 70 MPH wind on the profile cross-section of the bridge.
4. The span-sag-elevation of the bridge provides a 6.68-foot freeboard to the historical 100-year floodwater elevation of 400 feet for Pochuck Creek at the bridge center and 4.5 feet at the platforms.
5. Allowable soil bearing capacity of 500 PSF.
6. Wire rope safety factor of 4.5.
7. Soil power installed screw anchor safety factor of 3.

Design and Construction of the Bridge Towers

The design of the bridge towers required answers to a number of philosophical and practical questions. The first question was whether the towers should consist of a large number of lightweight structural members (like a "stickbuilt" framed house) or a few massive members (like a log cabin). The original design for the Pochuck Quagmire Bridge consisted of framed, built-up towers consisting of dimension CCA .60 southern yellow pine. This was a design necessity at the time because all material would have had to be hand-carried to the site, assembly would be done by layperson volunteers, and the total budget was $10,000.

This design premise was modified when GPU Energy joined the project as a volunteer. GPU Energy offered to provide, transport, install, and guy 40-foot tall #1 SYP transmission poles to serve as the catenary cable towers. Mr. John Karcher, a professional engineer with GPU Energy, provided technical literature on GPU Energy material and procedures.

The use of round non-uniform transmission poles for the primary structural members of the towers set a certain standard or premise for the project. Heavy timber connections are difficult to make efficiently, particularly when the connection is between a round pole and flat dimension lumber. It is similar to installing a square peg in a round hole. There is very little direct bearing between the two surfaces. The single curve spike grids do assist in addressing this problem. However, the problem in this project was compounded by the fact that the tower joint connections would be made in a remote field location, installed with hand tools, 34 feet in the air, accompanied by friendly mosquitoes. These practical considerations dictated that while the towers are H-Frame, X-braced structures (indeterminate), no allowance would be made for the benefits of the truss construction. The joints are the weak link. The design premise for the towers is that they are designed as simple tapered columns restrained at the base and braced at the top. The Euler effective length of the tower columns was taken as the distance between the top of the foundation and the upper guylines. The intermediate timber cross-members will act to reduce the effective length and increase the load-bearing capacity. But discounting the benefits of these intermediate members and designing the towers as a simple column resulted in a more conservative design.

The design of the towers was a several step process. The following steps were performed:

1. Identify the basic dimensions and geometry of the bridge. Span and the width of the walkway needed to meet the ADA code. These dimensions in concert with a live load of 60 PSF and a snow load of 18 PSF determine the total live load.
2. Design of the walkway structure, i.e., the ribs, chords, diagonals, joists, rails, and decking. The specific design and material used identified the dead load.

3. Identify hydrodynamic and wind loads.
4. Determine the design tension of the wire rope at the midpoint and the cable saddles by analyzing the distribution of the total design load via the suspension system and the sag-span ratio of the wire rope.
5. Utilize design procedures as specified in the "Design Manual for High Voltage Transmission Lines" Rural Electrification Administration (REA) Bulletin 62-1, Department of Agriculture. The Class I SYP transmission poles were checked to determine the maximum safe vertical load against buckling. While using this reference may seem odd at first, one will quickly recognize that transmission lines are "suspension structures." The REA manual presents the practical experience accrued from millions of miles of transmission lines. The REA procedure indicated that the poles discounting the structural benefits of intermediate cross-members could support 42,600 pounds with a safety factor of 3. This is 1.9 times the design load of 22,000 pounds.
6. Utilize design procedures for tapered poles as specified in Section 5 of the "Timber Construction Manual" 3rd edition, AITC. This is a more detailed design procedure than the REA methods. This incorporated the following elements:
   - Adjustments for taper
   - Identification of slenderness ratio and column classification
   - Euler formula for ultimate buckling strength
   - Live load duration modification factor
   - Allowable bending stress of 1,700 PSI (pounds per square inch)
   - Allowable compression parallel to the grain of 900 PSI
   - Modulus of elasticity of 1.5 million PSI

The AITC design procedure identified the allowable axial load on the poles as 32,500 pounds, or 1.48 times the design load of 22,000 pounds.

This six-step procedure resulted in the pole towers detailed on Plan Sheet 4 and Figure 3 on the following page.

Tower Installation

The photographs on pages 20 and 21 provide a pictorial of the tower installation. The extremely poor subsurface conditions required an extensive foundation system. The connection between the towers and the foundation required the poles to be in their final upright position prior to the foundation construction. This required the tower poles to be installed first on a temporary basis with braces and guylines. The foundation, which will be reviewed at length on pages 23-39, was installed immediately afterwards.

As indicated in the photographs, the first step was to auger holes for the poles. The poles were embedded in the soil a minimum of 6 feet for structural and safety purposes. This is common practice for 40-foot poles. Although the ground elevation varied from pole location to pole location by as much as 15 inches, it was important that all four pole tops be at the same elevation. Elevation benchmarks and a surveyors level were used to identify the embedment depth for each pole to ensure a common top elevation to the extent practical. The poles were winched up as shown in photos 2 and 3. Note that the top guyline cable bands were installed before the poles went up. The Chance® Power Installed Screw Anchors (PISA®) for the guylines were also installed before the poles went up. The pole bases were backfilled and tamped. As shown in photos 4 to 9,

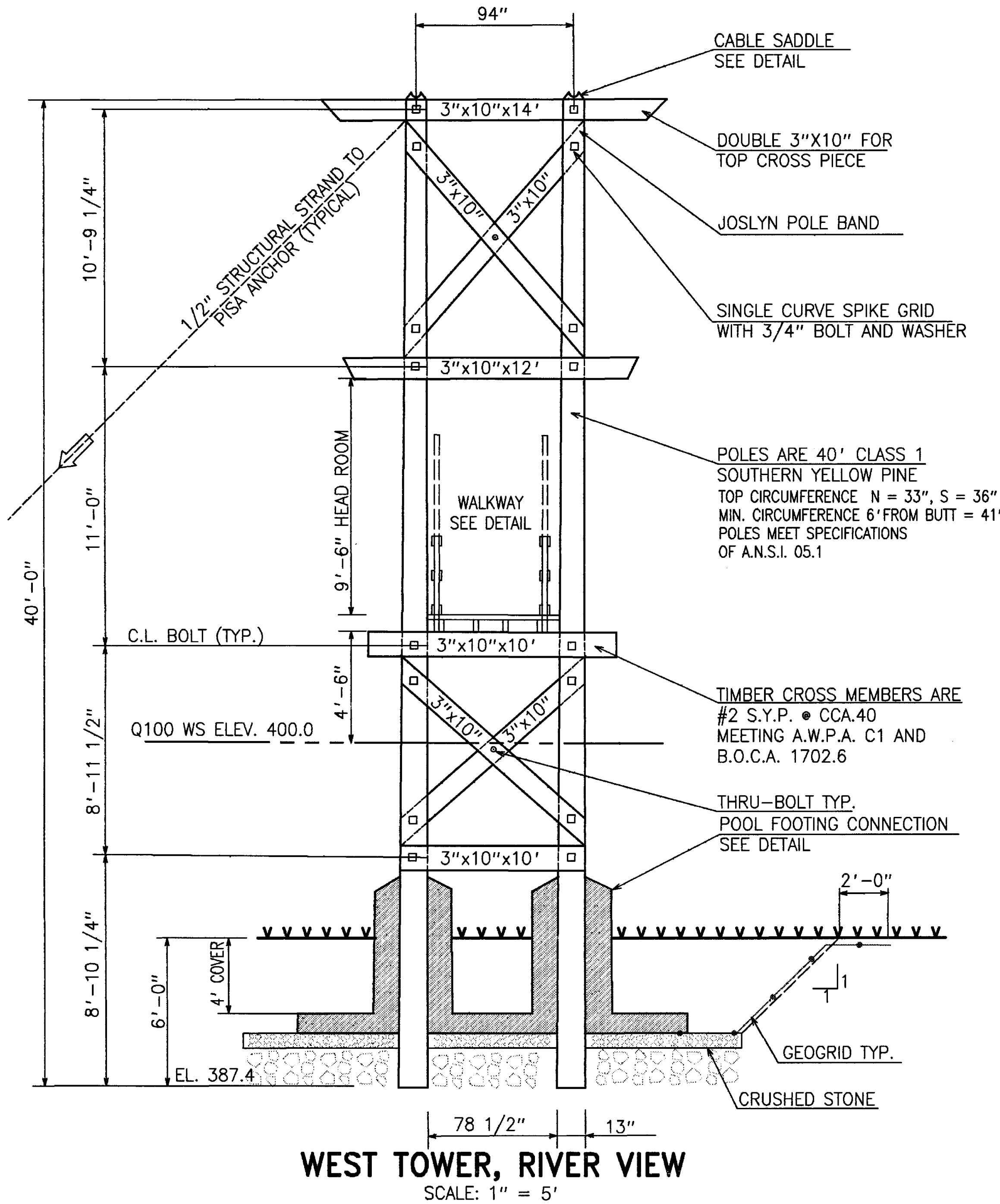


Figure 3. West Tower, River View. *Design plans courtesy of Tibor Latincsics, Conklin Associates.*

Photo 2. Installation of the west poles. The east tower is in the background. *Photo courtesy of Mr. Stephen Klein, Jr.*

Photo 3. Installation of the west poles. *Photo courtesy of Mr. Stephen Klein, Jr.*

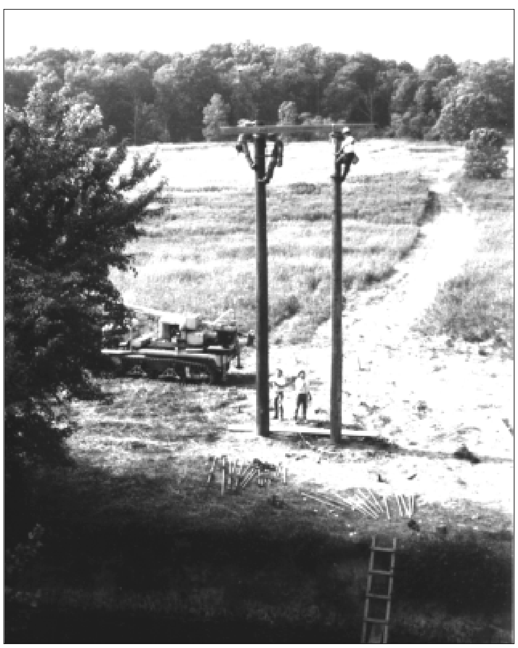


Photo 4. GPU Energy volunteers installing the tower cross-bracing on the west tower. *Photo Courtesy of Mr. Paul DeCoste.*

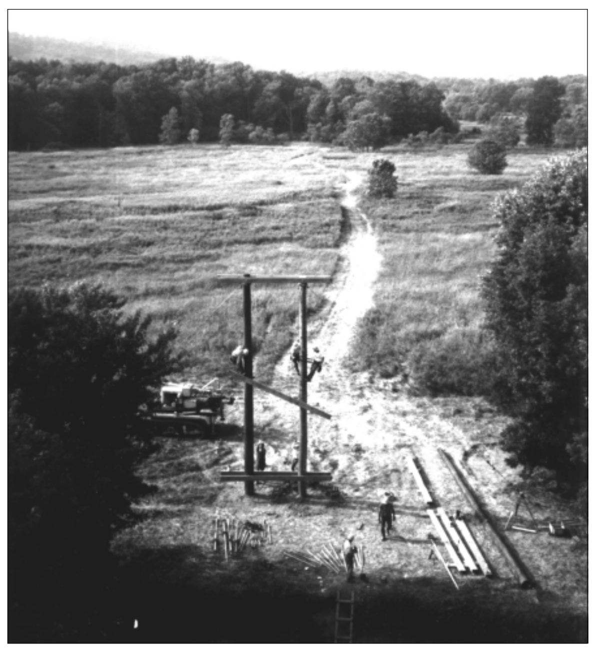


Photo 5. GPU Energy volunteers installing the tower cross-bracing. *Photo Courtesy of Mr. Paul DeCoste.*

Photo 6. GPU Energy volunteers installing the cross-braces and guylines. *Photo Courtesy of Mr. Tibor Latincsics.*

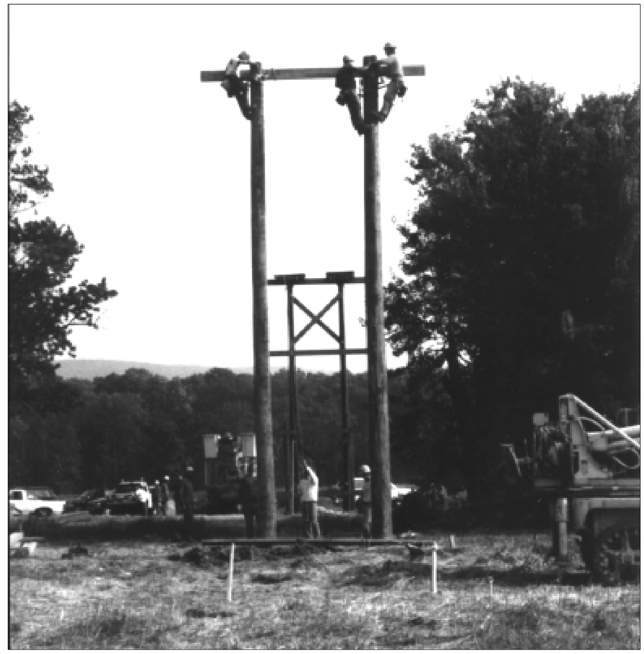


Photo 7. GPU Energy volunteers installing the cross-braces and guylines. *Photo Courtesy of Mr. Tibor Latincsics.*

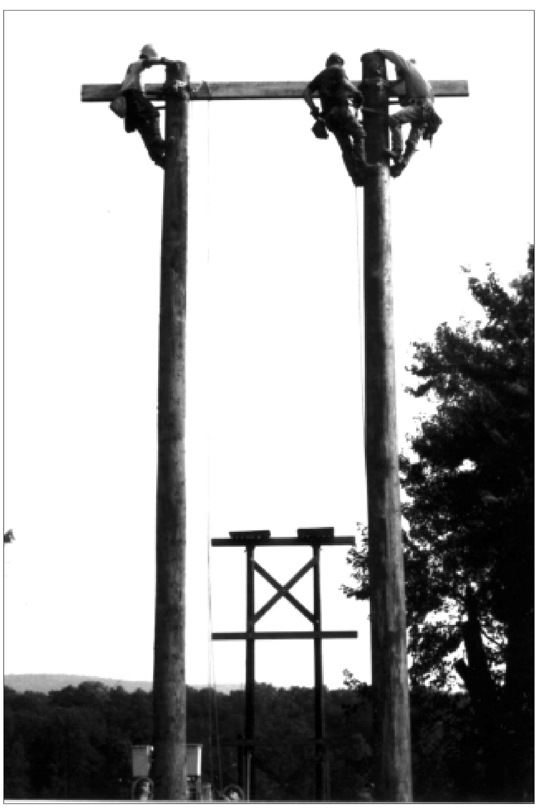


Photo 8. GPU Energy volunteers installing the cross-braces and guylines. *Photo Courtesy of Mr. Tibor Latincsics.*

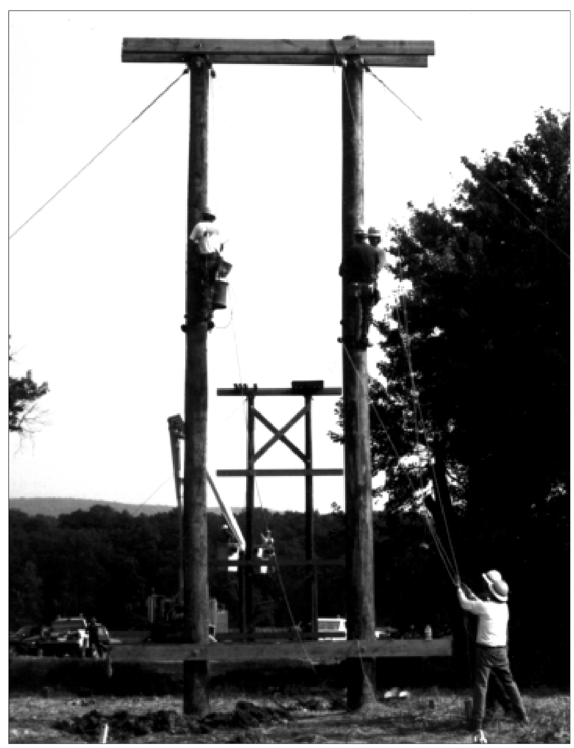


Photo 9. GPU Energy volunteers installing the cross-braces and guylines. *Photo Courtesy of Mr. Tibor Latincsics.*

GPU Energy volunteers climbed the poles and set the top cross-braces and guylines. The 1/2-inch structural strand guylines with preform ends shown in photo 9 were attached. These were also used to “plumb up” the poles. With the poles plumb, the remainder of the cross-braces and diagonals were installed. Galvanized 3/4-inch bolts and single curve spike grids were used to make the connection between the transmission poles and the 3-inch by 10-inch cross-braces. Spike grids (also known as gain grids) are most often used in heavy timber and pole construction, such as with docks and bulkheads. A well-known manufacturer of spike grids is Cleveland Steel Specialty (14400 South Industrial Avenue, Cleveland, OH 44137; Phone: 800-251-8351). The galvanized, malleable iron grids come in three configurations: flat, circular, or single curve. All three are sized for either a 3/4-inch or a 1-inch bolt.

The advantage of using the spike grids is that in lieu of the cross-arm or diagonal load being transferred to the bolt alone, the load is also transferred to a larger wood area. The spikes of the grid press into the wood fiber of both members and improve the shear and rotation resistance of the bolted joint. The single curve spike grids are specifically made to increase the bearing surface between a round pole and flat lumber. Spike grids have the added benefit of providing ventilation, which eliminates the potential decay at the contact area between the two wood surfaces. Spike grids increase the strength of a bolted timber connection. The 3-inch by 10-inch cross-braces were installed with the “bark side” towards the pole, so if the lumber cups, it improves the spike grid embedment.

As shown in photo 10, the two towers were also guyed to one another with structural strand guy wire. The Pochuck Quagmire Bridge is the only pedestrian bridge among those inventoried that utilizes guylines to brace the top of the towers. For the long term, the guylines can be viewed as “cheap insurance” as well as a cost-effective way of reducing the Euler effective length of the towers. The fact that GPU Energy donated all the guyline hardware and performed all the installation made it easy for the project partners. The guylines were essential to the sequence of construction. The foundation excavation could not have been performed without the guylines securing the cross-braced poles. Under normal loading conditions the guylines do not play a structural load. The guylines do have a structural benefit under extreme wind loads.

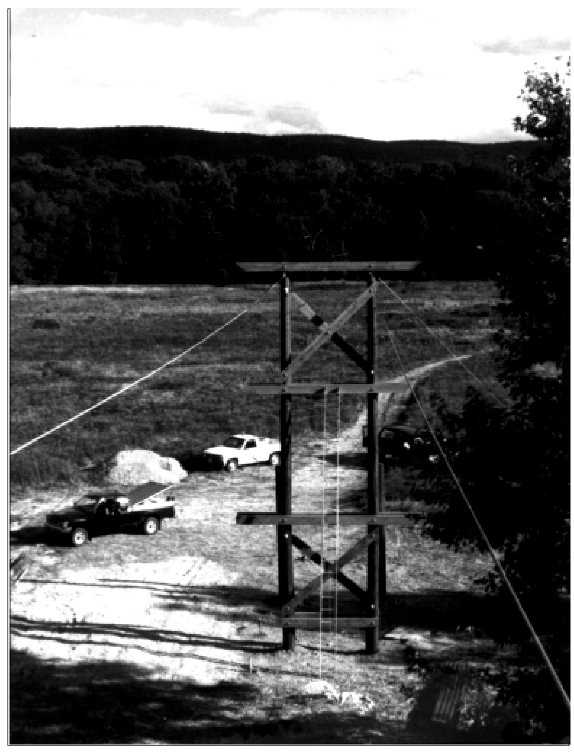


Photo 10. View from the east tower looking at the west tower and Wawayanda Mountain during construction. Shows the structural strand guylines running between the towers. *Photo Courtesy of Mr. Tibor Latincsics.*

As will be reviewed in greater detail later, the guylines running between the tower tops, as shown in photo 10, served an important role in the assembly of the walkway. It is important to remember that a portion of the horizontal load that guylines counteract is transferred to the towers as an axial load. Guylines can be very beneficial, but the designer must incorporate the loads in the tower and foundation design. The end result, as shown in photo 16 (page 29), was that the towers were framed out, guyed in all four directions, and embedded 6 feet in the earth. It was then practical and safe to excavate around the tower bases to construct the foundation.

Foundation Design and Construction

The design and construction of a foundation meeting the necessary structural requirements, the inaccessibility and environmental limitations of the site, and the limited labor and financial resources of the project partners were primary design challenges. The design process of the hybrid foundation followed a conventional route.

1. Identification of project objectives, design criteria, and project resources.
2. Investigation of site subsurface stratigraphy and soil conditions. Identification of depth to frost, water level, and special conditions.
3. Identification of the load-bearing horizon and its allowable bearing capacity.
4. Proportion a conceptual foundation, reviewed from the various perspectives of performance, constructability, practicality, economic feasibility, and resources.
5. Foundation design in accordance with applicable codes. Design of the foundation to tower connection.

The important first step in foundation design is advance subsurface investigation. Too often many projects do not have the funding for the proper thorough subsurface investigations required. Project owners tend to be hesitant about spending hard cash for geotechnical investigations when the project is in the concept or preliminary stage. But the subsurface information is required to proceed from the concept to the design phase. Failure to base a design on accurate subsurface data can lead to one or all of the following:

- Design changes once construction has commenced. This usually means additional unexpected expenses and time delays.
- Unexpected problems encountered early on in a project can lead to morale problems, if not lawsuits.
- Disaster.

The subsurface investigation procedures utilized for the Pochuck Quagmire Bridge were as follows:

1. Review of soils and geological mapping for the area.
2. Supervised test borings with track-mounted rotary wash drilling equipment. Representative samples were obtained from the borings. The borings were extended to a depth of 20 feet, which corresponded to a suitable bearing stratum.
3. Hand dug test holes to the footing level in which the project engineer conducted soil bearing tests over a one-year period.
4. The literature search information, boring data, lab results, and practical field testing were compiled and cross-checked. Design problems and criteria were identified.

With 20-20 hindsight, more soil borings should have been performed. The Smokey Angel Bridge design engineer, as well as the contractor on the Wallace Tract Trail Bridge, had identical post-construction comments on their bridge projects. This is among the most common post-construction comments in civil engineering. The soil borings that were performed indicated exceedingly poor subsurface conditions. The borings confirmed the information provided by the regional soils and geologic mapping. The river valley, being a former glacial lake bottom, has an overburden of alluvial silt and clay to a depth of 8 feet, then a layer of lacustrine organic muck, and then more clay. A suitable bearing sand layer was encountered at 15 feet. This was 10 feet below the seasonal low water table and 7 feet below the creek bed. In addition to the poor silts, clays, and unsuitable organic muck, the soil conditions had the unfortunate characteristic of a decreasing bearing capacity with depth until the sand layer was encountered. Normally the bearing capacity of a soil increases with depth as the lower layers are more condensed. The opposite is true for the Pochuck Quagmire Bridge site. The organic muck layer — 8 feet underground — was completely unsuitable for supporting a structure. It is also important to recognize that clay soils swell and shrink with change in water content and are very susceptible to frost heave. Frost heave was a concern for the bridge because it would be located at the center lowpoint of a narrow valley. One could expect temperatures to be 5 to 10 degrees colder at the bridge site than surrounding higher elevations. In short, the soil conditions were half jokingly - half seriously referred to as among the "Worst in the World."

The tower foundation system must transfer the tower design loads to suitable subsurface bearing stratum. The bearing capacity of a soil is the load in tons per square foot that can be applied to a given area without causing a settlement of more than a given amount. The ultimate bearing capacity of a soil is the load, usually in tons per square foot, that can be applied to a given area without causing a sudden settlement. The allowable bearing capacity is the recommended load per square foot that would be transmitted by the structure under full live and dead loads to the soil, adjusted by proper safety factors. The primary load the foundation for a pedestrian suspension bridge needs to be designed for is the axial column load of the full design live and dead loads. Uplift, overturning, and sliding under every possible combination of forces also need to be addressed. This should include wind and hydrodynamic loads. As important as provisions for preventing excessive settlement are design investigations and elements to prevent differential settlement. Excessive differential settlement would put the bridge towers out of plumb (i.e., Leaning Tower of Pisa).

Utilization of driven piles into the sand layer was not an economically or environmentally viable solution. A shored, pumped mass wet excavation to the sand layer and subsequent backfill with 3/4-inch crushed stone was equally unrealistic. For the project to proceed, a hand constructed shallow foundation addressing the structural needs of the bridge needed to be devised. The eventual foundation is best described as a hybrid. The twin tower foundations consist of a shallow combined reinforced concrete spread footing (12 feet by 16 feet by 12 inches) connected to Chance® Helical Anchors and Tensar® UX-1400 Geogrid. It was nicknamed "The Snowshoe." The elements of the foundation address settlement, shear strength, overturning, lateral stability, and buoyancy.

Review of Other Timber Tower Pedestrian Suspension Bridge Foundations

Prior to discussing the Pochuck Quagmire Bridge snowshoe foundation in greater detail, this case study shall diverge and briefly review more conventional foundations from other timber tower pedestrian suspension bridges listed on pages 12 and 13. This is presented in recognition that most readers of this case study who are planning a bridge will most likely not have soil conditions as poor as that of the Pochuck Quagmire. Review of more traditional foundations should be helpful. It will also serve to highlight the uniqueness of the "Pochuck Snowshoe."

Photo 11. Inclined towers of the Jackson River Bridge. *Photo Courtesy of Mr. Tibor Latincsics.*

The Jackson River Bridge is shown in photos 11 and 12. It is located in the Warm Springs Ranger District of the George

Photo 12. Jackson River Bridge in the George Washington and Jefferson National Forest. *Photo Courtesy of Mr. Tibor Latincsics.*

Washington and Jefferson National Forest (GW & JNF), Virginia. It was constructed in 1988. It is a trail bridge located a few miles north of Hidden Valley Campground. The author was advised of the bridge's location and particulars upon visiting the GW & JNF Headquarters in Harrisonburg, Virginia. Mr. William Talley, Mr. Terry Smith, and Mr. Lannie Simmons of the Forest Engineering staff were most helpful. They allowed review of the bridge plans and provided background information as well as an inventory of suspension bridges throughout GW & JNF.

The Jackson River Bridge has a 135-foot center span. It is supported by 26-foot tall, inclined, cross-braced southern yellow pine poles. An elegant visual element of the Jackson River Bridge is the inclined poles. This also provides lateral structural stability. The GW & JNF Forest Engineering staff advised the author that the professional contractor had an extremely difficult time setting the poles to the correct angle. This and other design criteria convinced the author to specify vertical poles for the Pochuck Quagmire Bridge. Figure 4 is a diagram of the Wild Oak Bridge, which is very similiar to the Jackson River Bridge. In this case, the Jackson River Bridge poles were set on a 4-foot by 16-foot by 16-inch reinforced concrete footing. The footing is 6 feet below grade. The base of the poles are set into a 2-foot vertical extension of the footing. The Jackson

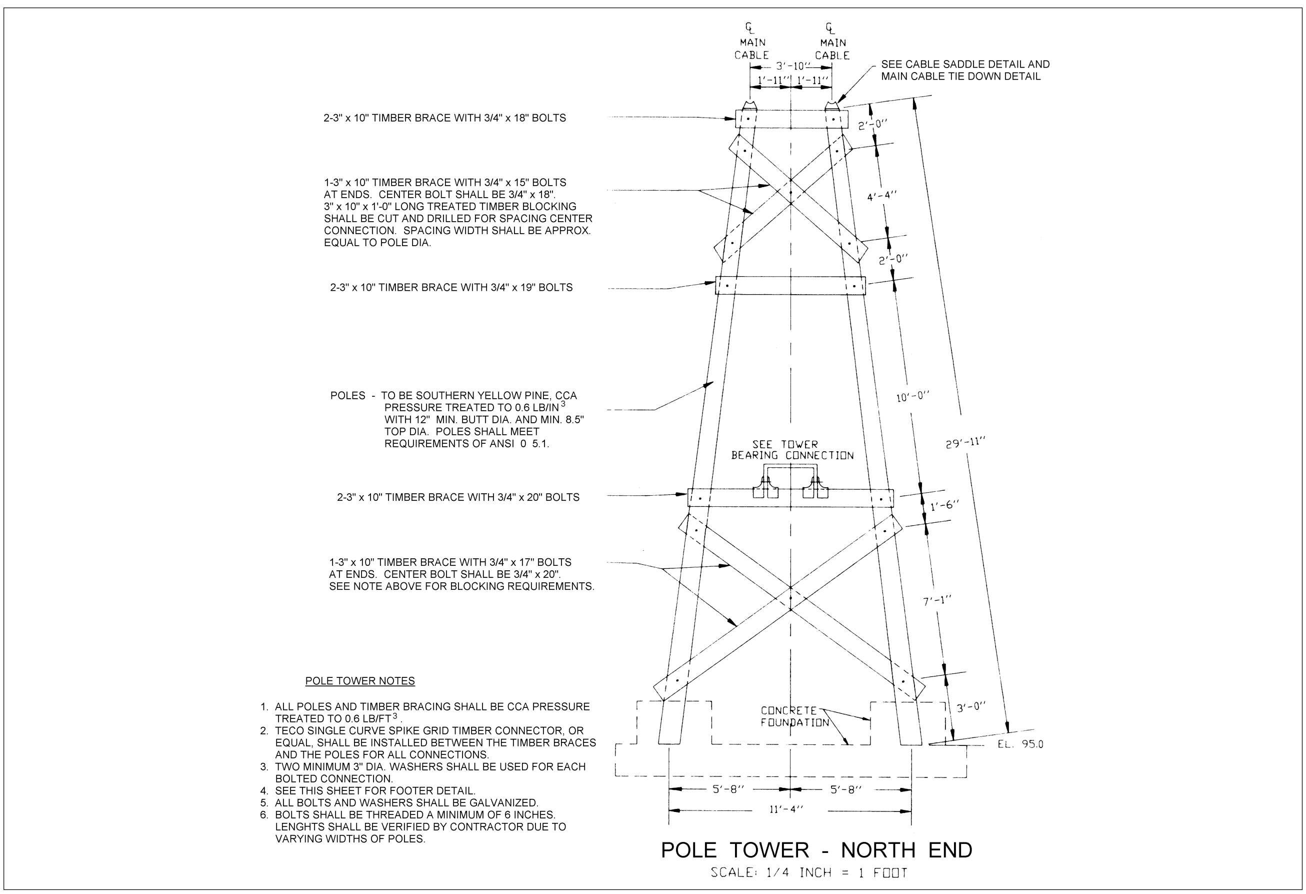
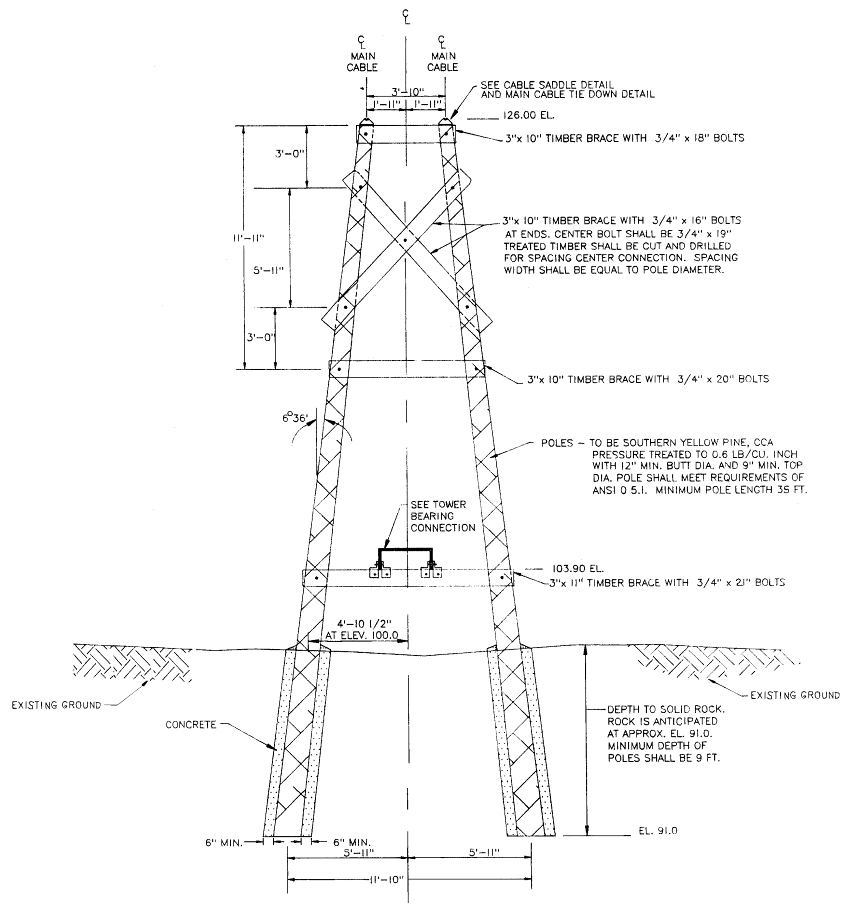


Figure 4. The Wild Oak Bridge Tower. *Diagram courtesy of the George Washington and Jefferson National Forest Engineering Staff.*

River Bridge and its foundation is typical of the suspension bridges in the GW & JNF. This includes the Tye River and Kimberly Creek Bridges, both of which are located on the Appalachian Trail.

A few miles to the northeast of the Jackson River Bridge is the Wallace Tract Trail Bridge. It is located within the Deerfield Ranger District of the George Washington and Jefferson National Forest. It is a 150-foot center span bridge over the Cow Pasture River. Constructed in 1991, it shares many design and construction features of the Jackson River Bridge. In this particular case, the good soil and geologic conditions allowed a simple but effective foundation. The foundation consists of augering down 9 feet to ledge rock, placing the transmission poles, and backfilling with concrete. The tower and foundation are detailed in Figure 5. A second reason this style foundation was utilized is that similar to the Pochuck Quagmire Bridge a local electric power company volunteered the poles, labor, and equipment to set them. The augered hole foundation was more suited to their normal operations. The *AITC Timber Construction Manual* provides a good review of the required embedment depth, allowable direct, and lateral bearing pressure for a pole foundation.



POLE TOWER

POLE TOWER NOTES

1. ALL POLES AND TIMBER BRACING SHALL BE CCA PRESSURE TREATED TO 0.6 LB/FT^3.
2. BOLTS SHALL BE THREADED A MINIMUM OF 6 INCHES. LENGHTS SHALL BE VERIFIED BY CONTRACTOR DUE TO VARYING WIDTHS OF POLES.
3. TECO SINGLE CURVE SPIKE GRID TIMBER CONNECTOR, OR EQUAL, SHALL BE INSTALLED BETWEEN THE TIMBER BRACES AND THE POLES FOR ALL CONNECTIONS.
4. TWO MINIMUM 3" DIA. WASHERS SHALL BE USED FOR EACH BOLTED CONNECTION.
5. ALL BOLTS AND WASHERS SHALL BE GALVANIZED.

Figure 5. Wallace Tract Bridge Pole Towers, George Washington and Jefferson National Forest. *Diagram courtesy of George Washington and Jefferson National Forest Engineering Staff.*

The USDA Forest Service also constructed a series of timber tower suspension bridges in the White Mountain National Forest (WMNF) in New Hampshire and Maine. As listed on pages 12-13, these include the Wilderness Trail Bridge, the Lincoln Woods Trail Bridge, the Dry River Bridge, and the Hastings Trail Bridge.

Photo 13. The Lincoln Woods Trail Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 14. The Lincoln Woods Trail Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 15. The Lincoln Woods Trail Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

The design of these bridges follows a similar pattern. Photos 13, 14, and 15 show the Lincoln Woods Trail Bridge.

The foundation used for the Wilderness Trail across the East Branch of the Pemigewasset River is typical of the foundations for the WMNF bridges (Figure 6). The design for these bridges utilizes a 3-foot wide reinforced concrete strip footing. A 12-inch reinforced concrete wall is keyed to and atop the centerline of the strip footing. The length of the footing and foundation is determined by the tower dimensions. The foundation wall extends several feet above grade. A 12-inch by 12-inch sill timber is attached to the foundation wall by anchor bolts. The 12-inch by 12-inch timber tower legs are attached to the sill with base plates, drift dowels, and steel angles. This assembly of footing-foundation wall sill connections is very similar to residential and pole style construction.

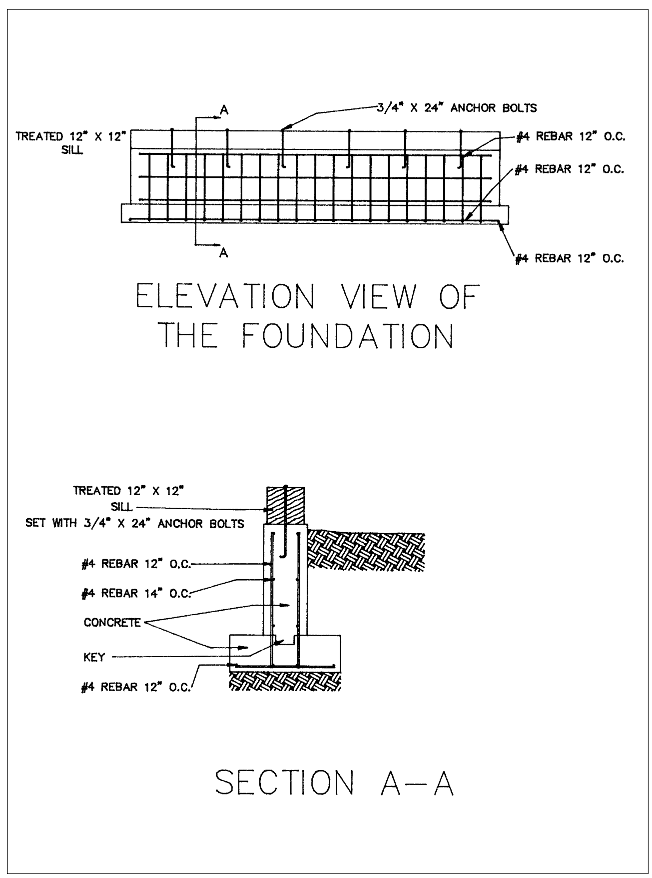


Figure 6. Simplified sketch of a typical foundation of the White Mountain National Forest suspension bridges. *Diagram courtesy of White Mountain National Forest Engineering Staff.*

The Pochuck Quagmire Bridge "Snowshoe" Foundation

The first step in the Pochuck Quagmire Bridge foundation design was to identify the allowable bearing capacity of the silt, clay, and muck soil horizons. The sub-surface investigation outlined on page 23 resulted in the project engineer utilizing a conservative bearing capacity of 500 PSF for the silt horizon. This 500 PSF was then adjusted for the weight of the concrete footing, soil backfill, and a foot of snow. The final allowable bearing capacity used in the sizing of the combined reinforced concrete spread footing was 123 PSF. Just as important as the allowable bearing capacity was the elevation at which the footing was constructed. The footing was constructed 4 feet below grade for the following reasons:

- Proper protection against frost heave.
- The footing was placed below the normal seasonal water level so as to account for the susceptibility of clay to swell and shrink with variations in water content.
- It was very important to resist the temptation to "go deeper." By keeping the underside of the foundation 3 to 4 feet above the muck horizon, the design took advantage of the recognized principle that loads spread out at 30° below a spread foundation. This resulted in a design load of 78 PSF on weak organic muck layer at 8 feet.

The reinforced concrete footing itself was designed and constructed in accordance with "ACI 318-83, The Building Code Requirements for Reinforced Concrete" and BOCA®. Two foundation elements were added to provide additional protection against settlement, overturning, lateral stability, and buoyancy. A Chance® Helical Pier was screwed in at each of the four corners into the bearing sand layer. This is shown in profile view on Plan Sheet 1 and photo 40 (page 39). Tensar® UX-1400 Geogrid was extended out 8 feet in all four directions from the concrete footing. These elements will be discussed further later in this text.

From a strict structural strength perspective, a 4-inch thick concrete slab spread footing would have been sufficient. However, the cover and dimension requirements of ACI and BOCA® codes determined that the footing slab be a minimum of 9 1/2-inches thick. This provided the 3-inch cover to earth (crushed stone on the underside) and provided the 6 inches of concrete to the top of rebar required by BOCA®. The design specified that the footing thickness be no more than necessary for the normal Pochuck Quagmire conditions — conditions that may have required the concrete be hand-carried in, hand mixed, floated, or helicoptered to the site. For similar reasons, the design specified epoxy coated rebar, just in case quagmire working conditions called for a reduction in concrete quantity. Epoxy coated rebar with 3 inches of top concrete cover, followed with a good quality bituminous waterproof coating could be justified. The 100-year drought conditions of the 1995 summer made these design precautions unnecessary. Subsequent to access road preparation by the Trail Conference volunteers, it was possible to drive loaded concrete trucks to the east side of Pochuck Creek. This was difficult even under the drought conditions. BOCA® requires a minimum of 2,500 PSI concrete for buried footings and 4,000 PSI for concrete exposed to the elements. While the majority of the concrete work is buried, the "concrete collars," shown in photos 31 and 32 (page 34), extend 2 feet above grade, so 4,000 PSI concrete was used.

After the transmission poles were securely cross-braced to one another, guyed in all four directions, and the platform joists in place, it was safe to start the foundation excavation. The towers were secure for the volunteer labor force to work under. Photos 16 and 17, on page 29, show two views of the east tower, before and during the tower excavation.

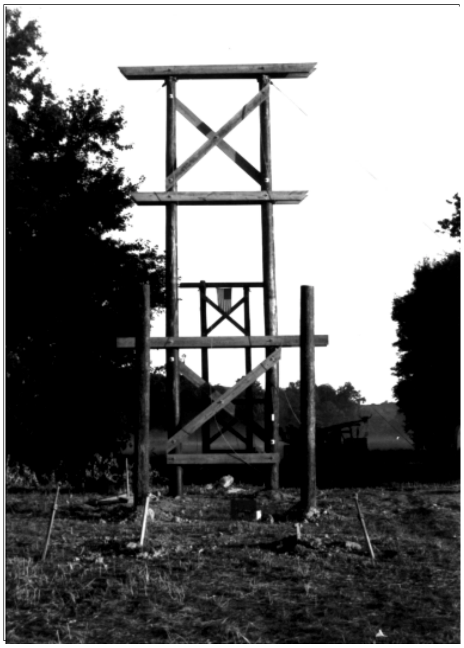


Photo 16. View looking through the east tower at west tower before foundation excavation. *Photo courtesy of Mr. Tibor Latincsics.*

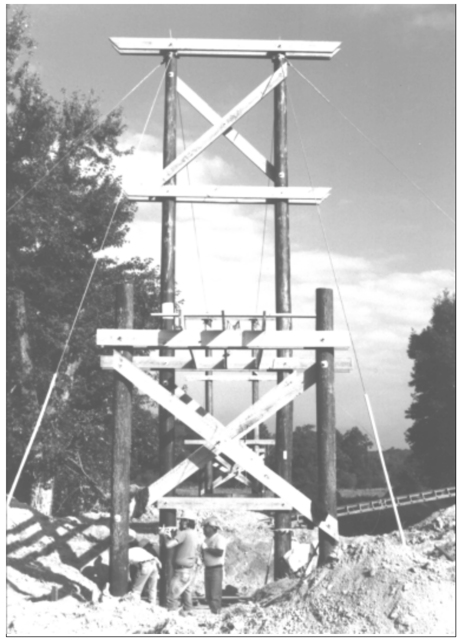


Photo 17. Same view as photo 16, but during foundation excavation. Note joist bracing and guylines. *Photo courtesy of Mr. Tibor Latincsics.*

Photos 18-20 indicate the good fortune that the driest August in 100 years in New Jersey brought to this project. Compare photo 18 to photo 1a on page 4, which is more typical of the Pochuck Quagmire conditions. The two photos were taken six weeks apart. The silt was excavated down 4 feet, 6 inches by the enthusiastic NY-NJ Trail Conference volunteers. Since the poles were embedded a minimum of 6 feet below grade, this provided an 18-inch toe-hold for the guyed and braced poles.

The next step in the Pochuck Quagmire Bridge construction, as indicated in photos 19 and 20, was to drill the base of the poles and slide a #18 rebar (2 1/4-inch diameter) through the base of the poles. This is the first element of the connection between the SYP poles and the "snowshoe" footing. As indicated on the plans, and very clearly in the photos, it is a simple, but foolproof bearing connection. A #18 rebar has a 2 1/4-inch diameter. When threaded through the minimum 13-inch butt diameter of a #1 transmission pole, there is a minimum of 29 1/4-square inches of bearing surface on a flat plane between the steel and timber. On the circular cross-section of the #18 rebar, there would be 45.9-square inches. Using the allowable 900 PSI compression parallel to the grain of #1 transmission poles results in an allowable bearing connection of 26,325 pounds. The axial load of each pole under full dead and live loads is 26,990 pounds. However, the Pochuck poles were oversized and had ellipsoid butts. This provided a bearing length of 18 to 21 inches on the rebar, or up to 42,525 pounds per pole.

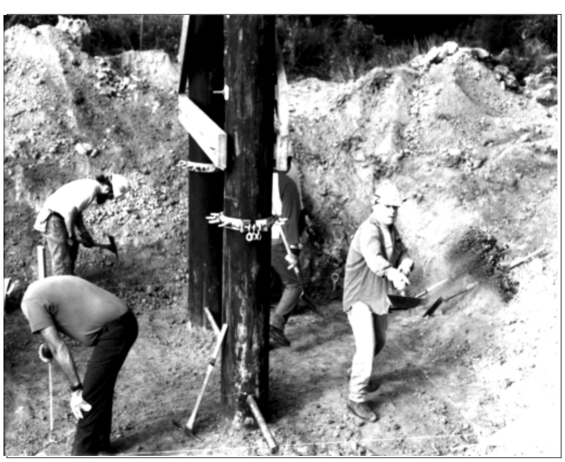


Photo 18. Bob Jonas and other volunteers excavating for the 12-foot by 16-foot "snowshoe" foundation. *Photo courtesy of Mr. Tibor Latincsics.*

Another important foundation connection task went on concurrently with threading the butt rebars. In photographs 18 and 19, one will see 1 1/2-inch square galvanized steel shafts terminating in oval eyes. These are the tops of the Chance® Helical Anchors. These will be discussed in greater detail later in this case study. At this point, it is sufficient to point out that these rod tops needed to be cut to the correct elevation so that the centerline of the oval eye lined up with the underside of the #18 rebar and was at least 4 inches above the future crushed stone (or six inches above the earth excavation). This is exactly what the volunteer in the lower left of photo 18 is measuring. The over length rods were measured, and the top two sections were disconnected and taken to a machine shop to be cut and drilled. At the same time several coats

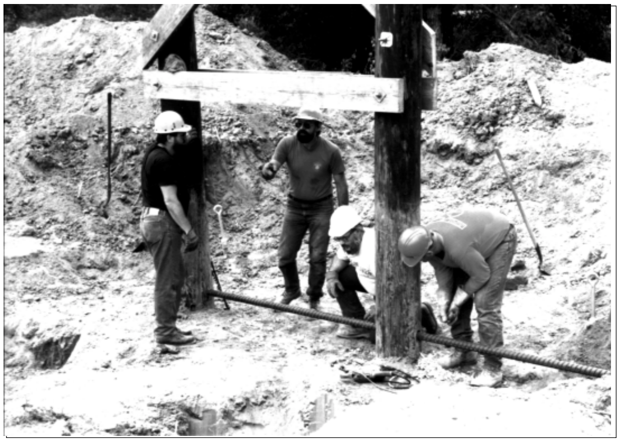


Photo 19. Wes Powers and Walt Palmer (center) and others threading the #18 rebar through the base of the poles. *Photo courtesy of Mr. Tibor Latincsics.*

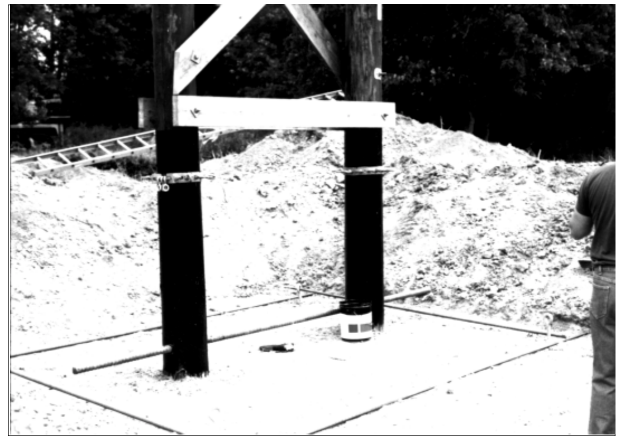


Photo 20. Bituminous waterproofing, rebar, universal bands, the start of the snowshoe. *Photo courtesy of Mr. Tibor Latincsics.*

of bituminous foundation water proofing were placed on the portions of the poles that would be either below grade or encased in concrete. This is an extra measure of protection on top of the pentachlorophenal preservative. After the bituminous was spread, the pole bands were installed. This is another example of an adaptive use of standard transmission line hardware used in this project. This good idea was a contribution by Mr. Pete Morrissey, a volunteer from GPU Energy, with professional expertise as a lineman foreman. The utility of the pole bands will become clear in later photos. Photo 20 shows the base of the tower poles prepared for the addition of the "snowshoe" foundation.

The next step was to place 4 inches of 3/4-inch size crushed stone at the base of the foundation excavation. This was done for several reasons; they are as follows:

- Using crushed stone to improve the bearing capacity of the subgrade by distributing loads to the subgrade has been a construction technique since the Romans.
- As shown in photo 18, the 100-year drought made for ideal excavation conditions. A "wet-sloppy" excavation normally would have been encountered in this location. The crushed stone stabilized the bottom of the excavation to provide a good working area. If excessive groundwater was encountered, the crushed stone would provide a medium from which to pump.
- While sufficient cover was provided, the 4 inches of crushed stone provided another precaution against frost heave.
- The time required to transport the concrete to this remote location dictated that the concrete may require a retardant. Concrete is made up of portland cement, sand, aggregates, and water. Any additional water beyond a specific amount results in a reduction in concrete strength. Excess water is able to drain into the voids between the crushed stone. This would shorten the curing time and improve the strength of the concrete.

Photo 21. Students from St. Benedicts Prep School and others. Top row (left to right) - William Stoltzfus, Barry Beaver, Paul Bell, Matt Higgens, Doug Hinkel, Jim Scholts, Jose Rosado, Walt Palmer, Jose Suarez. Bottom row (left to right) – Mike Friedman, Paul DeCoste, Hector Vasquez, David Rodriquez, Tibor Latincsics. *Photo courtesy of Ms. Anne Lutkenhouse.*

The students from Saint Benedicts Prep School of Newark, New Jersey, photo 21, deserve kudos for transporting the crushed stone to the west tower across the Pochuck Creek by bucket brigade.

Next the rebar (steel reinforced bars) grid was laid out, as shown in photos 22-30. The reinforced concrete "snowshoe" was designed as a 2-way reinforced slab in accordance with ACI code. The wood transmission poles were treated no differently than concrete columns. A live load factor of 1.7 and dead load factor of 1.4 was used for the design of the concrete collars and concrete foundation. The design checked for the "punching shear load" on the critical column perimeter a distance of half the column diameter from the pole face. This was compared against the shear strength of the slab. One-way beam shear was checked. The design includes a check for the bending moment at the face of each pole due to the upward soil pressure. The design met or exceeded the minimum shrinkage, temperature, and flexural reinforcement requirements of the ACI code.

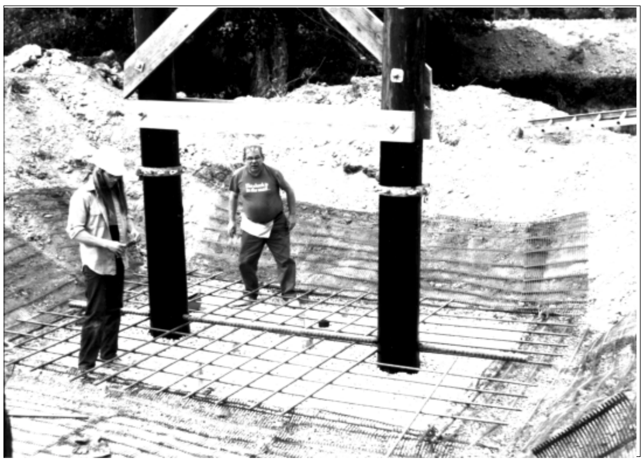


Photo 22. Crushed stone, 2-way rebar, and geogrid components. Jim Scholts and Paul Bell wiring the rebar in place. *Photo courtesy of Mr. Tibor Latincsics.*

All these requirements resulted in 2-way reinforcement of #6 rebar, with #8 rebar at the ends. This is specified on Plan Sheet 1 and the detail on Plan Sheet 5. Photos 22-30 indicate the layout and installation of the rebar grid as well as the Tensar® UX-1400 geogrid.

Photo 23. 2-way #6 rebar is under the #18 rebar. *Photo courtesy of Mr. Tibor Latincsics.*

As indicated in photos 22 and 23, the 2-way rebar lattice was installed under the #18 rebar. The theory here is very simple. The dead and live load of the bridge would be supported by the towers, which in turn bear on the #18 rebar, which distributes the load to the rebar lattice and concrete slab, which distributes the load to the soil. The rebar was placed so that there would be 3 inches of concrete cover from the underside of the #8 perimeter bars and 3 inches of cover atop the #18 rebar. This corresponded to a minimum slab thickness of 9 1/2 inches. As the drought conditions made the concrete transport easier, the slab thickness was increased to 12 inches. This additional concrete cover on the rebar allowed substitution of standard uncoated rebar in lieu of the epoxy coated rebar originally specified. This saved money, as well as time, for the epoxy rebar would have been a special order. At this point in time, the work force knew the fall hurricane season was on its way, and time was a precious commodity. The rebar is 60 kips per inch (KSI) (1 kip is equal to 1,000 pounds). As shown in photos 22 and 24, the rebar was wired to ensure proper placement.

Photo 24. Rebar was wired into place. *Photo courtesy of Mr. Tibor Latincsics.*

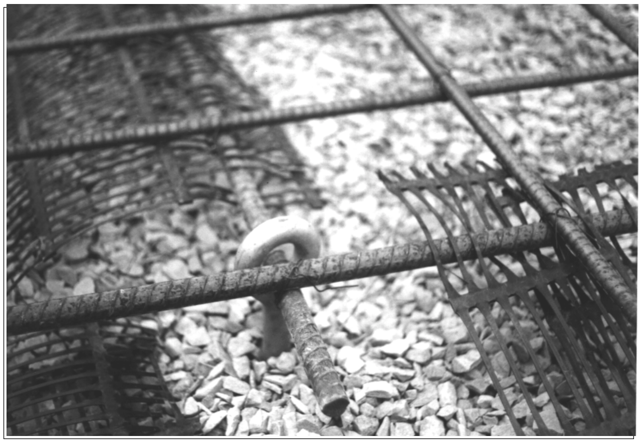


Photo 25. Foolproof connection between the Chance® Helical Piers and rebar. *Photo courtesy of Mr. Tibor Latincsics.*

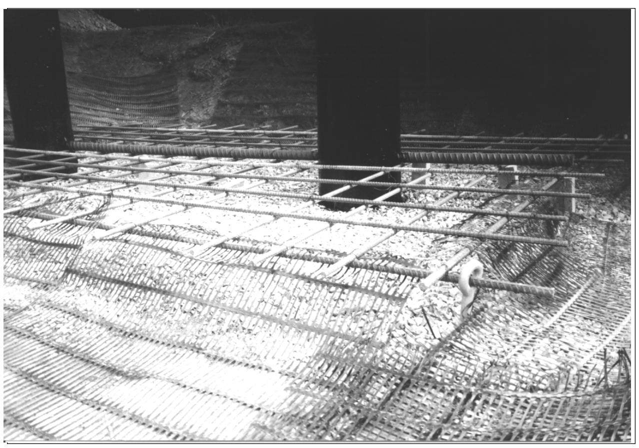


Photo 26. "Bobkin" connection between Tensar ® UX-1400 geogrid and perimeter #8 rebar. *Photo courtesy of Mr. Bob Jonas.*

Photo 28. Charles McCurry (center) of the NJ State Park Service checking that the vertical dowel bars were threaded through the universal band. *Photo courtesy of Mr. Stephen Klein, Jr.*

Indicated in photos 25 and 26 are the simple foolproof connections of the rebar to the Chance® Helical Anchors and geogrid. The #8 perimeter rebar was threaded through the eye of the Chance® 1 1/2-inch square shaft oval eye. When encased in concrete, this provided a good connection to the Helical Pier anchors, which extend down 20 to 32 feet into the bearing sand horizons. This addressed settlement of the snowshoe as well as overturning. The #8 perimeter rebar also supported the 2-way #6 rebar lattice until the concrete cured. The photos also show the "bobkin" connection between the geogrid and #8 rebar. The rebar is threaded through the grid of the Tensar® UX-1400 Geogrid. By interlocking with the soil backfill, the geogrid provides lateral stability and additional protection against overturning and settlement. As shown in photo 27, the geogrid also provides a connection between the main tower foundation and the platform pole foundation. The Tensar® UX-1400 Geogrid provided an easy method to expand the 12-foot by 16-foot concrete foundation to an effective 28-foot by 32-foot footprint.

Photo 27. Judy Babcock of the NJ State Park Service installing the geogrid connection between tower and platform pole foundations. *Photo courtesy of Mr. Stephen Klein, Jr.*

As indicated in photos 28-30, a number of galvanized lag screws and ribbed spikes were used to enhance the skin friction and interlock between the poles and the concrete collars. The concrete-timber connection was further secured by using a Joslyn Universal Pole Band to connect the vertical #5 dowel bars to the timber pole. ACI code requires that in a slab-column connection, 90° dowel bars

Photo 29. Formwork was installed for the concrete pour. *Photo courtesy of Mr. Stephen Klein, Jr.*

equivalent to 1/2 percent of the column area be utilized. This standard was far exceeded by utilizing up to 15 #5 dowels on each pole. As in the other cases, these connections were simple, conservative adaptations of ACI and AITC code utilizing readily available material. The connection between the pole and snowshoe foundation is comprised of the following components:

- Direct bearing and interconnection on #18 rebar.
- Skin friction between the pole and concrete.
- Connection between the pole and vertical dowel bars.
- Interlock between the concrete and timber by means of galvanized lag screws and spikes driven half way into the pole.

The great idea of using a universal pole band was provided by Mr. Morrissey. He also supplied and installed the universal bands. Normally pole bands are used for guyline and spararm purposes on transmission poles. In this case, the pole band was mounted on the pole and secured with spikes. The universal band itself provided another bearing and friction connection between the pole and concrete. Galvanized bolts connected female oval eyenuts to the pole band, through which #5 rebar was threaded. The #5 rebar was bent onsite. As shown in photo 30, the dowel bars were wired to the top of the two-way lattice of #6 rebar. Close examination of photo 30 shows the start of the #3 rebar used to wrap the vertical dowel rebar. The vertical bars were subsequently wrapped with #3 rebar and 6-inch by 6-inch wire fabric.

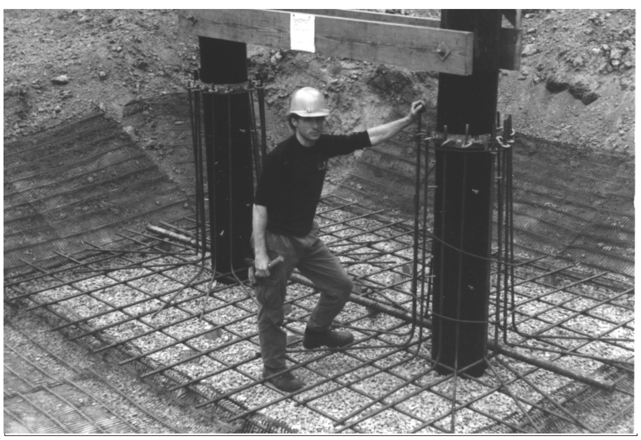


Photo 30. Crushed stone, helical piers, #18 rebar, 2-way #6 rebar, geogrid, #5 90^0 dowel bars, spikes, #3 rebar wrap, and project engineer. *Photo courtesy of Mr. Tibor Latincsics.*

While all this may seem like overkill, it provides a good connection between the dissimilar material of timber and concrete. Both timber and concrete expand and contract in response to temperature and moisture changes. A major concern of the project engineer initially was to ensure that the transmission poles do not "slip through" the concrete as the poles dry out and shrink with age. The threaded #18 rebar is a bomb-proof precaution against this occurring. In actuality, the opposite became a concern because of the drought conditions experienced during construction. The air-dried poles were going into dry soil that soon would be saturated by the normal Pochuck Quagmire flooding. The exposed end grain of the pole butts could provide a route for the moisture to expand the poles. The end grain should have been sealed with bituminous waterproofing and a plastic bag, but the tower erection went so fast that this detail was omitted. However, a counter action would address this concern; this will be reviewed later.

Photo 30 shows all the primary components of the hybrid combined reinforced concrete shallow spread footing prior to placing the 4,000 PSI concrete.

The "Snowshoe"

The snowshoe is composed of the following:

- Compacted crushed stone.
- #18 rebar threaded through pole butts.
- Two-way lattice of #6 rebar, with perimeter #3 rebar.
- Chance® Helical Pier anchors with thimble eye ends.
- Tensar® UX-1400 Geogrid to #8 rebar.
- Bituminous waterproofing on poles.
- Spikes and lag screws set into poles.
- Universal pole band and #5 dowel bar connection.

Photos 31 and 32 show the foundation after the 4,000 PSI concrete was placed, but prior to backfill. Three-foot diameter sonotubes were used to form the circular concrete "collars" around the poles, dowels, and cable

Photo 31. Foundation after concrete had set, but before backfill. *Photo courtesy of Mr. Tibor Latincsics.*

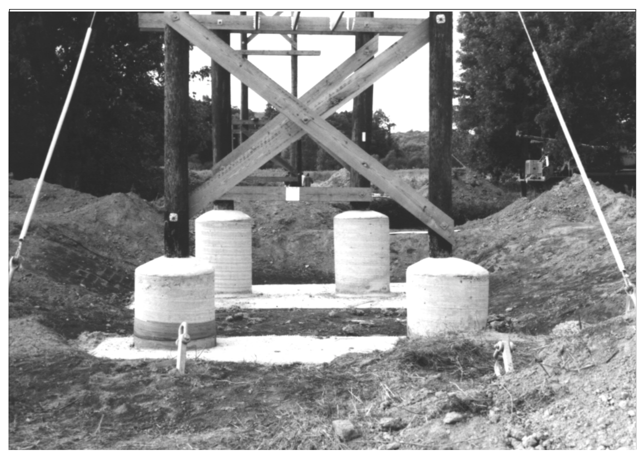


Photo 32. East foundation before backfill. *Photo courtesy of Mr. Tibor Latincsics.*

bands. The concrete was placed by the Mountainview correctional facility detail #11 work crew under the supervision of Mr.Wes Powers. The east tower was accessible by the concrete trucks. The concrete was pumped across the Pochuck Creek for the west foundation. Pea gravel was used for the concrete aggregate in lieu of the normal coarse aggregate to make the pumping easier. The rental cost of the concrete pumper was $635 as compared to the $960 value of the concrete it pumped.

As indicated on Plan Sheet 5 and in photos 31-33, the concrete "collar" about the tower poles was extended approximately 2 feet above finished grade and tapered so the top would drain. The concrete collar extension has several purposes. The first is structural. The taller the concrete collar extension, the shorter the Euler effective column length is. As previously discussed, the shorter the effective length is, the stronger a pole of a given cross-section is. There is also more area available for a mechanical, bearing, or friction connection between the pole and concrete. The concrete collar will also contribute to the durability of the poles by elevating the concrete-wood interface above the normal seasonal flood elevation of 395 feet. The transmission poles meet the American Wood Preservers Association (AWPA) standard C4 for preservative treated poles. The retention for pentachlorophenal treated poles is .38 pounds per cubic foot (PCF). It is generally recognized that such treatment can result in a useful field life of up to 50 years. The last 8 feet of the butt ends of the poles are treated to a higher level due to the incising. The upper portions of the poles will always quickly air dry. Raising the concrete collar-pole interface places the wood-concrete joint 2 feet above the ground line to limit moisture and allows the joint to air dry.

Adding to the durability of this critical location is a phenomenon well-documented by the following photograph. After treatment, transmission poles are stored on their sides. When the poles are installed in the vertical position, the excess pentachlorophenal solvent migrates down to the base of the poles. This is the discoloration on the concrete collar in photo 33. There are two perspectives to this, the first is "good — that is where the preservative will do the most good," which is true. This migration also keeps the pole base from shrinking as it dries. The second perspective is an environmental concern. The reader is referred to an excellent reference titled *"Best Management Practices for the Use of Treated Wood in the Aquatic Environments"* by the Western Wood Preservers Institute. This technical reference summarizes that the migration and leaching of preservatives into the aquatic environment is an environmental concern when there are large volumes of treated wood immersed in poorly circulating bodies of water, such as bulkhead lagoons. In the Pochuck Quagmire case, there are eight poles in the floodplain of a creek with a 93 square mile drainage area. This is a very small quantity of treated wood in a location of excessive run-off and circulation. Designers of future projects are advised to consider the aesthetic and environmental impacts of leaching preservatives. One obvious management practice is to store the poles in the vertical position prior to installation.

Photo 33. Tower pole and concrete collar connection. Note taper of concrete. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 33 also shows how the 3-inch by 10-inch cross members were positioned so that the "crest of the cup" is toward the spike grid. If the member continues to "cup," it shall only embed deeper into the spike grid.

Backstay Anchorages

A major problem that faced the project was how to secure the backstay of the catenary cables as well as the guylines. The backstay design tension load is when the bridge is fully loaded with 110 people weighing 180 pounds each (60 PSF) during a 30-inch snowstorm (18 PSF) is 23,455 pounds. This topic will be addressed in the cable design portion of this publication. It was determined that a safety factor of 3 against the full design live and dead loads, as is typical for foundation elements, would be appropriate for the anchorages. This would require 70,000 pounds of tension resistance for the backstays.

In normal situations, the backstay anchorages are enormous "deadmen" buried deep in the earth. This is true from colossal spans to simpler footbridges. The Brooklyn Bridge uses a deadman method originally developed by John Roebling for the Lackawaxen Bridge. John Roebling's Delaware River Aqueduct at Lackawaxen is the oldest suspension bridge in the country. Constructed in 1847, the bridge has been in continuous use since. The National Park Service purchased and renovated the bridge as a National Historic Landmark. It is located on the Delaware River, 30 miles upstream of Port Jervis, New York. The bridge has a total length of 535 feet over 4 spans. The bridge originally supported an aqueduct that carried the Delaware and Hudson Canal and its coal barge traffic high above the Delaware River. In 1900, it was converted to vehicular traffic. The bridge is a remarkable engineering achievement. It is in essence the prototype for Roebling's Brooklyn Bridge and many other suspension spans. This includes Japan's current world record Akashi Kaikyo Bridge that opened in April 1998 and has a center span of 6,532 feet and a total length of 12,829 feet. A 23-ton starburst-shaped anchor plate is at the bottom of each 60,000 ton masonry tower at either end of the Brooklyn Bridge. The two 60,023- ton anchorages are on either end of the 15.75-inch diameter cables that have an ultimate strength of 12,310 tons. The USDA Forest Service pedestrian suspension bridges listed in the author's inventory all utilize backstay anchorages made up of large blocks of reinforced concrete set into the riverbank. The Clarendon Gorge Appalachian Trail Bridge in Vermont is another example of the use of concrete deadmen. Five feet cubed appears to be the typical deadman dimension, weighing 15,625 pounds or 7.8 tons. The dead weight capacity of the concrete blocks can be increased by burying the concrete blocks so they act as a soil anchor. In such a case, the capacity of the deadmen are increased by the "cone of earth" identified by rotating a diverging line around the area of the anchor. The capacity of the deadman is the weight of the deadman, plus the weight of the cone of earth, plus the friction along the sides of the cone. The flare of the cone is equal to the angle of internal friction of the soil. It is important that the "cone" be undisturbed soil. Groundwater levels must be accounted for. The weight of the cone must be checked against the bearing capacity of the soil over the surface area of the deadman that acts against soil. The smaller of the two shall be the capacity of the deadman.

Archimedes' principle, site access, environmental concerns, and the project budget effectively eliminated the common concrete block backstay deadmen anchorages for the Pochuck Quagmire Bridge. Archimedes' principle is perhaps the most interesting. The principle states that when an object is immersed in water, the buoyant force on the object is equivalent to the volume of water the object displaces multiplied by the unit weight of water at 62.4 PCF. As the concrete backstay anchorages are located in a floodplain that may be immersed for months at a time, the design could credit only 50 percent of the concrete unit weight of 125 PCF to counteract the backstay loads.

Utilizing a safety factor of 3, the four backstay anchors required a cumulative tension capacity of 283,200 pounds. Normally, this would be equivalent to the dead weight of 84 cubic yards (CY) of reinforced concrete, but Archimedes' principle dictated that this be doubled to 168 CY. This much concrete would have cost $10,700 to purchase and transport to the site. Practical considerations were as follows:

- Even with the 1995 drought conditions, transporting 16 loaded concrete trucks across the quagmire would have been very difficult. Access and road preparation costs would have increased. In a normal year, it would have been impossible. Environmental impacts would have been much greater. Helicopters were investigated, but practical, budget, and safety considerations eliminated that option.

- The labor to excavate, form, place steel rebar, and pour concrete deadmen would have been significant. The concrete would have had to been pumped to the west side at an approximate cost of $3,300. Taking all elements into consideration, the concrete anchorages would have cost $20,000.

- The silt, clay, and organic muck subsoils may not have supported the large block concrete deadmen. If the concrete deadmen settled an excessive amount, the catenary cables would be negatively impacted.

A more cost-effective, practical, and environmentally sensitive solution needed to be found.

Helical Anchors — The Solution

Mr. Morrissey of GPU Energy provided a solution to the problem. During one of the innumerable site inspections, Mr. Morrissey suggested that the project partners consider using screwed helical anchors for the backstay anchors. Furthermore, if found to be appropriate from an engineering perspective, he volunteered to provide the experienced workers and specialized equipment needed to install the helical anchors. While the tower construction by GPU Energy is much more visually impressive, the helical anchor solution and installation to serve as the backstay anchors were a more significant contribution to the project. The helical anchors were essentially a dream come true for the project. This is another example where utility company practices were incorporated into the design and implementation of the project.

Helical anchors are known as Power Installed Screw Anchors (PISA®). A leader in this technology is the Chance® Company, 210 North Allen Street, Centralia, MO 65240; Phone: 314-682-8414. Chance® has been manufacturing soil anchors for 80 years. There are literally millions of field applications in place. While historically associated with electric transmission lines, the anchors are used in a variety of ways, including retaining wall tiebacks, moorings, street light foundations, pipeline supports, foundation support and underpinning, and boardwalk supports. The usefulness of the technology is gaining recognition outside the transmission line industry. The BOCA® code now includes helical anchors.

The helical anchors can be classified in two general categories. The first category is are power installed screw anchors that provide an anchor to resist a tension load, such as the backstay anchorages on the Pochuck Quagmire Bridge. The second category is helical pier anchors that transmit an axial load to a bearing stratum much like a concrete pier or a pile. Within each category of anchors, there is flexibility in the size of the shaft, diameter, and number of helices. The type of end attachments is also versatile, which allows one to customize the technology to specific needs. The Pochuck Quagmire Bridge utilized the Chance® Helical Pier system as a component of the snowshoe foundation. Photo 34 shows the author holding one-half of the six helix anchors (1.75-inch square shaft screw anchors) used for the backstay anchors. The six helix backstay anchors are detailed on Plan Sheet 7 and in Figure 7.

Photo 34. Tibor Latincsics holding one-half of the Chance® six helix square shaft screw anchor. *Photo courtesy of Mr. Tibor Latincsics.*

The design theory behind both the tension screw anchors and the compression helical piers is called the bearing capacity method. The capacity of the anchor is equal to the sum of the bearing capacities of the individual helices. Each helix bearing capacity is dependent on the unit bearing capacity of the soil stratum it is driven to. Chance® provides a good deal of technical engineering support, and the reader is advised to contact Chance® directly. Among the information Chance® provides are design tabulations, which allow one to relate anchor bearing capacity to standard penetration test blow counts for both cohesive and non-cohesive soils. Such design aids allow one to rough out a concept design prior to spending the time and money on more detail.

The beauty of helical anchors is that they allow one to easily screw through unsuitable soil horizons and install bearing helices into suitable soil. The system works well in environmentally sensitive and inaccessible sites, such as the Pochuck Quagmire. Exploratory soil borings for the Pochuck Quagmire Bridge site indicated that the bearing sand layer was overlain with at least 15 feet of unsuitable muck, organic silt, and clay. Photos 34-40 show how easily the Chance® Helical Pier system dealt with the problems.

Photo 35. Start of the helical anchor installation. *Photo courtesy of Mr. Stephen Klein, Jr.*

As shown in photo 35, a 30-inch deep pilot hole was augered. The location was surveyed and staked out in advance, so labor and machinery were not idle. Note that the GPU Energy drive rig has tracks that do not leave ruts as tire vehicles do. The angle of the gear shaft was adjustable and was set to the 43.3^0 backstay angle required by the design. Mr. Morrissey is preparing the shear pin torque indicator in the lower right of photo 35. The six helix anchor is attached to the rotating driveshaft by a kelly bar adapter and an anchor drive tool. This allows one to match the range of shaft sizes to a variety of installation equipment. Between the two is the shear pin torque indicator.

Photo 36. Pete Morrissey directing the helical anchor installation by Trail Conference and GPU Energy volunteers. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 37 shows the entire assembly and method of installation. The Chance® anchors have the benefit that there is a relationship between torque required to install an anchor and the anchor's capacity under load. There is no guess work associated with the installation. The "rule of thumb" is that a factor of 10 exists between installation torque and ultimate holding capacity. When the torque indicator shows the target level of resistance, the anchor has the target capacity. The Pochuck Quagmire Bridge backstays required 70,000 pounds of holding capacity in order to provide a 3:1 safety factor to the 23,000 pounds tension load in the primary cable under the full live load of 78 PSF over the bridge deck. This would be achieved when the torque indicator read 7,000 pounds. The six helix power installed screw anchors were installed to a shear pin torque indicator reading of 7,500 foot-pounds. It is recommended that pull-out load tests be performed for any installation involving public safety where feasible.

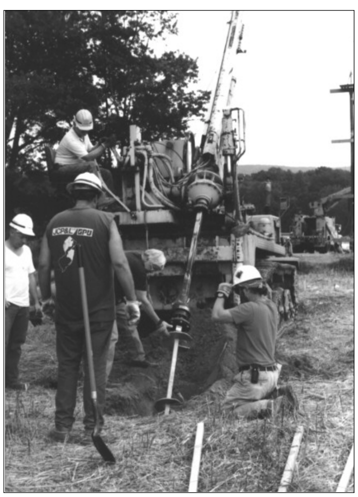


Photo 37. Drive rig, kelly bar adapter, and shear pin torque indicator all in line. *Photo courtesy of Mr. Tibor Latincsics.*

As the six helix anchor was advanced, extension rods had to be added. The extension rods are visible in photos 34, 37, and 40. They come in 5-, 7-, and 10-foot lengths and have male-female bolted couplings. Photo 39 shows Mr. Morrissey bolting a coupling between the two sections of the six helix anchor.

Based on the preconstruction soil borings, the 70,000 pound capacity should have been achieved at a shaft length-depth of 42 feet. The tabulation of the actual installed depths is listed on page 39 as well as shown on Figure 7, page 40, and on Plan Sheet 7 located in the back of this publication.

Photo 38. Helical anchors for the backstay anchorage were installed at 46 degrees. *Photo courtesy of Mr. Stephen Klein, Jr.*

Tabulation of Installed Depths

East Bank - North Pole	=	57’
East Bank - South Pole	=	48’-8”
West Bank - North Pole	=	34’
West Bank - South Pole	=	34’

Photo 40 shows the installation of the Chance® Helical Pier system, which would become an element of the snowshoe foundation for the towers. The single helix pier is in the foreground of the photo. The drivehead with torque indicator is in the center, and extension rods are to the rear. These extension rods terminate in the oval eyes shown in photos 25 and 26 (page 32).

Photo 39. Pete Morrissey bolting the coupling between the two halves of the six helix anchor. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 40. Installation of the Chance® Helical Pier at each corner of the snowshoe foundation. *Photo courtesy of Mr. Tibor Latincsics.*

Although not required for the upright tower construction, the advance installation of the foundation corner helical piers is a good example of how the construction schedule had to be flexible in order to adapt to the weather and availability of the volunteer workforce.

The Chance® screw anchors provided a fast, practical, economical, and environmentally-sound solution to the anchorage requirements of the cable backstays. The six helix anchors cost $2,170 in material. This compares well with the $10,700 in just material costs if concrete deadmen were utilized. Figure 7, on page 40, and Plan Sheet 7 is a diagram of the Helical Anchor.

Bridge Walkway — Stiffening Truss Railing Design and Construction

A design goal of modern suspension bridge design is to keep the roadway or walkway deck stiff or rigid. This provides for a stable walking or riding surface. This is normally done by incorporating stiffening trusses as part of the deck to suspender connections. The twin trusses act to distribute a concentrated load to several suspenders, which in turn distribute the load over a section of the catenary cable. This reduces oscillations in the deck. The trusses are also a component of the deck structural system and in this case, the safety rail system. To some extent, a suspension bridge is a truss bridge supported at intermediate panel points by the suspenders and catenary cables.

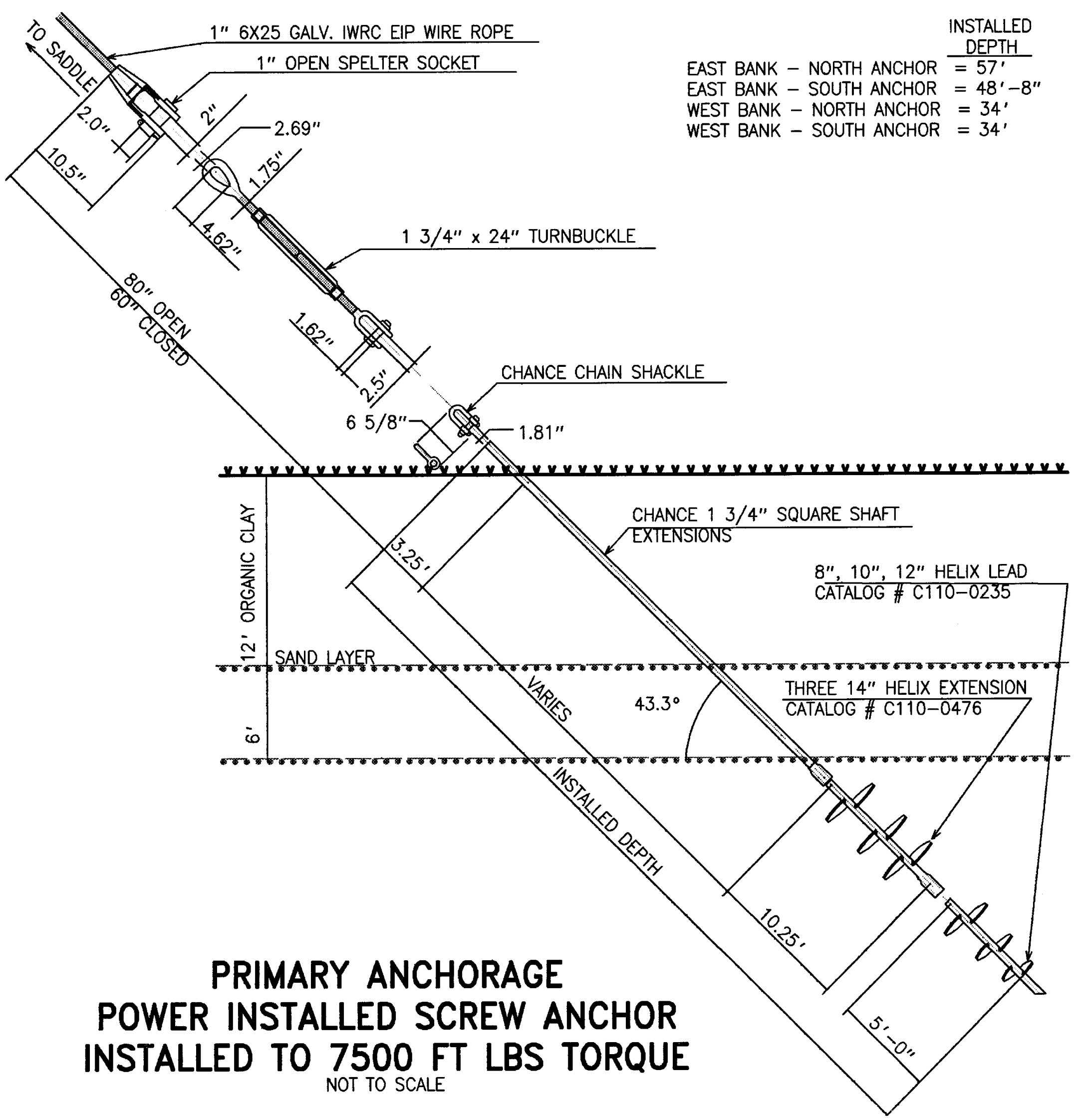


Figure 7. Helical Anchor diagram.

A defining trend in the evolution of suspension bridge design from Lackawaxen to Tacoma Narrows was to lighten and decrease the depth of both the towers and stiffening trusses, while increasing the span. Progress in engineering, materials, and construction techniques allowed this progression. The goals were both aesthetic and economic. Tall, slender towers accented by the curve of the catenary cables and suspender lacework resulted in a distinctive, pleasing structural profile. Lighter members also resulted in lower construction costs. This design trend terminated with the Tacoma Narrows Bridge failure on November 7, 1940. The first Tacoma Narrows Bridge was a 2,800-foot span suspension bridge over Puget Sound in Washington State. Its distinguishing feature was that its stiffening members were exceptionally shallow in order to provide a graceful architectural profile. On November 7, 1940, four months after it opened, the Tacoma Narrows Bridge self-destructed under a 44 mph wind. The spectacular oscillating-torsional death dance was captured on film. This film has been viewed by countless engineering and physics students for five decades. The destruction resulted in an examination of design principles for suspension bridges. The conclusions of the civil engineering profession were as follows:

- The Tacoma Narrows Bridge was a long, slender, shallow, lightweight, flexible bridge in an exposed position in a windy valley.
- The stiffening system was not a truss, but a solid plate girder. The floor was also solid. These two elements resulted in significant unanticipated aerodynamic forces.
- The configuration and dimensions of structural components can have significant aerodynamic impacts.

Several structural and aerodynamic design standards were redefined in the post Tacoma Narrows disaster analysis. The role of the stiffening trusses was expanded. The role of the stiffening trusses is to provide a rigid walkway and to distribute a concentrated point load over a section of the catenary cable. This load distribution is achieved by the multiple suspenders that connect each truss section to the catenary cable (see Plan Sheets 1 and 2). The importance of the stiffening trusses in aerodynamic stability was also defined. Some dimension design standards for the trusses were established. They are as follows:

- The depth of the stiffening trusses should be at least 1/180 of the span. The Pochuck Quagmire Bridge has 1/27.5 depth to span ratio.
- The spacing between the parallel trusses should not be less than 1/50 of the span. The Pochuck Quagmire Bridge truss spacing is 1/30 of the span.

Compared to the 31 east coast pedestrian suspension bridges inventoried by the author, only the Pochuck Quagmire Bridge has stiffening trusses. Information provided by the USDA Forest Service during the development of this case study indicates that stiffening trusses are common on USDA Forest Service pedestrian suspension bridges located in the western states. If a bridge is to have a rigid rail system for safety purposes, the rail can be constructed easily as a stiffening truss. The Pochuck Quagmire Bridge truss system was designed to be prefabricated off-site. As detailed on the plan sheets, the Pochuck Quagmire Bridge design laid out four standard 20-foot sections, a 15-foot center section, and two end sections, totaling 110 feet. The component sections were designed to be constructed with a minimum of cutting and waste. Each section had 64 pieces to be cut, fitted, drilled, and connected. The bridge walkway was designed to incorporate the premise that it would be constructed by Trail Conference volunteers in less than ideal conditions. For example, split ring or shear plates would have been a better connection than the through-bolts, but these were beyond the ability level of the volunteer work force. As indicated in photos 47 and 49 (page 43), the design made ample use of standard “Simpson” framing angles and hurricane ties.

The structural members of the walkway were designed for 60 PSF live load as per BOCA® Table 1606.1. This is consistent with general practice in 1995 for pedestrian bridges over 60 feet in length. The reader is advised that the 1997 AASHTO Guide Specifications provided in Appendix B would require 65 - 85 PSF today, depending on the walkway area. A snow load of 18 PSF was used. Identification of the dead load of the CCA .40 SYP dimension lumber took a little more time. Anyone who has worked with CCA lumber knows that it is significantly heavier than untreated lumber. In addition, the unit weight is variable dependent on the moisture content, grade, treater, and dimensions. Discussions with numerous suppliers and review of various technical references failed to identify a definitive CCA .40 SYP unit weight. The question was discussed at length with the Southern Forest Products Association. Estimates of the unit weight varied from 26-48 PCF. Reviewing the data available and weighing representative samples resulted in utilizing 38 PCF as the unit weight of CCA .40 SYP. The weight of each bridge element was identified. The dead load of the lumber elements of the walkway totaled 8,244 pounds or 16.4 PSF. Many engineers may have routinely assumed 10 PSF. The structural members were checked for compliance with the *"National Design Specification for Wood Construction,"* 1992, by the American Forest and Paper Association. Adjustment factors for duration of load and wet service were incorporated.

Photo 41. The very first "rib" of the truss walkway. *Photo courtesy of Mr. Paul DeCoste.*

Photo 43. Ribs, alternating portals, and inclined outriggers make up the first section. *Photo courtesy of Mr. Tibor Latincsics.*

The heart of the bridge walkway is the 6-inch by 6-inch cross-stringers to 4-inch by 6-inch "ribs" shown on Plan Sheet 2, in photo 41, and lower corner of photo 43. Photo 41 shows the placement of the very first rib in the prefab. These 21 ribs, each with spaced inclined "outrigger" bracing and alternating portals, provide transverse stability, the importance of which is highlighted by the Trout Brook Bridge collapse. The Trout Brook Bridge was a 40-foot Howe truss bridge on the Appalachian Trail in Sterling Forest,

Photo 42. Spaced chords were lined up with the spaced ribs. *Photo courtesy of Mr. Paul DeCoste.*

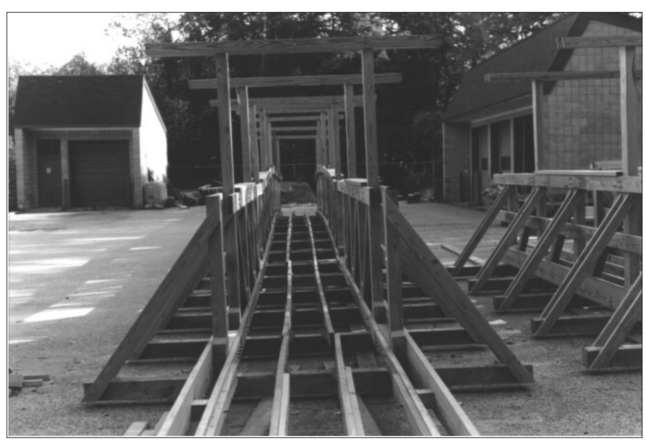


Photo 44. Entire walkway truss frame was prefabricated at Wawayanda State Park. *Photo courtesy of Mr. Stephen Klein, Jr.*

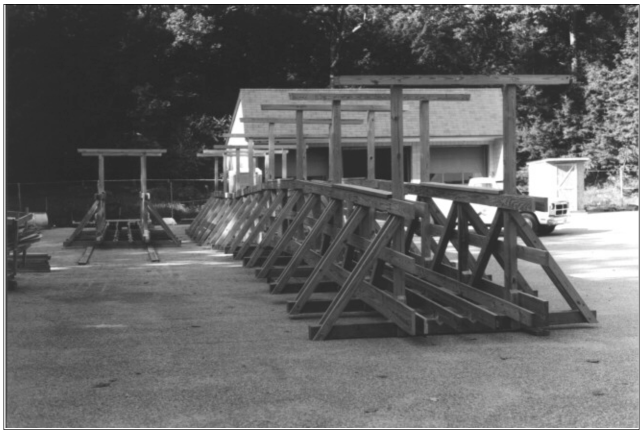


Photo 45. The east half of the bridge. *Photo courtesy of Mr. Stephen Klein, Jr.*

Photo 46. Using a car jack to set the bridge to a 3.5 percent slope it would assume in the air in order to fit joints correctly. *Photo courtesy of Mr. Bob Jonas.*

Photo 47. Bolts, lag screws, hurricane ties, and framing angles were used to make connections. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 48. Inclined outrigger supports. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 49. 2-inch by 6-inch joists atop the 6-inch by 6-inch stringers. *Photo courtesy of Mr. Tibor Latincsics.*

New York. It buckled sideways because of inadequate lateral bracing of the top compression chord, pulled off its abutments, and collapsed in 1993. Portals are not a common component of a bridge of this scale. The Pochuck Quagmire Bridge ribs were the first component prefabricated. The parallel chords and diagonals run from rib to rib to complete the truss. The parallel chords are spaced members that sandwich the vertical ribs, thus eliminating gusset plates. In addition, the horizontal members were spaced so that the 1992 AASHTO 2.7.1.2.4 pedestrian rail standard of 15-inch maximum spacing is met. This public safety element is extremely important. The truss siderails act as a stiffening structural member as well as a public safety element. Another clever dual-purpose component was the utilization of the lower outer 2-inch by 10-inch chord as the handicap toe curb for the walkway. The combination of the transverse ribs, portals, truss rail system of spaced members, framing angles, bolts, and screws resulted in an engineered structural system. While not necessary on simpler structures, #1 SYP CCA.40 KDAT 19% MC dimension lumber was specified for structural, dimension integrity, and dead load reasons.

The walkway cross section detail on Plan Sheet 2 provides the dimensions of the walkway. The clear inside dimension of 41 inches was chosen to allow one to install a handrail and still meet the 36-inch clearance required by ADA, and 41 inches is too narrow for snowmobiles and some all-terrain vehicles. The Appalachian Trail and this bridge is for foot traffic only. The guardrail system is 42 inches tall as required by BOCA®. The 7-foot, 3-inch headroom clearance is sufficient for most hikers, even those with tall extended toploaded backpacks. If one is designing a bridge for a multipurpose trail, be it mountain bikes, equestrian, or snowmobile use, these dimensions would have to be modified.

Photo 50. Fabricated bridge sections were trucked to the site by the NJ Forest Fire Service. *Photo courtesy of Mr. Tibor Latincsics.*

As indicated in photos 41-50, the entire bridge walkway, including the joint connections between each section, was prefabricated and assembled in the Wawayanda State Park maintenance yard. The structural integrity of the bridge sections was tested when they were dragged across the parking lot by backhoes. As shown in photo 46, the bridge walkway was set to the 3.5 percent camber it would assume in the air using car jacks in order to layout the joints for the center section. The bridge walkway sections were then loaded on trucks and delivered to the bridge site as indicated in photo 50. By this time it was October, and the hurricane season had commenced; site access had begun to deteriorate significantly.

The Project "Comes Together"

Many of the project volunteers found prefabrication of the walkway to be the most rewarding part of the project. At 8:00 a.m. on September 24,1995, 27 Trail Conference volunteers met at Wawayanda State Park. The #1 SYP CCA.40 KDAT 19% MC lumber was still in shipping bundles. Not a single volunteer knew the extent of the task before them. The project engineer explained the "big picture" and "micro-details." His explanations were met with glazed eyes and looks of disbelief. Specific tasks were given and work commenced. All of the volunteers were busy 110 percent of the time. Mr. Gene Bove, Mr. Tom Haas, and Mr. Rudy Haas are three professional carpenters from Vernon Township, New Jersey, who volunteered their time to help. Their professional knowledge helped streamline the carpentry tasks. By the end of the day, all 648 pieces of the bridge walkway were measured, cut, and drilled, and the first 20-foot section, as indicated in photo 43, was assembled. The volunteer work crew started to understand the big picture. The total of 400 person hours were required to prefabricate the truss walkway of the bridge. All components, with the exception of the metal Simpson connectors, were either bolted or screwed. This takes significantly more time than power nailing, but resulted in a superior and more durable end product.

Bridge Walkway Camber

As previously discussed and indicated on the plans and photographs, the bridge walkway has a 3.5 percent camber. While the camber does much for the visual aesthetics of the bridge, its first purpose is for practical reasons. The minimum recommended camber is 0.67 percent of the span. This is not noticeable by eye; the bridge will appear level. This will account for stretch in the catenary cable or elongation in the cable under high temperatures. Either condition could result in a “sag” in the walkway, if it was built level. The original design specified a 5 percent camber. This was revised when handicap accessibility became a design goal. ADA limits walkways to a maximum slope of 8 percent. If the slope is between 5 and 8 percent, intermediate level 5-foot long rest platforms are required every 30 feet. Constructing these on the bridge would have been difficult. Designing the camber at 3.5 percent eliminated the need for the intermediate level platforms. Using 3.5 percent also allowed for a margin of error in construction as well as assurance that the walkway slope would not exceed 5 percent even on the coldest days when the cables contract. The camber also plays a role in the interface between the bridge walkway and the tower platforms at either end. The camber results in a vertical load component that forces the walkway end to “sit down” on the platforms. This makes for a smooth ramp transition.

Cable Saddles

The catenary cables pass over the tops of the towers via the cable saddles, which are detailed on Plan Sheet 6, photo 51, and Figure 8. The saddles support the cable, change its direction, and in a perfect theoretical world would be a frictionless connection. This concept is important in the tower design. A frictionless saddle will transmit only axial loads to the tower, as opposed to a horizontal load that would result in bending moments. A column or pole is much stronger in axial compression than bending. Large bridges

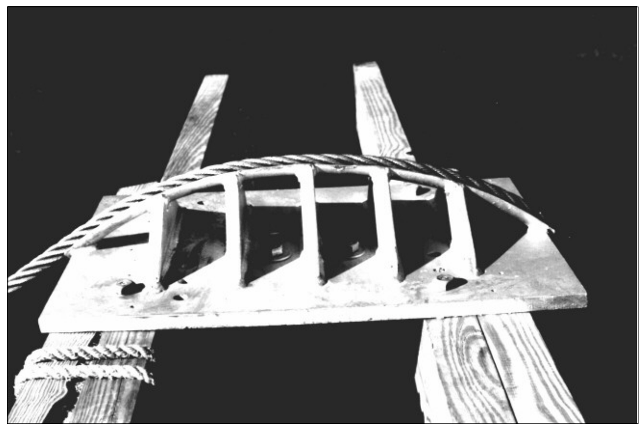


Photo 51. West tower - north pole cable saddle. *Photo courtesy of Mr. Tibor Latincsics.*

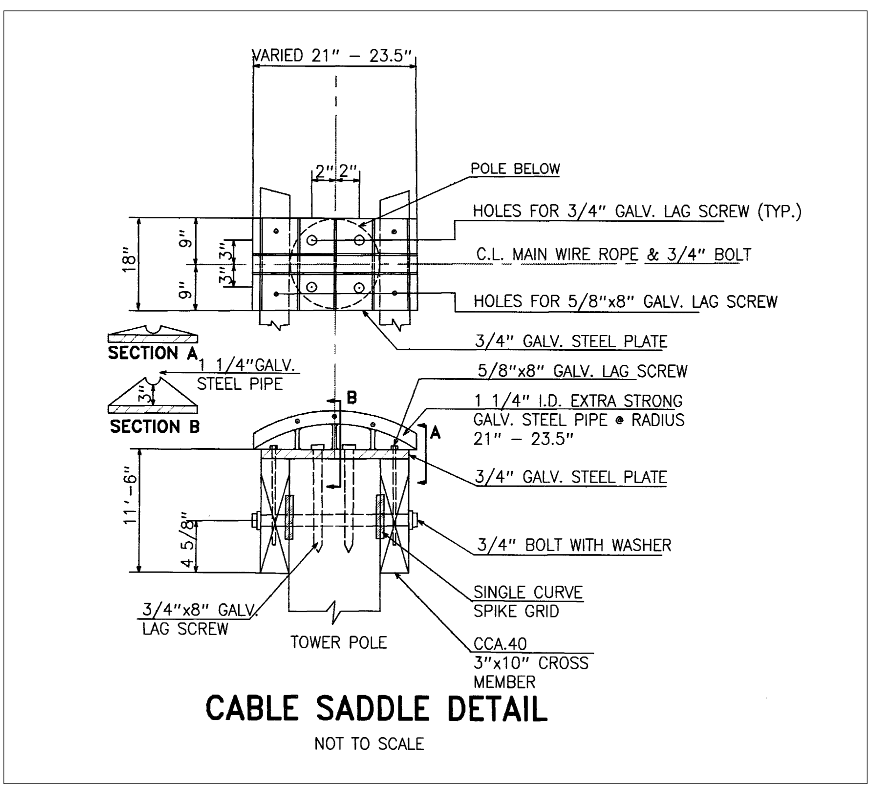


Figure 8. Cable saddle detail.

support their cable saddles on a nest of rollers. The original design concept for the Pochuck Quagmire Bridge envisioned a ball bearing axle mounted grooved sheave for the cable supports. The field inventory by the project engineer indicated that split pipe saddles utilized by the USDA Forest Service have a long history of adequate service. The cable saddle on the 1972 Tye River Bridge and the 1992 Kimberly Creek Bridge are identical. The cable saddles detailed in Figure 8 and photo 51 were substituted for mounted sheaves to simplify the design and installation. The saddles are made of 3/4-inch galvanized plate steel. A side benefit of the zinc plating is that it made the saddles very smooth, almost frictionless. Future project planners are advised that such custom galvanizing is expensive, but may be well worth it, because of less rusting of steel that is exposed to the weather.

An important design element of the cable saddles is to provide the proper bending radius for the type of wire rope being used. The minimum bending radius varies with wire rope diameter, type of steel wire in the rope, and the construction of the wire rope. A rule of thumb is that the bending radius should be 400-600 times the diameter of the outer wires of the outer strands of the wire rope. The minimum bending radius of 6 x 25 wire rope varies from 13 to 15 inches, with the larger the better. A bending radius of 21 inches was utilized for the Pochuck Quagmire Bridge saddles. The bending radius of the Pochuck Quagmire Bridge saddles meets the recommendations of the wire rope industry. Too small a bending radius subjects a wire rope to excessive bending stresses with the resultant fatigue of individual wires. The wires adjacent to the core of the rope are affected first. This condition is impossible to detect.

The bending radius of the saddle is also an important element in determining the radial pressure on the wire rope. The freebody figure of the towers on page 51 shows that for equilibrium to be achieved, the horizontal component of the loads in the catenary and backstay cables must be equal. The downward vertical component of the cable loads are counteracted or supported by the tower and foundation system. The bearing surface between the wire rope and the saddle must be of sufficient area so the radial pressure exerted does not exceed the allowable bearing of either material. In this application, the wire rope is the weaker of the two and becomes the determining design element. The radial pressure 6 x 25 wire rope is rated for one to two thousand PSI. Using the lower value required a bearing length of 22 inches for the Pochuck Quagmire Bridge. Twenty-five and a half inches or more of bearing surface was provided.

The last major element of the saddle design is the groove diameter or “seat” of the actual saddle. As shown in photo 51, a 1 1/4-inch extra strong steel pipe was cut in half and bent to the proper radius. The half pipe saddle keeps the wire rope in its proper location. It is important that the diameter of the groove or “seat” be only slightly larger than the diameter of the wire rope. Grooves that are too large do not provide the proper support the wire rope requires. If the wire rope is not properly supported, it may deform to an elliptical shape compromising the strength.

In summary, if the cable saddles do not have the proper bending radius, bearing surface, or groove diameter, the wire rope is negatively impacted. The full strength of the wire rope will not be available. From the field inventory, it appears that excluding the USDA Forest Service bridges, proper bending radius and bearing surface are often overlooked in trail bridge designs. These omissions are compensated for by the large number of safety factors utilized with wire rope. Another problem the inventory revealed is that in order to reduce the up and down oscillations of walkways, which do not have stiffening trusses, some bridge maintainers clamp the wire rope to the cable saddle. This is a very poor idea! This will transfer a horizontal overturning load to the bridge tower. In many cases, the towers may not have been designed for this loading.

Once the poles and cross arms were installed, the project engineer measured the final dimensions and provided customized shop drawings of the cable saddles for each individual pole top to R.S. Phillips Steel. The project was fortunate in that R.S. Phillips Steel, a well-known steel fabricator, is located in Vernon Township, New Jersey. The customized details for each non-uniform pole top ensured that the saddle fasteners lined-up with the center of the cross arms and quarter points of the poles as well as providing maximum bearing surface. As the pole heights varied in elevation by 2.4 inches from bank to bank, the project engineer designed the apex of all four saddles to match in elevation by varying the radius of the bent pipe saddle. The saddles were to be attached to the poles via 3/4-inch lag screws and 5/8-inch bolts. Once driven, there was no room for adjustment, given the bore and bite of such large connectors. In anticipation of this, the project engineer had #12 nail bore holes drilled into the saddles to allow the saddles to be tacked down, checked, and then the major fasteners driven.

The project engineer arrived 10 minutes after the stalwart volunteers started work on October 5, 1995, the night of the saddle installation. By that time, the energetic and enthusiastic volunteers had installed the east tower saddles, driving the major connections first. Unfortunately, they confused east and west and installed the west saddles on the east tower. This is an example of communication problems that can be expected in a complex project, for which all the planning and detailed plans cannot prevent. The end result is that the cable saddles vary in elevation by 5 inches from one side of the river to the other. This shifted the sag low point 2.5 inches from dead center. This is not visible by eye. The subsequent change in the suspender lengths was accommodated by the built-in adjustment capability. See the suspender detail on Plan Sheet 8 and photographs 58-61. To ensure a good connection of the saddles to the towers, the top cross arms were doubled up, and 5/8-inch through bolts into the cross-braces were substituted for the 5/8-inch lag screws. A profile view of the installation of the saddle on the west tower is shown in photo 51 (page 45).

Catenary Cable Geometry

When suspended between two supports, a uniformly loaded wire rope assumes the shape of a catenary curve. The specific shape of the catenary curve is established by the sag-span ratio. The sag-span is the ratio between the sag of the wire rope to the span between the supports. The dilemma facing bridge engineers is that the larger the sag for a given span and loading, the lower the tension load in the cable. However, the reduction in the cable tension load (or cable size) comes at the expense of taller towers. The benefit in reducing the cable diameter within the safety factor of 4 to 5 is not just the cost savings in the cable, but also the cost savings in the multiple suspender attachments. Economics is very much an element of good engineering. Structural-practical economic criteria place most bridge sag-span ratios in the 1/8 to 1/12 range. For example, the Bear Mountain Bridge sag-span is 1/8, the Brooklyn Bridge is 1/12.5, the George Washington Bridge is 1/10.75. The USDA Forest Service Bridges at Jackson River is 1/10.0 and the Pemigewasset River is 1/13.0. The Pochuck Quagmire Bridge has a high sag (17.75 feet) to span (110.20 feet) ratio of 1/6.2. This is beneficial and allowed the use of 1-inch wire rope for the design loading. In lightweight pedestrian bridges, excessive sag should be avoided because it can lead to excessive side sway in the bridge.

A combination of physical constraints established the sag-span ratio of the Pochuck Quagmire Bridge. They were as follows:

- Donated 40-foot long Class I SYP transmission poles.
- Required 6 feet embedment of the pole.
- 57-foot wide Pochuck Creek.
- 25-foot clearance to eroding banks.
- Clearance to the 100-year flood level.
- Minimum practical suspender length at the cable lowpoint.

Floodwater Clearance

The importance of adequate clearance to the 100-year flood level is critical. In New Jersey, the minimum standard for bridges is 1-foot clearance to the 100-year flood level. Subsequent to canoeing the Pochuck Creek several times, it became very evident to the project engineer that the Pochuck Creek has a chronic log jam problem. There are no less than 27 major log jams upstream and downstream of the Pochuck Quagmire Bridge. Some of these log jams are so extensive that they have developed their own ecosystems complete with soil and vegetation. These log jam dams also act to raise the flood levels by obstructing flow. It became obvious that a 1-foot clearance to floodwaters would be insufficient to pass floodwater carried debris, especially trees! The clearance to the 100-year flood level of the Pochuck Quagmire Bridge at the creek centerline is 6.68 feet and 4.5 feet at the platforms at either end. This is indicated on Plan Sheet 1. The walkway is approximately 12 feet above top of bank. Due to its location in a broad, level, open valley, the Pochuck Quagmire Bridge appears unusually elevated; however, it is not. The field inventory of similar structures showed that a 14-foot clearance to the normal water level was typical. However, most of the bridges are in narrow valleys where the steep side slopes make the bridge look diminutive. The Pochuck Quagmire Bridge only appears excessively elevated by virtue of its location in relation to visual landmarks.

The importance of proper floodwater clearance is emphasized. Floodwater driven debris is the most frequent factor in the destruction of such bridges. Suspension bridges are susceptible to floodwater damage as the strength of the bridge is parallel to the axis of the cables not with the direction of the river. The history of trail bridge destruction and associated deaths, which the author is aware of, due to floodwaters is lengthy. The following are known cases:

- 1973 Appalachian Trail Clarendon Gorge Suspension Bridge in Vermont destroyed - 1 death.
- 1973 Deerfield Creek Suspension Bridge in Vermont destroyed.
- 1973 Schoolhouse Road Suspension Bridge in Vermont destroyed (30 feet clear of river).
- 1995 Wilson Creek Suspension Bridge in North Carolina - 2 deaths.
- 1995 Hastings Trail Suspension Bridge, Wild River, WMNF in Maine, destroyed - $142,675 replacement cost.
- 1996 January 20th snow meltdown and ice jams damaged the Winooski Wonder Suspension Bridge and three other snowmobile suspension bridges in Vermont.

Proper clearance to floodwater is critical!

The Wilson Creek Bridge destruction is especially tragic. Wilson Creek is located in Caldwell County in western North Carolina. In mid-January of 1995, a Scout Troop from Atlanta, Georgia, was camping in Pisgah National Forest. Four to nine inches of rain fell over the weekend causing extensive flooding. Three scouts were crossing a private suspension bridge when the bridge dipped under their weight. The torrent tore the bridge from its foundation and swept two of the scouts to their death.

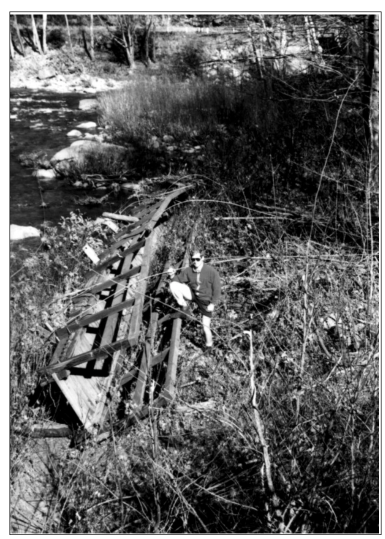


Photo 52. Tibor Latincsics and remains of the Hastings Trail Suspension Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

The Hastings Trail Bridge in White Mountain National Forest highlights the destructive power of floodwater driven debris. On October 22, 1995, Hurricane Opal dropped up to 10 inches of rain in Vermont and New Hampshire. The Wild River drains the eastern slope of the White

Photo 53. The timber towers were sheared at the base by floodwater driven debris. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 54. Hastings Bridge walkway remains flung downstream. *Photo courtesy of Mr. Tibor Latincsics.*

Mountains. In this case, the floodwaters picked up an old logging bridge and carried it downstream. The Hastings Trail Bridge was a 180-foot suspension bridge with a 17-foot clearance to the normal water level of the Wild River. However, the logging bridge snagged on the low hanging wind guys of the bridge. The impact force and hydrodynamic loads sheared the bridge towers at their base. Twenty-thousand pounds of buried concrete deadmen were plucked out of the soil and flung 200 feet downstream. Proper clearance to floodwater is critical!

The Hastings Creek Bridge was reconstructed in the Fall of 1997, to USDA Forest Service specifications. The new 180-foot bridge has a clear travel lane dimension of 5.5 feet to allow snowmobile traffic. There is a paved road directly to the site. The original tower foundations were reused. The replacement cost for the bridge superstructure by a professional contractor was $142,675.

Identifying the 100-Year Flood Level

Identification of the 100-year flood level can be made one of several ways. The project engineer investigated every option. Within the State of New Jersey, most major watercourses have had a hydrologic and hydraulic study performed by the NJDEP Flood Study Section. This was the first place to look to determine the 100-year flood level. Studied watercourses are known as delineated watercourses, and they have recognized 100-year flood levels. The Pochuck Creek is probably the largest non-delineated watercourse in New Jersey. There is no NJDEP recognized flood level data. The second step was to check the Federal Emergency Management Agency (FEMA) Flood Insurance maps. The Pochuck Creek is also an unstudied FEMA watercourse, although the FEMA maps indicated a 100-year flood elevation of 400 feet above sea level based on the highwater mark of floods dating to 1937. The Army Corps of Engineers did not have any specific flood data for the Pochuck Creek.

The last resort was to perform a Hydraulic Engineering Center-II (HEC) analysis. A downstream gauging station provided the stream flows for the 2-, 10-, 25-, and 100-year storms. The HEC-II computer analysis models stream flow through a channel and overbank reach as steady open channel flow. Among the results are the water surface elevation and velocity of flow. The project engineer performed this analysis to check if the 100-year flood elevation of 400 feet identified by the historical highwater marks was realistic. The results were very interesting. If one excluded the log jams in the HEC-II model, the 100-year flood level was much below elevation 400. With the log jams modeled, the flood level rose. The elevation of 400 feet was used as the design and regulatory standard.

The Main Cables – Catenary Cables

Thus far, the main cables have been referred to as catenary cables. For a cable to assume the shape of a catenary, the load on the cable must be uniformly distributed. Under the spaced suspender loading, the shape is closer to a parabola. The difference between the two is very slight. Since the equation for a parabola is easier to work with, most engineers use the parabola equation in the design of simple suspension bridges. Since this case study is presented as a planning document, not an engineering text, the author has refrained from including design equations. However presenting some basic wire rope equations for a single-span suspension bridge at this point has some value (see Figure 9).

- e = sag of catenary cable.
- ℓ = the span or horizontal distance from center of each cable saddle to opposite cable saddle. In the case of the Pochuck Quagmire Bridge, the as-built distance is 110.20 feet.
- W = the total live and dead load of the bridge expressed as load per unit length of span. Assumes backstays have no suspender loads.

Length of a uniformly loaded cable between two supports at equal elevation:

$$L = \ell\left(1+\left[\frac{8}{3}\right]e^2/\ell^2 - \left[32/5\right]e^4/\ell^4 + \left[\frac{256}{7}\right]\frac{e^6}{\ell^6}\right)$$

The maximum tension in the cable is immediately before the cable saddle:

$$T_{saddle} = \left[W/8e\right]\sqrt{l^4 + 16e^2\ell^2}$$

The minimum tension in the cable is at the midpoint sag lowpoint of the cable: $T_{Lowpoint} = w\ell^2/8e$

Tension at a given point B: $T_B = w/8e\sqrt{\ell^4 + 64e^2 - y^2}$

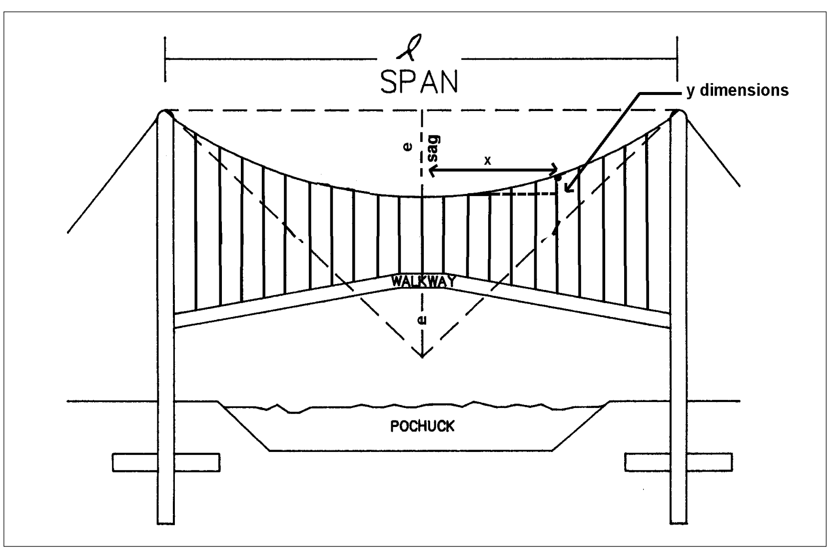
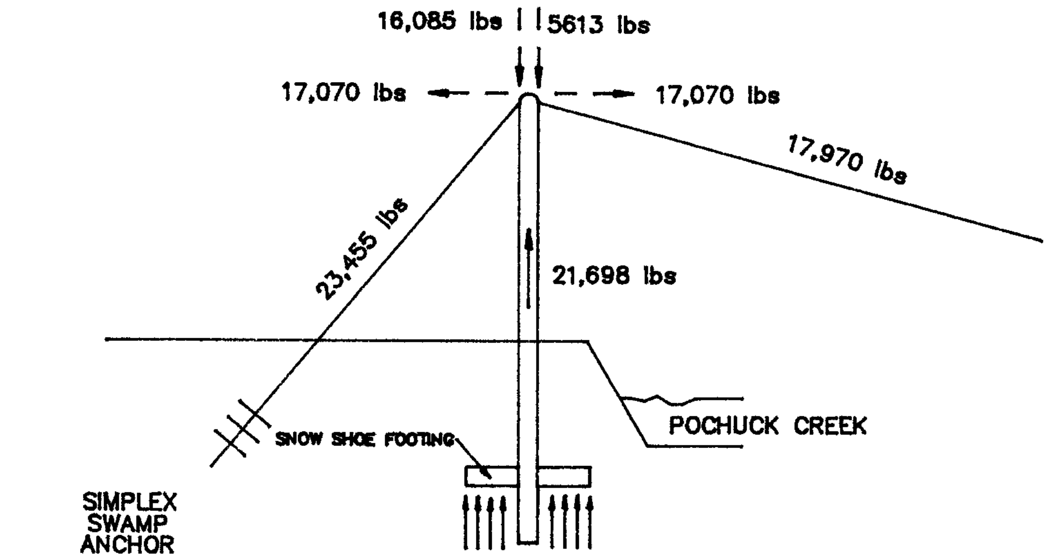
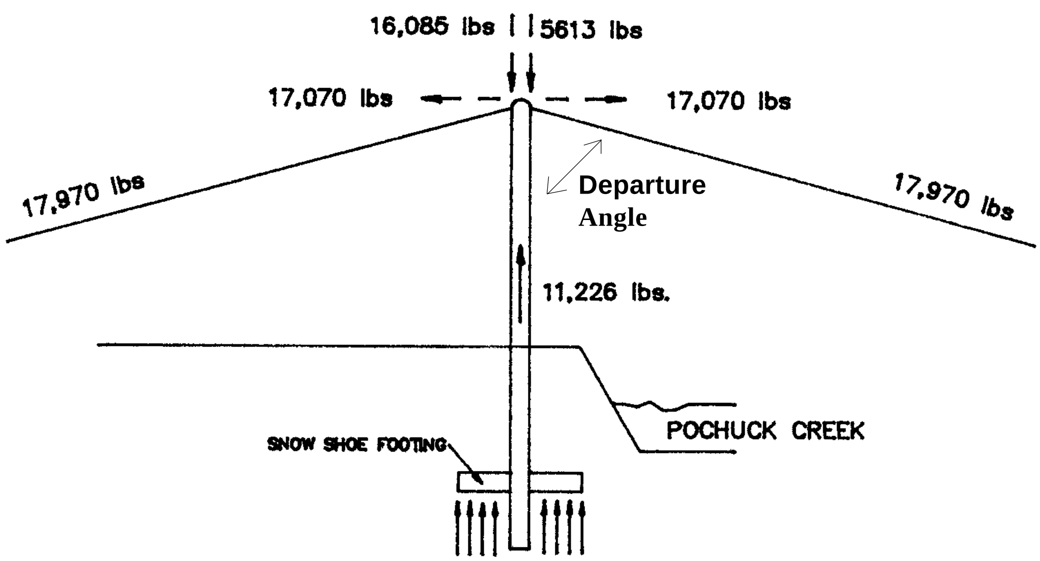


Figure 9. Nomenclature for wire rope equations.

Figure 10 provides freebody vector diagram for the Pochuck Quagmire Bridge cable saddles and tower tops. The identified loads were calculated utilizing the previous equations, bridge loads, and bridge dimensions. The freebody vector diagram illustrate the important design element, that where practical, the cable departure angle on either side of the cable saddle should be equal. Equilibrium is easier to obtain if the angles are equal. If the departure angles are not equal, additional loads are transferred to the backstay and tower. In the Pochuck Quagmire



As-built Freebody Diagram. Departure Angle of Catenary and Backstay angles differ.



Ideal configuration: Departure angle for Catenary and Backstay cables are equal.

Figure 10. The freebody diagram for the Pochuck Quagmire Bridge tower poles.

Bridge, the difference in the departure angle almost doubled the axial load on the poles. The unbalanced tension loads at the cable saddle times the friction coefficient of the saddles result in an overturning load on the towers. This overturning is counteracted by the tower foundation and guylines. Equal departure angles were not utilized on the Pochuck Quagmire Bridge because the poor subsurface soil conditions dictated that the six helix helical anchor be installed at 46°. An installation angle as shallow as 18.2° would have led to difficult installation problems with the helical anchors. Having equal departure angles is easier to attain when the riverbank topography rises up steeply as in a river gorge or when the sag-span ratio is high.

So far, the discussion has concerned the geometry of the wire rope in the vertical plane. The horizontal plane must also be considered. As defined on page 14, cradle and flare must also be considered. As shown by Figure 2 on page 15, the flare is the horizontal offset distance (or angle) between the straight line established by the cable saddles and the connection to the anchorages. A 1.5°-2.0° angle is recommended. The Pochuck Quagmire Bridge backstays have a 2° flare.

The backstay anchorage locations were originally staked out in advance by the survey crew of Conklin Associates. As often happens, the survey stakeout and offset stakes were knocked out during excavation. The only way to ensure the correct flare on short notice was to set up a transit on top of the east poles and to turn angles; this is shown in photo 3 (page 20). Not too often is a transit set up on top of a 34-foot tall transmission pole. The Pochuck Quagmire Bridge cable and suspenders do not have cradle. While it would be easy to vary the offset distance of the bore holes in the 6-inch by 6-inch cross-stringer to achieve cradle in the horizontal plane, this would conflict with the 3.5 percent (or 2 degrees) bevel cut that set the walkway slope. The Lincoln Woods Trail Bridge in WMNF, New Hampshire, is a good example of a suspension bridge with cradle.

The wire rope industry, as well as the Occupational Safety and Health Act (OSHA), recommend that a safety factor of 5 be utilized for wire rope installations. A more formal way of stating this is that the working load should not exceed 1/5 of the ultimate breaking strength. While this may seem high compared to other structural system safety factors, it is prudent. This large safety factor takes into consideration misuse, poor maintenance, and public safety. From a historical perspective, John Roebling specified a safety factor of 6 for the Brooklyn Bridge main cables. However, it was reduced to a safety factor 5. The Brooklyn Bridge, an American icon, carries traffic loads never envisioned by its designer 113 years later.

As shown by Figures 11 and 12, wire rope has a number of components. Individual wires are laid together to form a strand. A number of strands

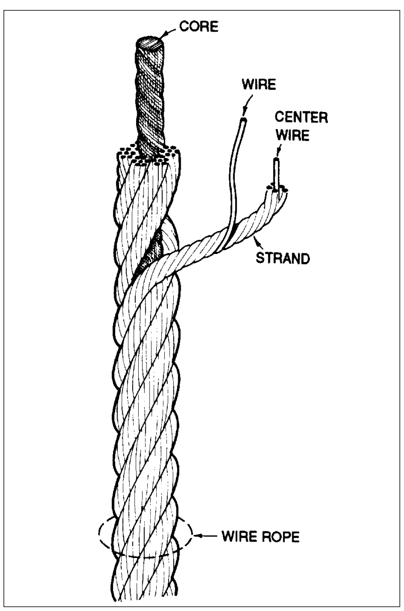


Figure 11. Typical wire rope components. *Courtesy of the Wire Rope Technical Board, Granbury, Texas.*

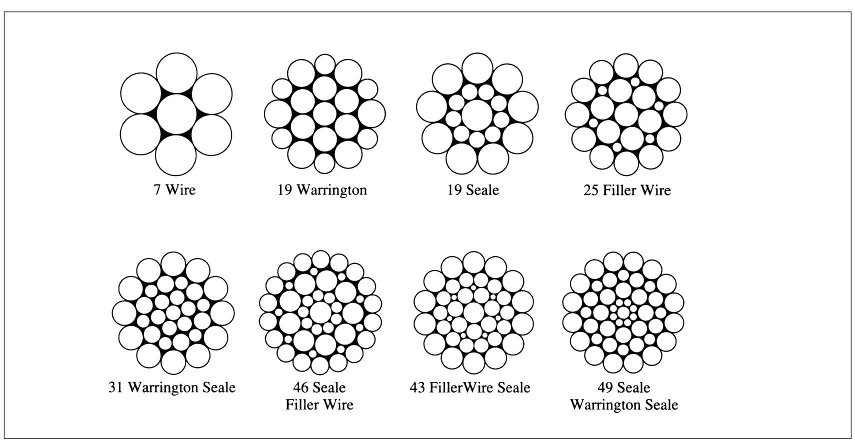


Figure 12. Strand patterns. *Courtesy of the Wire Rope Technical Board, Granbury, Texas.*

are laid in a helical path around a center core to form the wire rope. It is important to remember that the wires and strands all move in relation to one another. A wire rope must be lubricated! The purpose of the wire rope core is to position the strands properly and to allow them to slide freely so each strand picks up an equal portion of the load. The core can be a fiber or an independent wire rope core (IWRC) when additional strength is required. In classifying wire rope, the first number is the number of strands in the rope, and the second number is the number of wires in a strand. For example: 6 x 19 = 6 strands of 19 wires; 6 x 37 = 6 strands of 37 wires; 7 x 7 = 7 strands of 7 wires.

Another primary characteristic is the “lay” of the wire rope. The lay of a wire rope is determined by the direction in which the strands are laid into the rope and by the direction in which the wires are laid into the strands. Each type of lay gives specific characteristics to a wire rope.

- Right lay = Strands form a right hand helix.
- Left lay = Strands form a left hand helix.
- Regular lay = Lay of strands is opposite the wire lay.
- Lang lay = Lay of strands and wires are common.

Different grades of steel, finishes, cores, number of strands, number of wires in a strand, and lay allows a manufacturer to produce a wire rope that has specific characteristics. For example, a 19 x 7 is a spin resistant wire rope good for hoisting applications. The wire rope that is specifically made for suspension bridges is galvanized structural bridge rope. It is made in a right and regular lay. It is commonly a 7 x 7 IWRC, 6 x 7 IWRC, 6 x 25 IWRC, or 6 x 43 IWRC construction depending on diameter. The distinguishing feature of structural bridge rope is that it has a high Modulus of Elasticity (E). The Modulus of Elasticity of a material in tension is the ratio of unit stress to unit strain. The Modulus of Elasticity determines the stretch of a wire rope under load over a period of time. The E for structural bridge rope is 20 million PSI.

The only difficulty with structural bridge rope for small scale projects is that it is not a common item. It is difficult to obtain in short lengths, and it needs to be ordered far in advance. A normal minimum order of structural bridge rope is 5,000 feet. Needing only 404 feet, the project engineer performed a search among suppliers for “left over” lengths of 1-inch bridge rope. None were available. This practical problem was compounded by the purchasing responsibilities among the project partners, the accelerated construction schedule, and the six week construction “window” in the Pochuck Quagmire.

The purchase procedures for the project were set up so each project partner provided the material that they were most familiar with. This stretched the public dollars. The State of New Jersey Division of Parks and Forestry purchased the lumber and common components. The NY-NJ Trail Conference was advancing the money to purchase the specialty items, such as the anchors and the wire rope. This money would be reimbursed by a grant issued by the USDA Forest Service, Wood In Transportation program, when the bridge was complete. The Trail Conference could not commit to purchasing specialty items until all the pieces of the Pochuck puzzle were in place. These puzzle pieces included the environmental and construction permits, approved safety plan, rights of vehicular access, cooperative weather, permits, availability of GPU Energy, volunteer support, and other factors. However, once the critical mass of paperwork, machinery, and peoplepower were finally in sync, one could not say “Oh, the cable will be here in six weeks.” The solution was to substitute a more commonly available wire rope that was equal to bridge rope. Upon consultation with manufacturers, 1-inch 6 x 25 EIP IWRC RRL wire rope was specified. A regular lay rope withstands crushing action well. This is important in the cable saddle use. The nominal breaking strength of the 1-inch 6 x 25 EIP IWRC RRL was certified by the manufacturer to be 105,619 pounds of tension. A break test is performed on each run of cable manufactured. This provided a safety factor of 4.5 against the full dead and live design loads of the bridge. Increasing the wire rope diameter to 1 1/8-inch or 1 1/4-inch to achieve a safety factor of 5 would have increased the cost of the piggyback clips and other hardware. The benefits did not justify the additional expense in light of the rare chance that the bridge will ever have 110 people on it during a 30-inch snowstorm. Prior to making the decision, the project engineer calculated the wire rope safety factor of the other five pedestrian suspension bridges on the Appalachian Trail to determine what safety factor is common and customary for trail bridges. This was performed using their as-built span, sag, walkway surface areas, regional snow loads, design live loads, as-built dead loads, and end attachment efficiency factors. The wire rope safety factors for the Appalachian Trail bridges were as follows:

- Great Gulf = 1.3
- Tye River = 1.5
- Clarendon Gorge = 2.1
- Kimberly Creek = 3.1
- Pochuck Quagmire = 4.5
- Big Branch = 4.85

The Pochuck Quagmire Bridge is clearly at the conservative end of the scale.

A brief comparison of the two wire rope alternatives follows.

	1-inch Bridge Rope	1-inch 6 x 25 Wire Rope
Ultimate Strength	91,400 pounds	105,600 pounds
Cross-Section Area	.471 in^2	.404 in^2
Modulus of Elasticity (E)	20,000,000	13,000,000
Stretch in 202 feet	.10 foot	.18 foot
Cost per foot	$3.50/foot	$2.00/foot

The major difference between the two is that the higher E of the bridge rope results in .1 foot (1.2 inches) versus .18 feet (2.2 inches) of stretch under fully loaded conditions in each 202 feet of catenary cable. This may be significant in large size, heavily traveled steel and concrete bridges, but it is not significant in a 110-foot center span timber trail suspension bridge. There is a turnbuckle, as shown in photo 55 (page 55), at the end of each wire rope that provides for 2 feet of adjustment. Steps were taken to minimize the long-term stretch of the 1-inch 6 x 25 EIP IWRC wire rope. The wire rope was proof tested under a load of 36,000 pounds subsequent to cutting and installation of the wire rope sockets. This ensured the integrity of the wire rope sockets. This was 1.5 times the ultimate design load and multiple times the everyday working load. The use of the 6 x 25 wire rope was a sound decision. It was the last construction material ordered. The order was placed when the towers were up and ready to receive them. GPU Energy donated a truck and peoplepower to pick up the cable. The wire rope catenary cables were installed that same evening, and the project moved forward without missing a beat. The suspenders were installed immediately afterwards. By this time, it was October, and the hurricane season was in full stride. The site had begun to deteriorate rapidly, and time was of the essence.

Spelter Sockets

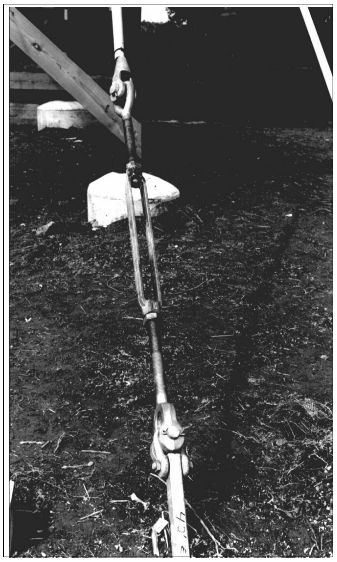


Photo 55. The various connections between the wire rope - spelter socket - turnbuckles with eye and jaw-shackle - Chance® 1.75 ss rod. *Photo courtesy of Mr. Stephen Klein, Jr.*

Photo 56. A terminal turnbuckle. Note the spelter socket connection to the eye at the top and the jaw-shackle connection to the Chance® Anchor at the bottom. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 55 shows the termination of the wire rope in open spelter sockets. These in turn connect to a 1 3/4-inch by 24-inch turnbuckle with one closed and one open end, which in turn connects to the end of the Chance® 1 3/4-inch square shaft helical simplex anchor, with a chain shackle. The turnbuckles are rated for 28,000 pounds working load and 140,000 pounds ultimate load. The entire assembly is detailed on page 40 (Figure 7) and Plan Sheet 7.

There are only two ways to attach anything to the end of a wire rope. Either form a loop in the wire rope or attach a fitting to it. Following is a listing of various types of attachments and the approximate efficiency of the attachment as compared to the strength of the rope. See Figure 13 (page 56) for various types of attachments.

Bridge socket (closed or open)	=	100 percent
Molten zinc or resin spelter sockets (PQB main cables)	=	100 percent
Cold formed swaged sockets (PQB suspender)	=	95-100 percent
Mechanical splice loop (PQB flemish sleeve)	=	90-95 percent
Hand tucked splice loop	=	80-90 percent
Wire rope clips	=	75 percent
Wedge sockets	=	75 percent

The working load capacity and safety factor of a wire rope system is based on its weakest link. The selection of the proper (or practical) attachment method for a wire rope can have major impacts. Doran Sling in Hillside, New Jersey, prepared resin spelter sockets for use on the Pochuck Quagmire Bridge. They resulted in 100 percent efficiency of the 105,619 pounds of the breaking strength of the wire rope. They are also a relatively vandal proof attachment. What the spelter sockets do not provide is field adaptability. The calculated length of the cut wire rope had better be correct.

In the case of the Pochuck Quagmire Bridge, once the towers and cable saddles were installed, the as-built dimensions of the bridge were measured every which way. The saddle-to-saddle span and elevation difference was measured. The saddle apex to square shaft rod top for each backstay was measured. Each measurement was made by an electronic distance meter and double checked with a calibrated steel tape. The take-off elevation of the as-built towers, the 3.5 percent grade of the walkway, and the K suspender length established the final sag elevation of the catenary cable sag low point. As shown on Plan Sheet 1, each pair of suspenders had an alphabetical designation, A through K. The K suspender is at the midpoint of the span and the lowpoint of the catenary cable. The length of the various attachments were incorporated. All this as-built information and the equation on page 50 identified the 202.00 and 200.94 lengths of the south and north cables. Various volunteers asked why all the fuss about the cable length when there is 24 inches of adjustment because ofthe turnbuckles at either end of each cable. The position of the project engineer was that the turnbuckles

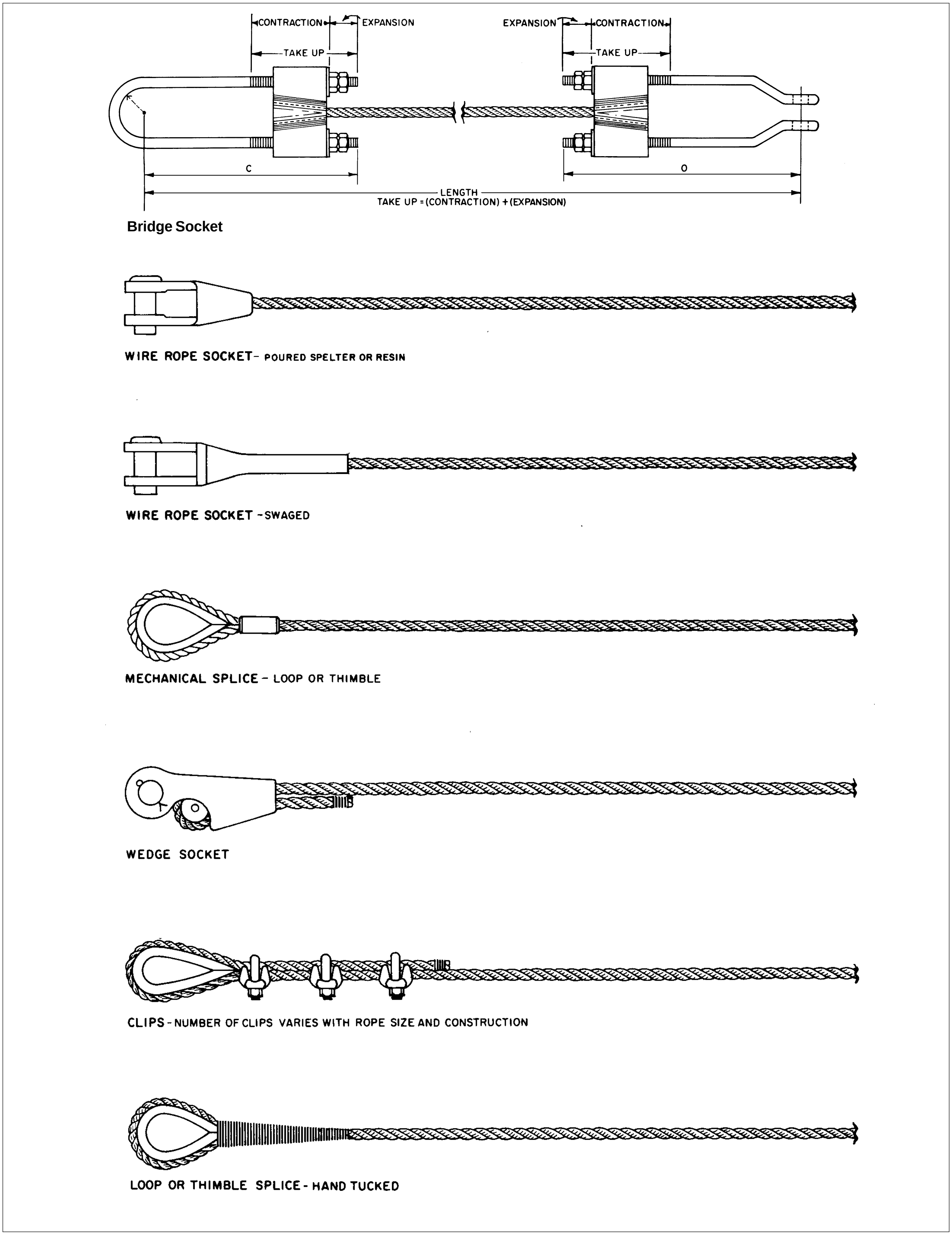


Figure 13. Attachment options for end of a wire rope. *Courtesy of the Wire Rope Technical Board.*

were to micro-tune the bridge and for long-term stretch in the wire rope. One should not squander this capability by not accurately calculating the cable length.

The author's field inventory of 31 trail suspension bridges showed that wire rope clips are the most frequently used terminal attachment method in the eastern states. The exceptions to this are the Pochuck Quagmire Bridge and the White Mountain National Forest bridges, which used spelter sockets. Bridge sockets are utilized on USDA Forest Service bridges in Idaho and Montana. While wire rope clips are less efficient than a bridge socket, spelter socket, or a swaged connection, they are easy to install in the field. They also provide for an easy method of adjusting the catenary cable length during initial installation. In using wire rope clips, one must recognize the 25 percent reduction in the wire rope assembly strength. The wire rope clips are the weak link. Structural efficiency is sacrificed for practicality. Photo 57 shows a typical wire rope clip and thimble attachment.

Photo 57. Wire rope clips on the Jackson River Bridge, GW & JNF in Virginia. *Photo courtesy of Mr. Tibor Latincsics.*

If wire rope clips are the chosen end attachment, several basic rules must be observed. They are as follows:

- The clips must be forged steel. Malleable clips are only appropriate for light duty uses.
- A metal thimble must be used to form the loop. The bending radius and groove of the thimble must match the diameter and type of wire rope construction.
- The turnback on the wire rope must be of a specific minimum length, for example at least 26 inches for a 1-inch wire rope.
- The correct number of clips must be used. For example, five is the minimum number for 1-inch wire rope.
- The U-bolt is applied over the dead end of the wire rope, and the live end rests in the saddle of the clip. Never saddle a dead horse! (Figure 15)
- The clips must be uniformly torqued to a recommended torque of the manufacturer.

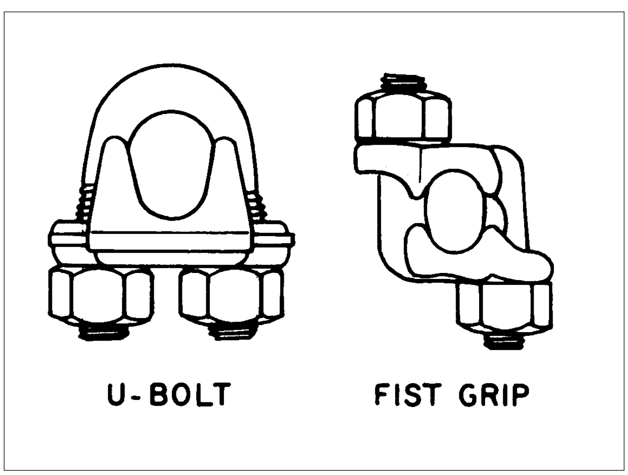


Figure 14. Wire rope clips.
Courtesy of the Wire Rope Technical Board.

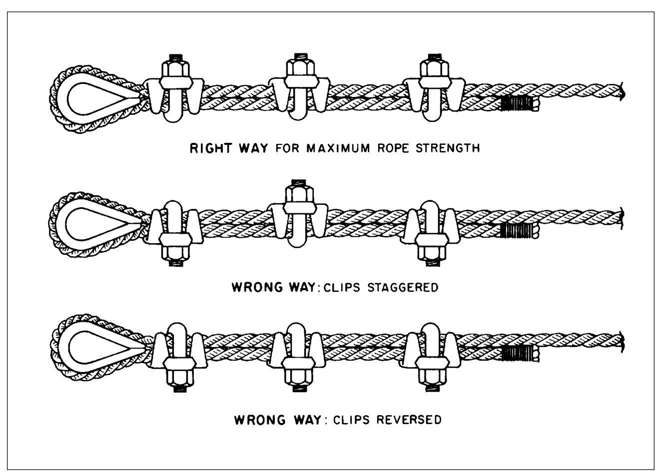


Figure 15. The correct way to attach wire rope clips.
Courtesy of the Wwire Rope Technical Board.

The field inventory did reveal a potentially dangerous situation involving the use of wire rope clips and thimbles as a terminal end attachment. As discussed in the cable saddle section, a wire rope must have a proper bending radius. Proper diameter wire rope thimbles should be used with wire rope that is manufactured for flexibility. This usually means a larger number of wire in a strand, such as a 6 x 49 construction. Structural bridge rope that is 7 x 7 or 6 x 7 should not be used with thimbles and wire rope without recognition that this combination results in a 50 percent reduction in the bridge rope strength. Structural bridge rope has a large bending radius requirement. It is manufactured to be used with spelter or swaged sockets.

Suspender Design and Installation

The primary purpose of the suspenders is to transfer the walkway load to the catenary cables. The stiffening trusses distribute a point live load to several suspenders. This reduces the vertical oscillations of the walkway under non-uniform loading. The suspender design and installation had to meet several criteria; they had to be:

- Structurally sound.
- Vandal resistant.
- Minimum number of parts or connections.
- Have a vertical adjustment capacity.
- Practical to install under adverse conditions.
- Cost-effective with no adverse impact on public safety.

The first five would be easy to accomplish if it was not for the sixth criteria. The final suspender design is detailed on Plan Sheet 8 and Figure 16.

The suspender assembly utilized for the Pochuck Quagmire Bridge is more sophisticated, but at the same time simpler than suspender assemblies for similar bridges. Working top to bottom, as detailed on Plan Sheet 8, Figure 16, and photographs 59-62, the individual components are as follows:

- CM Big Orange Piggyback wedge socket clip attachment to the catenary cable.
- Flemish eye loop with a 1/2-inch extra heavy duty wire rope thimble and flemish sleeve.
- 1/2-inch 6 x 19 galvanized EIP IWRC wire rope.
- Muncy 1-inch thread stud, electro zinc galvanized, swaged to the 1/2-inch wire rope.
- 1 1/16-inch bore hole through 6-inch by 6-inch cross-stringer.
- 3-inch by 3-inch by 3/16-inch galvanized square washer.
- 1-inch bore galvanized square washer.
- Standard 1-inch square nut.
- 1-inch lock nut (not shown in construction photos).

A distinguishing feature is the vertical adjustment capability by utilizing the threaded stud.

Practical elements and concerns about vandalism became the determining factors in the suspender design rather than pure structural criteria. The number and 5-foot spacing of the suspenders was determined by the design of the cross-stringers. The design of the cross-stringers was in turn influenced by the size of the borehole

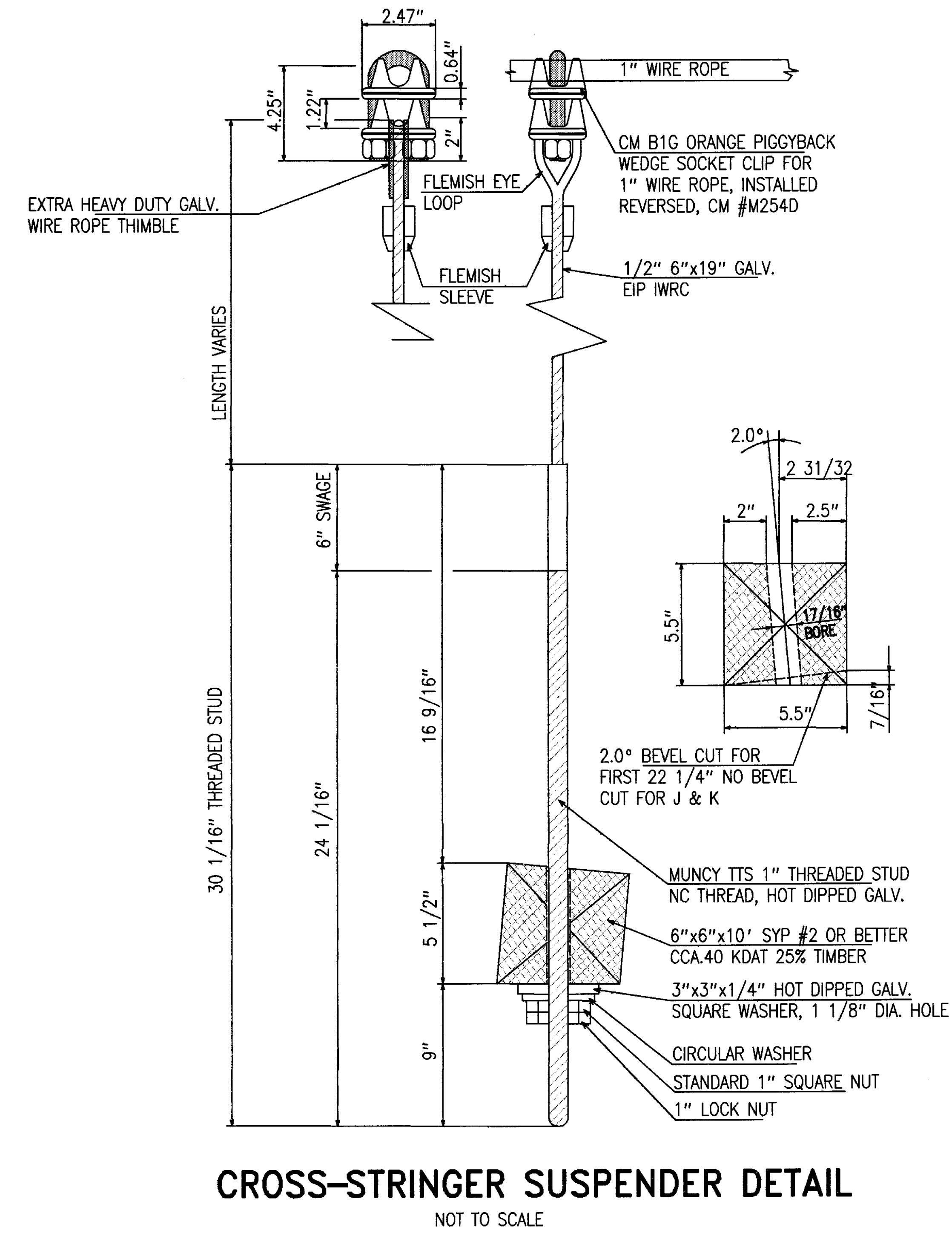


Figure 16. Cross-stringer suspender detail.

required to pass the threaded rod. A 4-inch by 6-inch cross-stringer would have been sufficient from a loading perspective, but the project engineer was concerned about the long-term impact of the 1 1/8-inch bore hole. Would the 4-inch by 6-inch cross-stringer crack at the bore hole when the bridge shifted in the wind? This concern resulted in the 6-inch by 6-inch cross-stringers being specified for the suspenders. Slightly over-sizing the suspender bore hole had two benefits. The first ensured that the threaded rod would easily pass through even if the cross-stringer swelled if it became wet prior to assembly. This was a prudent precaution because the Pochuck Quagmire Bridge was eventually assembled in torrential rains. The second benefit was to allow a little play in the system so the cross-stringer would not spilt as the bridge shifted in the wind. Vandalism concerns determined the 1/2-inch 6 x 19 wire rope being specified. The 1/2-inch wire rope has a nominal breaking strength of 13 tons, which is far in excess of the 650 pound design load on each suspender. However, using a smaller diameter seemed to invite vandals to "snip" the critical connector. This is a prudent precaution for the Pochuck Quagmire Bridge location as it is in a relatively remote, unsupervised location yet accessible to a wide variety of users. Local youths were drinking beer and "recreating" at the site before the bridge was finished.

The upper end of the wire rope terminates in a flemish loop, which is shown in photo 58. The flemish loop is created by the galvanized heavy duty thimble and the crimped flemish sleeve. The flemish sleeve is the weak link of the suspender assembly in that it has a rated capacity of 2.4 tons. This is typical of the fact that connections are the "weak link" in a structural system. The flemish loop was used in lieu of three wire rope clips typically used for this connection. Shown in photo 59 is the wire rope clip suspender connection of the Appalachian Trail Tye River Bridge.

Photo 58. Suspender connection on the PQB. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 59. Suspender connection on the Appalachian Trail Tye River Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

The flemish loop offers the following advantages:

- Vandal resistant.
- Strong.
- Cost-effective.
- Arrives prefabricated - fewer small parts to accidentally drop into the river.
- Less long-term maintenance.
- Better looking - professional end product.

However, the flemish loop does not have the in-the-field adjustment capability of simple wire rope clips. This adjustment capability is provided by the threaded rods at the lower end of the Pochuck Quagmire Bridge suspender assembly. This shall be discussed later. One should be aware that using a flemish loop requires accurate calculation of suspender lengths.

Photos 58 and 60 show the CM Big Orange Piggyback clip that provides the interconnection between the suspender and catenary cable. Also provided are three photographs of alternate connections used on other bridges inspected in the author's inventory. A comparison of these four structurally acceptable alternatives provides an interesting contrast of practical elements and costs. All costs are presented in 1996 dollars.
The drop forged CM Big Orange Piggyback clip provides a direct connection from the flemish loop thimble to

the catenary cable. The number of parts required are minimized. The piggybacks cost $22.50 each. Photo 61 shows the method used on the Tye River Bridge. Although the bridge was originally built in 1972, the walkway and suspender assemblies were replaced in 1992 because several suspenders had corroded to the point of being unsafe. The connection consists of a 1-inch Crosby drop forged wire rope clip and a 7/8-inch screw pin chain shackle. The cost for this connection hardware is $35.98. The cost is so high because individual chain shackles are a specialty item. One might ask, "Why not connect the flemish loop with just the wire rope clip and eliminate the shackle?" This would result in the two wire ropes rubbing against one another every time the bridge is loaded or the wind blows. Such a wear point could lead to long-term problems.

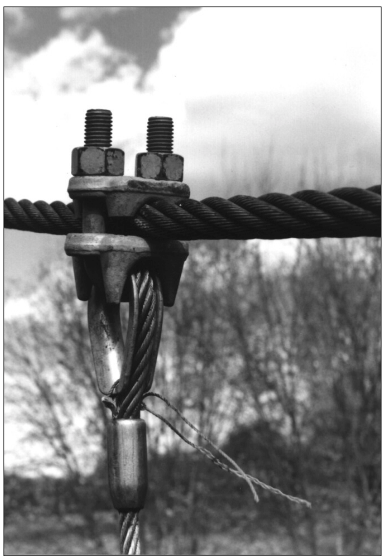


Photo 60. PQB CM Big Orange Piggyback Clip and flemish loop. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 61. Appalachian Trail Tye River Bridge Crosby Clip, chain shackle, and wire rope. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 62. Jackson River Bridge Crosby Clip, chain shackle, and swage socket. *Photo courtesy of Mr. Tibor Latincsics.*

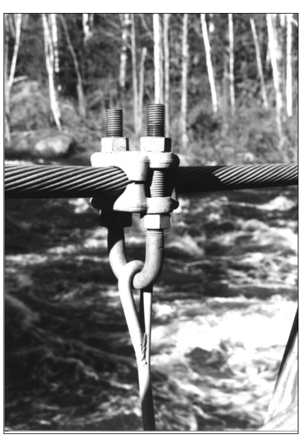


Photo 63. WMNF Lincoln Woods Trail Bridge clamp to rod suspender. *Photo courtesy of Mr. Tibor Latincsics.*

The third alternative, as shown in photo 62, was used on the Jackson River Bridge in Virginia. It is a 1-inch wire rope clip and chain shackle in concert with a half open swage socket. This is a good connection, which addresses the vandalism and maintenance problems of numerous wire rope clips. The cost is $59.08.

The fourth alternative, which is a bridge clamp, is shown in photo 63. This particular one is on the Lincoln Woods Trail Bridge off the Kangamangus highway in White Mountain National Forest. They are also used on other suspension bridges built by the USDA Forest Service in the White Mountains. The bridge clamps cost $108 each and are a specialty item having a long delivery time. Ignoring the cost-benefit ratio, it is the best wire rope connector. The cost of the four alternatives, if used for the 42 Pochuck Quagmire Bridge suspenders, is as follows:

Pochuck Quagmire Bridge piggybacks	(42)	($22.50)	=	$945
Tye River clip and shackle	(42)	($35.93)	=	$1,511
Jackson River swage socket	(42)	($59.08)	=	$2,481
White Mountain bridge clamp	(42)	($108.00)	=	$4,536

The $4,536 cost and long delivery time required for the bridge clamps was not within the project scope. Such a cost would have been 13 percent of the total project budget. A long delivery time would have doomed the project, which depended on accelerated construction during a narrow construction "window" in the Pochuck Quagmire. The Pochuck Quagmire Bridge piggybacks meet the six design criteria listed at the beginning of this section.

Photo 64. Underside 3.5 percent bevel cut on the 6-inch by 6-inch cross-stringer set the walkway slope. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 65. Threaded rod through cross-stringer. Flat washer on top and bottom. *Photo courtesy of Mr. Tibor Latincsics.*

The next major element of the suspender assembly is the connection to the 6-inch by 6-inch cross-stringer. This was performed by swaging a 30-inch long, 1-inch diameter threaded stud to the 1/2-inch wire rope. The threaded stud is shown in photos 64 and 65, Figure 16 on page 59, and detailed on Plan Sheet 8. The swaged threaded stud provides another vandal proof simple connection. A swage connection is a very structurally sound connection developing 95 to 100 percent of the wire rope strength. The threaded stud was simply threaded through a 1 1/8-inch vertical bore hole in the cross-stringer.

This provides two major benefits.

- The threaded stud provides a vertical adjustment capability to fine tune the bridge camber. This capability should not be used as a reason not to accurately calculate the various suspender lengths.
- As shown in photo 64 and Figure 16, by beveling the underside of the 6-inch by 6-inch cross-stringer to the slope of the bridge camber, the bridge walkway is automatically set to the desired slope. In this case that was 3.5 percent. The suspender hangs vertical (plumb) and the 3-inch by 3-inch bearing washer is perpendicular to the suspender and flush to the beveled underside of the cross-stringer.

Photo 66. Suspender assembly. *Photo courtesy of Mr. Tibor Latincsics.*

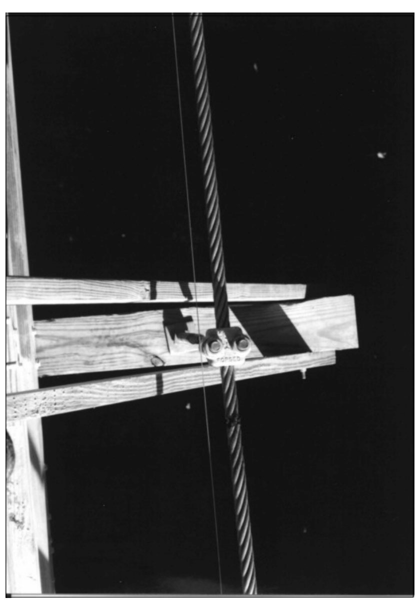


Photo 67. Suspender assembly — top view. *Photo courtesy of Mr. Tibor Latincsics.*

These two design components saved a significant amount of time in the bridge construction. Photo 68 on page 63 shows an alternative to the threaded rod used on the Tye River Bridge – a turnbuckle connected to an eyebolt. This alternative is not as desirable as the threaded rod for the following reasons:

- Turnbuckles are easily vandalized and are high maintenance.

Photo 68. Suspender - stringer connection on Appalachian Trail Tye River Bridge, GW & JNF. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 69. U-bolt connection. Dry River Bridge, WMNF. *Photo courtesy of Mr. Tibor Latincsics.*

- More wire rope clip connections and connections in general are needed.

The White Mountain Forest Service Bridges use a U-bolt to make the stringer connection, as shown in photo 69. This provides a limited vertical adjustment capability. The White Mountain Bridges have a distinct design feature in that the suspenders are a steel rod with a welded loop at either end. The loop connects to the bridge clamp at the top and the stringer U-bolt at the bottom. While the White Mountain Bridges appear to be very successful, this method may have the following limitations:

- Manufacturing the steel rod to the correct length is difficult and time consuming.
- There is little or no long-term adjustment capability to account for wood shrinkage or cable stretch.
- The rigid steel rods transfer walkway oscillations to the catenary cables more readily than the wire rope suspenders.

The combination of longer threaded U-bolts, bevel cut on the stringer underside, and a flemish sleeve connection would give a designer the ability to specify adjustability, walkway slope, and cradle all at the same time.

A Practical Lesson – "The Hard Way"

The installation of the piggyback clips provided a hard-learned lesson, which is applicable to other projects. The catenary cables and suspenders were fabricated by Mr. Dick Doran, an internationally known wire rope expert, of Doran Sling. As was the case with almost everyone who came in contact with the project, Mr. Doran became interested in the project on both a professional and personal level. He provided a wealth of practical information. The project specifications called for the catenary wire rope to be cut in the shop and the spelter sockets attached. The suspenders would be fabricated to the varying correct lengths and mounted on the primary catenary at calculated locations. The entire prefabricated assembly would then be reeled on an oversized spool and transported to the bridge site for installation. Due to their interest in the project, as well as keeping the accelerated construction schedule going, GPU Energy volunteers offered to pick up the cable early and mount the suspenders in the field. This would be done while the prefab of the bridge walkway was proceeding at Wawayanda State Park. The suspenders were not mounted in the shop. Out in the field (in 6 inches of mud and pouring rain), it was discovered the seat of the 1-inch piggyback clips would not snug up to the 1-inch wire rope. This would have been a minor problem in the Doran shop, but out in the field, it was another story. There was no power nor the right power tools. All the material had been accepted from the fabricator and was onsite. The work crew was waiting and ready to work. The field solution was to flip the piggybacks and to "burn" off the tops of the tines. The reader should compare photos 58 and 60 to the detail on Plan Sheet 8. This modification required shaving 168 tempered steel tines. Some 40 saw-zal blades later, the reversed piggybacks fit. This points to several old adages.

- Measure twice – cut once.
- Plan your work – work your plan.
- Be prepared – field modifications can be expected.

With the suspenders attached to the primary cable, the cables were placed in the cable saddles, tension applied, and hoisted up. The cable work assumed the distinctive parabolic profile of single-span suspension bridges, as shown in photos 70 and 71.

Photo 70. Catenary cables and suspender assemblies ready to go! *Photo courtesy of Mr. Stephen Klein, Jr.*

Photo 71. Twenty-one pairs of calculated suspenders. *Photo courtesy of Mr. Tibor Latincsics.*

The primary cable and the 42 vertical suspenders assumed the correct geometry shown in photos 70 and 71. This was due to the advance design work and then a fine-tune design to fit as-built conditions. As is the case with the majority of single-span suspension bridges, the primary cable between the towers was designed as a symmetrical equal tangent parabolic curve. The reader should not assume that suspension bridges are limited to symmetrical equal tangent single spans. One is referred to the "Wire Rope Engineering Handbook" for information on the stresses and geometry of a variety of suspended cable configurations.

The basic mathematical characteristics of a parabola were used to design and fabricate the suspender lengths. Figure 17 (page 65) is a simplified sketch of the bridge profile shown on Plan Sheet 1. As on Plan Sheet 1, the suspenders are identified A to K depending on their location. Figure 18 (page 65) is a further simplification showing the mathematical relationship between the chord, tangents, tangent offsets, and the parabolic curve. Two useful basic properties of a parabola allow one to calculate the suspender lengths. The properties are as follows:

- The parabolic curve bisects a line joining the midpoint of the chord and the intersection of the tangents at the ends of the chord. The distance from the vertex to the curve and from the vertex to the chord are equal and called the middle ordinate distance. This distance is called "e" among engineers, and in the case of suspension bridges is also the "sag."
- The distance from the tangent to the curve varies as the square of the distance along the tangent from the point of tangency to the chord midpoint.

Referring to Figure 18, the distance from the tangent to the curve at point "z" is as follows:

Distance zw = $(3/4)^2$ e = 9/16 e

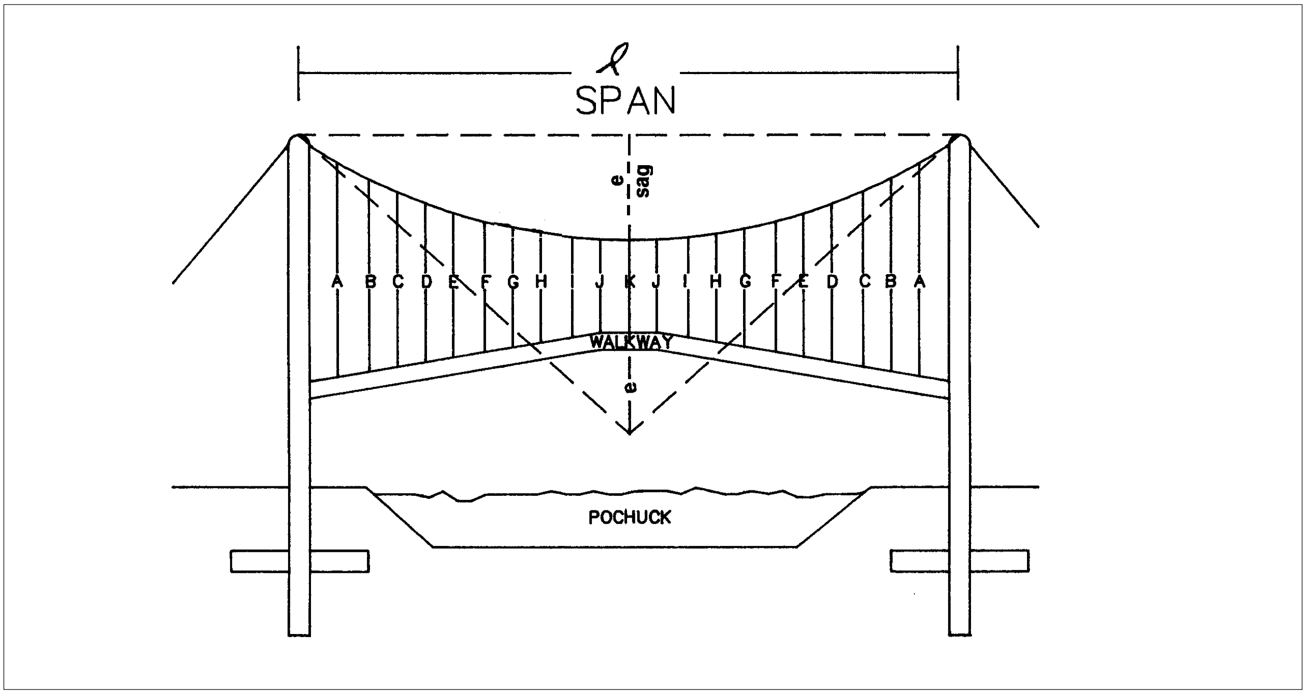


Figure 17. Sketch of Pochuck Quagmire Bridge in profile showing parabolic curve relationships.

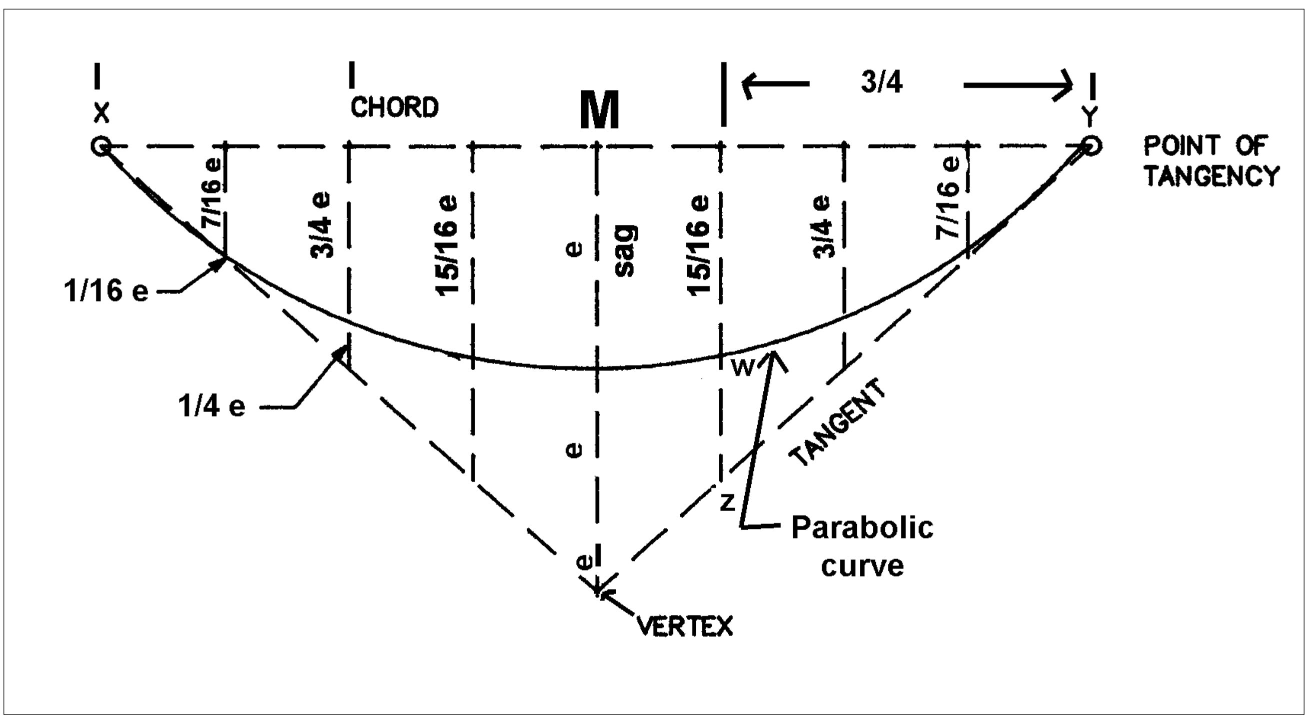


Figure 18. Symmetrical equal tangent parabolic curve mathematical relationship.

These basic relationships allow one to calculate the suspender lengths. In the case of the Pochuck Quagmire Bridge, the walkway had an upward camber rise of 3.5 percent. It was important to identify the 42 suspender lengths between two converging bridge elements — the downcast parabolic cable and the rising walkway. The suspender detail, Figure 19 and Plan Sheet 8, indicates the only variable of the suspender assembly to be the length of the 1/2-inch 6 x 19 galvanized EIP IWRC. It was critical to be aware that in the suspenders the minimum length of 1/2-inch 6 x 19 EIP IWRC allowed between the flemish sleeve and the swaged threaded rod was 12 inches. This is a wire rope industry standard. This determined the overall length of the center K suspender of the Pochuck Quagmire Bridge, which in combination with the tower heights and walkway slope, established the sag or "e" of the main cable.

Figure 19 is the sketch and an example of the step-by-step procedure used to calculate the Pochuck Quagmire Bridge suspenders. The author has refrained from presenting specific calculations in this case study, but a number of people have asked that this procedure be detailed. The reader should also refer to the bridge profile and suspender detail. Suspender F on the east side of the south cable shall be the example.

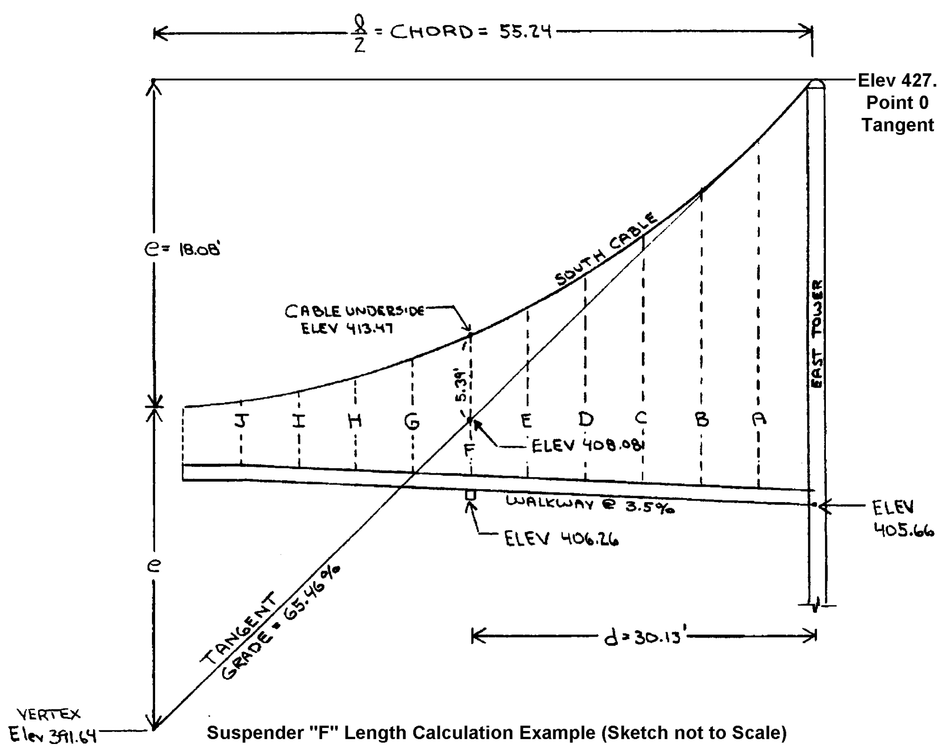


Figure 19. Suspender length calculation example.

- Tangent Elevation at Suspender F = 427.80 - (30.13)(.6546) = 408.08
- Distance from the tangent point @ F to the underside of the 1-inch wire rope is:
  $(30.13/55.24)^2e = (.2975)(18.08) = 5.39$
- Elevation of underside of cable = 408.08 + 5.39 = 413.47

- Elevation of the underside of the bevel cut 6-inch x 6-inch stringer is determined by the platform elevation and the run/rise of the walkway:

$$405.66 + (30.13)(3.5\%) - \frac{5.5"}{12"/\text{ft}} = \text{Elevation } 406.26$$

- Elevation of the top of the F threaded stud:
  406.26'+(5 ½" + 19 19/16"//12"/ft) = Elevation 408.35

- Length of wire rope from top of threaded rod to the inside crest of the flemish loop wire rope thimble (see suspender detail) is as follows:

  Elevation 413.47 - (1.86"/12"/ft) - Elevation 408.35 = 4.965'

- Wire Rope Length of Suspender F = 4.965' = 4'-11 9/16"

This 7-step calculation was performed 84 times — 21 times for each suspender pair to "rough out" the design; 21 times for the final design and to provide an estimate of the 1/2-inch wire rope needed; and 42 times to customize each suspender for the as-built conditions of the towers and saddles. Doran Sling and Assembly was provided with a "cut sheet" that identified the suspender lengths to within 1/16-inch. The suspenders were fabricated to this tolerance. Each suspender was identified by its correct location, for example, south cable, east side – F Suspender. A secure, weatherproof tag was used to distinguish each suspender. To make the field fabrication even easier, the project engineer had the suspender locations and spacing marked on the main cables at the Doran shop. This was calculated by applying the length of curve equation on page 50 to the as-built tower dimensions and distributing the distance evenly between the suspenders. For example, the south cable suspender spacing was as follows:

- $$Suspender\ Spacing = \frac{\ell\left(1+\left[\frac{8}{3}\right]\frac{e^2}{\ell^2}-\left[\frac{32}{5}\right]\frac{e^4}{\ell^4}+\left[\frac{256}{7}\right]\frac{e^6}{\ell^6}\right)}{\#\ of\ \ suspenders+1}$$

- $$\text{Spacing} = 110.47\left(1+\left[\frac{8}{3}\right]\left[\frac{18.08^2}{110.47^2}\right]\left[\frac{32}{5}\right]+\left[\frac{18.08^4}{110.47^4}\right]+\left[\frac{256}{7}\right]\left[\frac{18.08^6}{110.47^6}\right]\right)=\frac{(110.47)(1.0675)}{22}=5.36$$

All this time-consuming measuring and "number crunching" would pay dividends in the time it would save in the aerial assembly and "tuning" of the bridge.

Aerial Bridge Assembly

All the planning, measuring, and prefabrication led to the aerial connection of the seven prefabricated bridge sections. This is shown in photos 72-77. The sections were hoisted via "come-along" winch hoists, as shown in photos 72-74. The pair of top overhead 9/16-inch structural strand guylines, (shown in photo 10, page 22), that run from top of tower to top of tower serve two purposes: first as guylines and secondly as a cable runway for the pulley sheaves used to pull the bridge panels into place. This is shown in photo 74. It is very important to recognize that during the aerial maneuvering of the 1500-pound bridge sections, the weight of the individual bridge sections was carried by the overhead 9/16-inch structural strand. The workers' fall protection lines were connected to the main catenary cables. If the bridge sections dropped for whatever reason, the workers would not be carried down with it. When the bridge section was in the correct position, the male-female elements of the truss chords were bolted together. The weight of the bridge section was

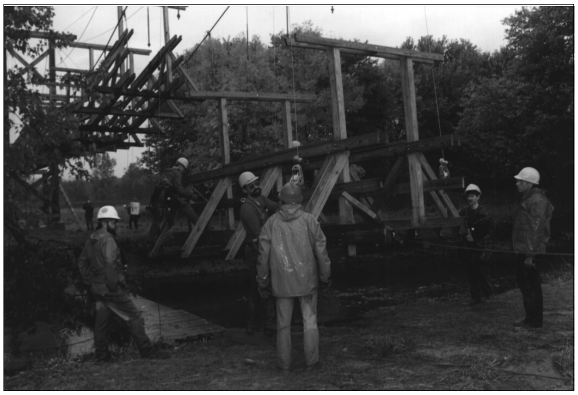


Photo 72. Trail conference volunteers preparing a bridge section for "lift off." *Photo courtesy of Ms. Marcy Dubinsky.*

Photo 73. Hoisting up a bridge section with muscle power. *Photo courtesy of Ms. Marcy Dubinsky.*

Photo 74. Aligning the prepared joints. *Photo courtesy of Ms. Marcy Dubinsky.*

transferred to the main catenary cables by simply threading the rod of the suspender through the pre-bored hole in the 6-inch by 6-inch cross-stringer and installing the square washer and nut. This is shown in photo 75. With these simple tools and some muscle, the bridge sections were hoisted into place. The pre-fitted, pre-cut, pre-drilled spaced joints were married together. Details of these bolted-blocked section joints are shown in photos 80 and 81.

The #1 CCA.40 SYP KDAT 19% MC lumber was specified for structural, dimensional integrity, and weight purposes. Howls of protest were originally voiced over

Photo 75. Tibor Latincsics threading the suspender rod through a stringer. *Photo courtesy of Ms. Marcy Dubinsky.*

Photo 76. To reduce weight, bridge sections were joined without decking in place. *Photo courtesy of Ms. Marcy Dubinsky.*

Photo 77. Paul DeCoste, Greg Ludwig, and Alan Breach on the aerial assembly. *Photo courtesy of Ms. Marcy Dubinsky.*

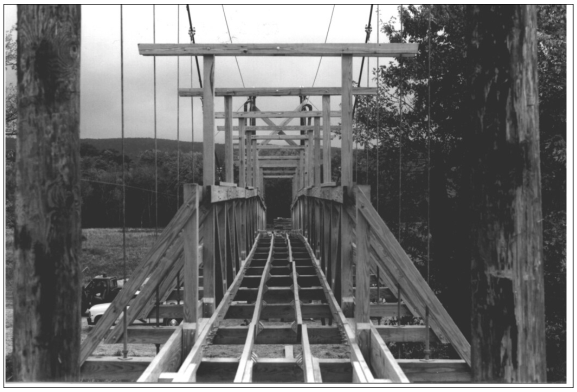


Photo 78. Walkway structural skeleton before decking. *Photo courtesy of Mr. Stephen Klein, Jr.*

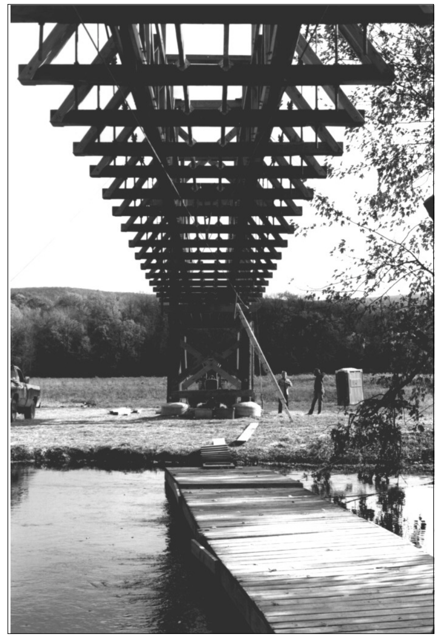


Photo 79. Structural skeleton from underside prior to decking. *Photo courtesy of Mr. Stephen Klein, Jr.*

the #1 KDAT specification. Each 20-foot panel weighed 1,500 pounds. Handling the panels with the winch hoists required the operators to mount the panels. This added another 400-900 pounds. If #1 CCA treated lumber that was not dried after treatment was used, another 500 to 1,000 pounds would have been added due to the additional moisture in the wood. The assembled bridge skeleton prior to the installation of decking is shown in photos 78-80. Photo 81 shows the spaced chord connections and the sistered interior 2-inch by 6-inch connections between the bridge sections. The design plans had the interior walkway joists sistered connections offset in a 10-foot stagger. In order to simplify the prefabrication and transport, this was changed to a common 20-foot spacing.

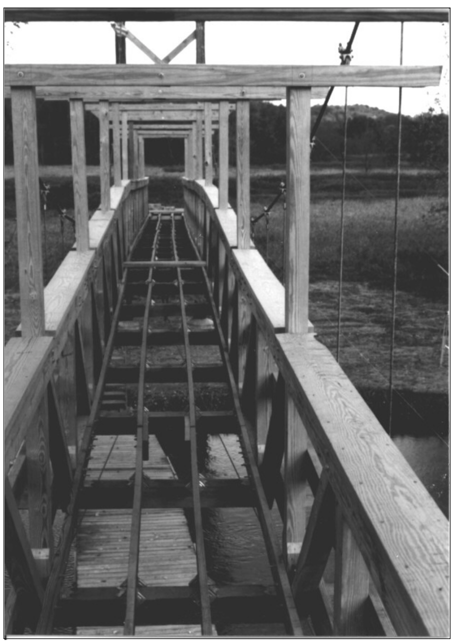


Photo 80. Top view of bridge section connections. *Photo courtesy of Mr. Tibor Latincsics.*

Final Cable Tuning

When the catenary cable was uniformly and continuously loaded, the final tuning of the suspension system commenced. The following criteria were adhered to:

- The design walkway camber of 3.5 percent, which meets ADA standards.
- Clearance to the 100-year flood level.

The exact elevation of the catenary sag point was set by the project engineer utilizing the turnbuckles. Subsequent to this, each individual suspender threaded rod had to be adjusted to smooth out the camber of the bridge. As the threaded rods hang plumb, the 3.5 percent camber of the bridge was automatically set by the bevel cut on the

Photo 81. Underside view of bridge section connections. *Photo courtesy of Mr. Tibor Latincsics.*

underside of the 6-inch by 6-inch cross-stringer. This is detailed on Plan Sheet 8, Figure 16 (page 59), and photo 64 (page 62). As each threaded rod adjustment affected the load on its neighbor, the final bridge tuning was a repetitive process. Photo 82, perhaps the definitive photo during the construction period, shows the bridge camber after two adjustments.

Photo 82. Bridge prior to decking and stairs. *Photo courtesy of Mr. Tibor Latincsics.*

Decking and Stairs

The plans specified 2-inch by 6-inch #1 SYP CCA.40 KDAT 19% MC decking, screwed down bark side up with a 1/8-inch gap between boards to accommodate swelling. The screw holes were pre-drilled, and the soaped square drive, galvanized 3-inch bugle head deck screws were driven two per joist at 14.5 inches on center (o.c.) This was a very time-consuming process as opposed to power nailing. This is shown in photo 83. Out of the 31 other pedestrian suspension bridges inventoried by the author, only the Dry River Bridge in the WMNF used screws; all others were nailed. Screws are a superior connector, especially for an elevated bridge subject to cross-winds.

Photo 83. Chris Mazza and other Trail conference volunteers screwing down the walkway 2-inch by 6-inch decking. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 84. East side staircase construction. *Photo courtesy of Mr. Tibor Latincsics.*

The staircases are detailed on Plan Sheet 3, and the construction is shown in photo 84. When the wire mesh and handrail are completed, the staircases will comply with the BOCA® code, with the exception that the total rise on the west staircase is 12 feet, 3 inches, which is 3 inches more rise than allowed by BOCA® without an intermediate landing. Given the location on a wilderness footpath, the project partners and project owner found this to be acceptable.

Field Modifications

Following is a list of field modifications.

1. Because of the drought, the site was accessible to concrete trucks, up to 30 CY of concrete was utilized for the snowshoe foundation in lieu of the 20 CY specified by the plans. This improved the protective concrete cover on the rebar.
2. The tower base rebar was upgraded from a #14 to a #18 due to availability.

3. The epoxy coating was eliminated from the rebar because of more than adequate concrete cover. This saved money as well as time because of easy availability of standard rebar. All rebar is 60 KSI.
4. To allow bending in the field, the dowel bars were changed from #6 to #5, but the number of dowel bars was increased to maintain the same cross-sectional area. A Joslyn Universal pole band was utilized to connect the #5 bars to the transmission poles, instead of the pipe straps.
5. GPU Energy provided single curve spike grids. GPU Energy also provided 3-inch by 3-inch by 1/4-inch square washers for the suspenders, in lieu of the 4-inch by 4-inch specified.
6. The walkway portal crossarm centerpoints were lag-screwed in lieu of through-bolted.
7. The cable saddles were customized for the individual non-uniform pole tops. See previous discussion on page 45. Top crossarms were doubled-up.
8. The walkway interior 2-inch by 6-inch stringers (joists) were not staggered for ease of prefabrication and transport.
9. The west staircase has a total rise of 12 feet, 3 inches in lieu of 12 feet.
10. An underbelly wind guy was added.
11. In order to ensure Americans with Disabilities Act compliance, bridge walkway slope was revised from 4.5 to 3.5 percent.
12. For ease of prefabrication, the bridge walkway rail truss was revised from a “Pratt” to a “Howe” configuration.
13. Available 2-inch by 12-inch lumber was substituted for the 2-inch by 6-inch stock on the staircase treads.

Americans with Disabilities Act (ADA) Compliance

As indicated in the project goals and project correspondence, the bridge is the central element in what may become a handicapped-accessible segment of the Appalachian Trail. It is NJDEP policy to meet the recreational needs of citizens with disabilities. In order to provide a standard of which to design to, the project engineer treated the walkway of the bridge no differently than any other public pedestrian walkway. Project design adhered to the handicapped-accessible standards of the following three codes or standards:

- The BOCA® National Building Code
- N.J.A.C. 5:23-7, Barrier Free Subcode
- Title III of the Americans With Disabilities Act

In order to meet ADA requirements, the bridge walkway had to meet specific dimensional, clearance, and slope criteria. Specific design elements referenced to the appropriate ADA section numbers are as follows:

4.8.1 The walkway slope is 3.5 percent or 1:22.5. As it is under 5 percent, it is not considered a ramp. The length and rise limitations of section 4.8 are not applicable.

4.8.3 The walkway clear width of 39 inches exceeds the minimum standard of 36 inches.

4.8.4 Although not required as the walkway is not a ramp, a 10-foot level platform is provided at the center of the bridge, and a 6-foot long by 8-foot wide level platform is provided at either end.

4.8.7 In addition to having an AASHTO and BOCA® rail system, a 2.5-inch curb is provided.

A step or series of steps at either end of the walkway down to the platform as is typical for such bridges was not acceptable in this case because of the ADA goals. The ramp transition from the platform to the bridge walkway is detailed on Plan Sheet 2.

Subsequent to the construction of the bridge, two guidance documents became available that provide accessibility guidelines for the design and construction of recreation trails in a variety of settings. These two documents are as follows:

- "Recommendations for Accessibility Guidelines, Recreational Facilities and Outdoor Developed Areas" by the Recreation Access Advisory Committee, 1331 F Street NW, Suite 1000, Washington, DC 20004
- "Design Guide for Accessible Outdoor Recreation" by the USDA Forest Service and USDI National Park Service, USDA Forest Service, 201 14th Street SW at Independence Avenue SW, Washington, DC 20250

Environmental Integrity

The bridge plans and construction were subject to a comprehensive review by the NJDEP Bureau of Land Use for compliance with the Flood Hazard Area Control Act and the Freshwater Wetlands Protection Act. Stream Encroachment and Wetlands Permits were issued. Mr. Paul Drake, the environmental specialist within the NJDEP Bureau of Land Use, who reviewed the permit application, also performed site inspections during construction. All participants were very pleased over the minimal environmental impact on the fragile quagmire ecosystem.

Aesthetics

Palladio, an Italian architect of the 16th century, compared a good bridge to a fine fabric. "A bridge must be convenient, beautiful, and durable." Those eight words provide the fundamental principles of bridge design.

Trail groups within the project partnership felt strongly that the bridge should have a rustic appearance in order to preserve the primitive trail experience of the Appalachian Trail. Without question, this goal was attained. The fact that the entire bridge, other than the cables and connectors, is #1 southern yellow pine gives it an inherently rustic flavor. Although the bridge owes more to John Roebling, it appears as if Daniel Boone built it.

The Pochuck Quagmire Bridge is a classic example of structural functionalism. All members are necessary. But within this structural functionalism, attention was paid to architectural lines. The camber of the bridge was incorporated for aesthetic as well as functional reasons. The smooth upward 3.5 percent camber of the walkway serves to accent the parabola of the catenary cables. The simple act of trimming the tower crossarm ends to 45 degrees gave the towers a finished look. This 45 degree end treatment was carried through the walkway portals.

This bridge is in harmony with its setting. Photo 85 with Wawayanda Mountain in the background shows how the solid and rustic bridge blends with the landscape. As one worker said while leaving on the last day, “It looks as if it’s always been there.”

A valid criticism from an aesthetic perspective is, of course, the height of the bridge, but this is absolutely necessary for environmental and durability reasons. The bridge does end abruptly; however. The engineer was advised on numerous occasions that handicap ramps up to the bridge platform are phase II of the project. These ramps shall serve to improve the geometric aesthetics of the bridge as well as its functional convenience.

Photo 85. View of bridge looking east. Wawayanda Mountain is in the background. *Photo courtesy of Mr. Stephen Klein, Jr.*

Project Supervision and Labor Force

The project was fortunate in that it had in essence four construction supervisors who worked cooperatively. Each had an area of responsibility but routinely consulted one another. This resulted in someone always being available to direct the volunteer labor force in a productive manner. These were hands-on working supervisors, which contributed to morale and productivity. The supervisors, in alphabetical order, were:

- Mr. Paul DeCoste, NJ Appalachian Trail Management Committee of the NY-NJ Trail Conference
- Mr. Tibor Latincsics, P.E., Conklin Associates
- Mr. Pete Morrissey, GPU Energy
- Mr. Wes Powers, NJ State Park Service

As indicated in the “Peoplepower Breakdown” discussion on page 87-88, the labor force was a unique public-private partnership grounded in volunteer spirit. As the bridge rose out of the Pochuck Quagmire, the days grew shorter and colder, and site access deteriorated, but the work force’s interest and enthusiasm only increased. The NY-NJ Trail Conference volunteers handled a large quantity of diverse tasks from site access to carpentry. Mr. Powers, Project Site Manager, brought to the project his 27 years of experience with the New Jersey State Park Service. Mr. McCurry and the Waway-anda State Park staff provided a skilled labor force for work that could only be performed during normal business hours. The state correctional inmates provided a great deal of hard work, such as moving concrete. The expertise, material, and machinery of GPU Energy, under the supervision of Mr. Morrissey, made the tower and wire work a reality. Mr. DeCoste provided people management skills and community coordination. The organization of the volunteer workforce was due to Mr. DeCoste’s countless phone calls. Mr. Bell brought to the project his unique networking abilities, statesmanship, and a deep, personal interest in the project. He originally approached the Trail Conference concerning a memorial donation in the name of his son, Duane Bell, who was

Photo 86. “Project Principals” Standing (left to right) Tibor Latincsics, Anne Lutkenhouse, Pete Morrissey, Paul DeCoste, Kneeling - Paul Bell, Wes Powers. *Photo courtesy of Ms. Marcy Dubinsky.*

an avid Appalachian Trail hiker who died tragically in a car accident. Ms. Anne Lutkenhouse, the Project Director of the NY-NJ Trail Conference, provided critical behind-the-scenes administrative support.

A true cooperative public-private partnership, the bridge construction would not have been completed as quickly nor successfully as it was without each partner's contribution.

Site Access

The project received a major boost from Mother Nature in the summer of 1995, for it was North Jersey's driest summer in the past 100 years. Areas of the project site that are normally inundated were bone dry. At the start of the project, access to the site was achieved by cutting back the weeds, incorporating stone wheel blankets, and using stone and temporary culverts in major low points. In addition, two adjacent property owners graciously allowed temporary construction vehicle access across their property. From the east, John Hill Corporation allowed use of a 2,500-foot long dirt road that led directly from a paved road to the "east meadow." From the west, Mrs. Esposito allowed traffic across her property. This provided the only possible route across the west quagmire for the tracked construction equipment. These three factors made construction access significantly easier than ever imagined. After the first eight weeks, the weather turned for the worse. While the heavy rains slowed the project, the subsurface work was already complete.

Public Safety, Worker Safety, and Project Partner Risk Management

As stated earlier, the primary project goals were to eliminate the dangerous 2.1 mile roadwalk along the heavily traveled county road and to place the Appalachian Trail, for aesthetic reasons, within the designated and previously purchased trail corridor. This would require the construction of a safe, practical, cost-effective, and durable bridge over the Pochuck Creek. The responsibility for placement of the trail within the corridor and over the creek crossing lay with the NJ Division of Parks and Forestry. The NY-NJ Trail Conference and other project volunteers were more than willing to assist with the planning, design, and environmental permits for what was essentially a public works project. This involvement focused the project, gave it a specific direction, and stretched public funding. By taking an active role in the elimination of a dangerous roadwalk and creek crossing, the project partners were exposing themselves to risk (liability).

The conundrum of public safety and elevated suspension bridges is demonstrated by the 1973 Appalachian Trail tragedy at Clarendon Gorge in Vermont. Clarendon Gorge is an awe-inspiring rocky gorge of the Mill River. It has sheer rock walls of 100 feet or more in height. The Appalachian and Long Trails pass over the Gorge via the Robert Brugman Memorial Suspension Bridge. The combination of the rocky gorge, tumultuous waters below, clifftop conifers, the bridge height, and narrow walkway make for a beautiful but eerie crossing. The bridge is 32 feet above the river, but the sensation one gets is that it is significantly higher. The first suspension bridge over Clarendon Gorge was designed and built by Emile Boselli of the Green Mountain Club. It was opened to foot traffic in 1958. The 55-foot span suspension bridge, 32-feet above the river replaced log bridges down in the gorge. The rudimentary log bridges were routinely washed away, leaving hikers to negotiate a dangerous ford. In late June 1973, several heavy rainstorms in a short period of time hit Vermont resulting in severe flooding. The north tower of the Clarendon Gorge Suspension Bridge gave way to high water on June 30, 1973. The bridge cablework held together and slapped against the south wall of the gorge. This may seem incredulous to anyone who has passed over the elevated bridge, but it should be recognized that while both the original and present bridge have significant clearance (32 feet) to the river, the gorge is a constriction in the river. On July 4, 1973, Robert J. Brugman, 17, a southbound Appalachian Trail thruhiker from Flemington, New Jersey, reached Clarendon Gorge. Because the bridge was destroyed, he attempted to cross the swollen river by means of a fallen pine tree. He slipped into the river, was swept downstream and drowned. His body was recovered on July 8, 1973. A new 65-foot span suspension bridge for Clarendon Gorge was designed by the Vermont Highway Department and installed by the Earle & Miller Construction Company. The new bridge, which opened on August 24, 1974, was dedicated to the memory of Robert Brugman. It has been in continuous use since.

Suspension bridges provide a structural solution to wide crossings, be it a rocky gorge or a quagmire. In many cases, floodwater clearance requirements dictate that the bridge be elevated. A properly designed bridge is vastly safer than fording a river, as demonstrated by the Brugman tragedy at Clarendon Gorge. The inherent characteristics of a wide span, elevated bridge require prudent common sense design, construction, and use.

The Pochuck Quagmire Bridge project volunteers were especially concerned about risk (liability) because of potential misuse of the bridge by the public. This is an especially valid concern for the Pochuck Quagmire Bridge as it is on the fringe of suburbia in a readily accessible but unsupervised location. In order for the bridge to be durable and to comply with NJDEP floodwater clearance regulations, it had to be elevated. Risk management by all project partners and on behalf of all project partners became a central element during project planning and construction.

The safety program and risk management for the Pochuck Quagmire Bridge had the following components:

- Proper bridge design from a structural and safety perspective.
- User education.
- Project construction safety plan – worker safety.
- Insurance for all project partners and participants.

Public Safety

The first step in risk management was to design a structurally sound bridge to applicable codes and public safety standards as well as normal and customary standards. This was difficult at first because there are no codes or customary standards for such a unique and peculiar structure. The literature search and bridge inventory by the project engineer was as much risk management as it was a practical and engineering exercise. Following is a listing of the bridge components other than structural elements that deal specifically with public safety. The listing is referenced to various codes.

- BOCA® 1014.6; staircases have a uniform 6 7/8-inch rise and an 11 1/2-inch thread. The stairs have a rounded bullnose (N.J.A.C. 5:23-7.18 (a) 2).
- BOCA® 1014.6.1; staircases have solid risers.
- BOCA® 1014.7 & 1022.0; staircases were designed to have a handrail that meets the grip and location standards.

A frustrating element was trying to obtain a definitive answer about which guard rail standard applies to the project: 1992 AASHTO 2.7.1.2.4 or BOCA® 1021.3. The BOCA® standard is the stricter standard. BOCA® focuses on making sure small children playing unattended on an elevated deck will be safe. Central elements of the 1993 BOCA® standard follow:

> ***1005.5 Open-sided floor areas:*** *Guards shall be located along open-sided walking surfaces, mezzanines and landings which are located more than 30 inches (762mm) above the floor or grade below. The guards shall be constructed in accordance with Section 1021.0.*
>
> ***1021.2 Height:*** *The guards shall be at least 42 inches (1067mm) in height measured vertically above the leading edge of the tread or adjacent walking surface.*
>
> ***1021.3 Opening limitations:*** *In occupancies in Use Groups A, B, E, H-4, I-1, I-2, M and R, and in public garages and open parking structures, open guards shall have balusters or be of solid material such that a sphere with a diameter of 4 inches (102mm) cannot pass through any opening. Guards shall not have an ornamental pattern that would provide a ladder effect.*

In practice, the BOCA® standard often is implemented by 1-inch wooden balusters spaced 3 7/8-inches as is typical for new residential decks.

The 1992 AASHTO standard is more consistent with the expected use of a pedestrian bridge. The dimensional requirements are presented below.

> ***Rail Spacing.*** *Within a vertical band bordered by the walkway surface and a horizontal line 3 feet 6 inches above the surface for pedestrian railing, and 4 feet 6 inches above the surface for bicycle railing, the maximum clear vertical opening between horizontal rail elements is 15 inches (AASHTO 2.7.1.2.4 and 2.7.2.2.2). Vertical elements of the railing assembly shall have a maximum clear spacing of 8 inches within this band. If the railing uses both horizontal and vertical elements, the spacing requirements apply to one or the other, but not to both.*

In 1996, after the Pochuck Quagmire Bridge was completed, the AASHTO standard was revised to a more stringent 6-inch and 8-inch spacing between the horizontal rail members. The 1996 AASHTO standard is presented below.

> ***2.7.3.2.1*** *The minimum height of a pedestrian railing shall be 42 inches measured from the top of the walkway to the top of the upper rail member. Within a band bordered by the walkway surface and a line 27 inches above it, all elements of the railing assembly shall be spaced such that a 6-inch sphere will not pass through any opening. For elements between 27 and 42 inches above the walking surface, elements shall be spaced such that an eight-inch sphere will not pass through any opening.*

The intent of the AASHTO standard is to prevent pedestrians from falling through the rail system. Aside from the spacing limitations, the major difference between the two standards is that AASHTO allows a horizontal rail system, which under BOCA would provide a “ladder effect.”

After much discussion, the bridge was built to both the AASHTO and BOCA® guardrail standards. This was prudent from a public safety and risk management perspective. The rail system at the platform at either end of the bridge was built to the 1992 AASHTO rail standard, but had 1-inch by 1-inch polycoated wire mesh attached to the inside face. This exceeds the BOCA® standard, but seemed appropriate because this is where people would tend to gather. The suspended walkway “truss” rail system was built to the 1992 AASHTO rail standard.

User Education

Although the bridge is constructed to code requirements and exceeds normal and customary standards for trail suspension bridges, good risk management dictated some public education concerning the use of the bridge. Public education consists of a series of notices and signs on both sides of the bridge advising the user public as follows:

- The bridge is limited to foot traffic.
- Although the bridge is designed for a live load of 30,000 pounds (110 people in a snowstorm), it was decided to post the occupancy of the bridge at 20 people. This was done for common sense reasons.

Case law in New Jersey indicates that when one has a bridge over a body of water and the body of water is known to be used for recreational purposes, it is prudent for the owner to post warning signs advising the public as to the inherent risk of jumping off the bridge. Either end of the Pochuck Quagmire Bridge is posted with a sign that reads “Shallow Water - Hidden Hazards.”

Project Safety Plan — Worker Safety

The 5,239 people hours on the bridge construction was completed with no accidents or injuries. This track record is especially good in that 53 percent of the people hours were performed by NY-NJ Trail Conference layperson volunteers performing a large variety of unfamiliar tasks in sometimes less than ideal conditions. This success on project safety was in large part due to the positive management style of Mr. Powers that created an awareness among all participants.

Prior to each day’s work, a “tailgate” meeting at the jobsite was held. The meeting would include the following:

- The work tasks to be undertaken that day. What-Who-Where-How.
- The possible hazards and safety measures to be employed.
- It was stressed to all the volunteers that if they were uncomfortable with a given task, either ask questions or ask for another job — there was plenty of work to go around.

The position the project engineer took is that although the project was volunteer driven, it should be treated no differently than any other major construction project. If the Pochuck Quagmire Bridge was being built by a professional contractor, the work force would be subject to Occupational Safety and Health Act (OSHA) regulations. Since NJ Parks and Forestry employees were involved, and indeed in charge of the job site, Public Employees Occupational Safety and Health Act (PEOSHA) applied to the project. In addition to the moral responsibility, a legal responsibility existed to implement a project health and safety plan, which was based on the following:

- Health and safety policy and program of the NJDEP, 5/20/91.
- N.J.S.A. 34:6A-25 PEOSHA.
- Condition 6 of the NJDEP stream encroachment permit specified that “no work shall be undertaken until such time as all other required approvals and permits have been obtained.”

Worker safety, legal requirements, and common sense risk management dictated that the Pochuck Quagmire Bridge have a written safety plan for the project manager to implement.

Ms. Mary Z. Rudakewych, the Program Manager of the NJDEP Office of Occupational Health and Safety, prepared a project specific-site specific Health and Safety Plan for the Pochuck Quagmire Bridge. The entire plan is included in Appendix A. It is not a standard or specification, but is offered as a planning guide for parties considering a similar project. It is an essential part of work safety and risk management to have a planned, written safety plan.

A court case, which was winding its way through the legal system while the Pochuck Quagmire Bridge was under construction, highlights the responsibility of project professionals to worker safety. In May 1996, the Supreme Court of New Jersey held in *Carvalho v. Toll Brothers and Developers, et al.* 143 N.J. 565, 675 A.2d 209 (S. Ct. N.J., 1996) that an engineer with authority to stop work on the project but no contractual obligation to ensure worker safety at the job site, nevertheless has a duty to stop work when he (or she) becomes aware of on-site conditions posing a foreseeable risk of serious injury to workers of a contractor or subcontractor. In *Carvalho, supra*, a worker was killed when a deep sewer trench collapsed. The trench was not shored, nor was a trench box being utilized. The Court also inferred in its decision that exculpatory or indemnification provisions in an engineer's agreement with the owner or contractor will not exonerate the engineer from potential third-party negligence claims arising out of worker injuries from unsafe site conditions.

The *Carvalho, supra,* court case involved facts that are comparable to the Pochuck Quagmire Bridge project as well as procedures common to many construction projects. The project engineer in *Carvalho, supra,* was retained by West Windsor Township to prepare plans for the construction of sewer service in Assunpink Basin. Upon receiving project approvals and permits, the engineer entered into a separate agreement with the Township to oversee the progress of the work and to conduct periodic site inspections to confirm that the work was being performed in conformance with the plans (similar to the Pochuck Quagmire Bridge project). The engineer was neither contractually responsible for the contractor's "means and methods" on the job, nor was the engineer obligated to ensure the contractor's compliance with worker safety programs and guidelines (similar to the Pochuck Quagmire Bridge project). The engineer was not in "control" of the job site. Historically, only the party who controls the site and has the authority to stop work can be responsible for safety. The Engineer-Township agreement also contained a clause exculpating the engineer from third-party tort claims arising out of his supervision of the work on the project. In addition, the contract between the Township and the contractor contained a clause requiring the contractor to name the Township and the engineer as additional insureds on its general liability policy.

As in most construction projects, the engineer in *Carvalho, supra,* had the right to stop work if something was not being performed in accordance with the plans and specifications. This responsibility was inferred in the NJDEP Permits issued on the Pochuck Quagmire Bridge project as well as the Department of Treasury Division of Building and Construction (DBC) contract. The *Carvalho, supra*, engineer had a full time on-site inspector to ensure compliance with the project specifications.

The *Carvalho, supra*, decision held that the engineer's duty was not defined and limited solely by the contractor. The court relied on the ruling in the case of *Balagna v. Shawnee County*, 233 Kan. 1068, 668 P.2d 157 (1983). In that case, the engineer, who had prepared the contract provisions covering safety, knew that an unshored trench was dangerous and violated government standards. As in the *Carvalho, supra*, case, the engineer had the authority to stop the work, or at least to say something to the contractor, and could not deny that he had knowledge of the importance of safety precautions during the excavation of the trench.

Despite his knowledge, the engineer claimed that he would have exceeded his authority had he made efforts to warn the workers in the trench of its dangerous condition. The court held that it was up to a jury to decide if the engineer had acted reasonably. The New Jersey court decided that fairness and public policy require the imposition of a duty upon the engineer having actual knowledge of unsafe practices on the job site to do something to prevent injury to the workers imperiled.

The *Carvalho, supra*, court determined that the engineer had sufficient control to halt work until adequate safety measures were taken. The court also determined that the engineer, through its on-site inspector, had actual knowledge of a dangerous condition at the jobsite. In failing to avert harm, the court decided that the engineer breached a legal duty to the worker who was killed as a result of an unsafe site condition. The *Carvalho, supra*, court further ruled that an exculpatory clause in the engineer's contract regarding liability for third-party tort claims is unenforceable as to a direct claim for negligence by the injured plaintiff. Thus, although the engineer in *Carvalho, supra*, may have had contractual remedies against the Township and/or contractor for indemnification, the engineer was left "holding the bag" because the contractor's insurer was insolvent and the tort claim asserted against the Township was dismissed as untimely.

While each case will obviously turn on its own unique set of facts and circumstances, the *Carvalho, supra*, decision places engineers, project directors, managers, coordinators, and other professionals on notice that they can be exposed to tort claims and potential liability arising from on-site injuries to workers, regardless of what contractual protection they obtain from owners or contractors against such claims. A contract obligation to inspect work for conformance with the contract or permit documents coupled with the general authority to halt work on a job site appears now to have given rise to a duty to stop work on a job, or at least say something to the contractor, where any known, apparent or reasonably foreseeable safety hazard exists. In addition, the *Carvalho, supra*, decision makes it clear that where such a duty is found to exist, it may prevail over exculpatory or indemnification provisions included in the contract for work.

> ** Comments of the above case represent the author's opinion and are not a conclusive statement of the law of the case.**

Insurance

The last element of the Safety and Risk Management Plan of the Pochuck Quagmire Bridge was to provide proper insurance protection for all the participants. The primary liability (tort claim) and injury protections due to volunteers working on the Pochuck Quagmire Bridge were afforded through the federal Volunteers-in-the-Parks program (known as VIP), and administered by the National Park Service (NPS) for "operation, development, maintenance and monitoring of the Appalachian Trail." This program has a sister program - the Volunteers-in-the-Forests (VIF) that extends to volunteers working on the Appalachian Trail in National Forests. The program considers bona fide Appalachian Trail volunteers as federal workers vis-a-vis the Trail, thus enjoining the US Government to defend (provide indemnity to, and legal representation for) volunteers if they are named in a liability lawsuit concerning alleged injury or damages while on the Appalachian Trail.

The program also considers Appalachian Trail volunteers as federal employees to receive supplemental medical coverage in the case of in-the-field injury in connection with their Appalachian Trail duties as quoted above. This coverage is intended to supplement a volunteer's own medical insurance, but can be used as the primary coverage if a volunteer has no medical coverage. Use of the medical provision, as a primary coverage, for treatment has not been tested on NY-NJ Trail Conference projects in terms of a claim actually being paid by the US Government (luckily no in-the-field mishaps). As would be expected, the paperwork is tedious and very time-consuming. The Trail Conference (or other officially designated Appalachian Trail clubs) must be the intermediary to get the appropriate information to, and forms from, the NPS Appalachian Trail office concerning any injury, claim, or lawsuit. The NPS provided VIP protection for the 2,285 volunteer work hours on the Pochuck Quagmire Bridge project.

The Trail Conference has its own commercial liability insurance to protect the organization, its officers, staff, and volunteers. Such a policy may not be feasible to all non-profits (especially small groups), and they should investigate state and federal agency programs to include volunteers, similar to the VIP/VIF. The Conference's policy covers Trail Conference volunteers for liability claims (alleged bodily and property injury to others) when the volunteers are acting within the "scope" of their work (trail maintenance, building, planning, development) for the Conference. While the NJ State Park Service does not have liability protection for organized group volunteers, such as those working for the Trail Conference, they do have an individual VIP program called their "direct VIP." In the case of the Pochuck Quagmire Bridge, the State was considering all volunteers direct VIPs rather than volunteers under the Trail Conference's banner. Then, volunteers could be considered State employees and eligible for protections similar to the federal VIP program. During the development of this case study, volunteer protection legislation has passed both the New Jersey State Assembly and Senate. It was signed by Governor Christine Todd Whitman in August of 1997. This legislation extended provisions for worker's compensation and casual liability protection to volunteer workers on state park lands. In addition, on May 21, 1991, the U.S. Congress passed the Volunteer Protection Act of 1997 (H.R. 911) which was subsequently signed by President Bill Clinton.

Unfortunately, the various insurance programs did not provide appropriate insurance protection to a key volunteer, the project engineer. This problem would delay the construction one year as well as result in significant additional administrative time and monetary expense.

When the NY-NJ Trail Conference undertook the planning of the project in 1991, the 10,000 person membership was canvassed for those with experience in the design and construction of bridges. Mr. Tibor Latincsics, P.E., an individual member of both the NY-NJ Trail Conference and Appalachian Trail Conference responded to the inquiry. His volunteer services were provided to the NJDEP Division of Parks and Forestry via the NY-NJ Trail Conference. These services included a diverse range of tasks, such as monitoring soil test holes, writing public notices, environmental permits, grant applications, and the various bridge designs. Several NJ state laws require that a bridge must be designed by a licensed professional engineer. This fundamental requirement ensures the safety, health, and welfare of the public. The numerous construction and environmental permits required to construct the bridge also needed to be prepared under the direction of a professional engineer (P.E.) simply to be filed. Once approved, the permits would only be valid if the project was under the supervision of a P.E.

When the NY-NJ Trail Conference targeted the bridge project with the NJDEP Division of Parks and Forestry in 1991, the only provision to the volunteer administrative, planning, and engineering services being provided was that the volunteer engineer be provided with appropriate insurance protection. The concern was not structural failures but rather nuisance lawsuits from people slipping, tripping, or inappropriately jumping off the bridge. The volunteer engineer and the non-profit Trail Conference were advised that this was possible. Field work was initiated, and administrative and engineering tasks were completed. Environmental and construction permits were obtained. Construction of the CCA.60 Light Frame Construction Suspension Bridge Design was initiated.

Subsequently, the NJDEP Division of Parks and Forestry advised the NY-NJ Trail Conference and the engineer that they could not provide insurance protection for the engineer as a matter of policy. The request for insurance protection was revised to an indemnification document against tort claims. The NJDEP also rejected this alternative. A dilemma developed: after years of planning with the critical mass of design-permits-material and peoplepower ready to go, there appeared no mechanism for the NJDEP to provide tort liability insurance to a P.E. acting in a volunteer capacity. The engineer withdrew from the project. Without a professional engineer's formal participation the project came to a standstill in the quagmire.

With the short construction window of the 1994 autumn rapidly approaching, alternative means of insurance were scrutinized. The VIP program was reviewed, and it was determined that its main focus was bodily injury to a volunteer while working on a project. The fact that the VIP insurance program had never been tested did not provide a high confidence level. The general liability policy of the NY-NJ Trail Conference was examined, and it was determined that the design and construction oversight of suspension bridges was outside the normal scope of the insured activities.

The insurance dilemma is a common one facing public service organizations. How does an organization attract interested volunteers if they face the threat of lawsuits in exchange for their good will? Some protection is provided in New Jersey under N.J.S.A. 2A:53A-7. This information was provided to the project partnership by the NJDEP Division of Parks and Forestry in an attempt to restart the project. N.J.S.A. 2A:53A-7 reads as follows:

> ***25A:53A-7.*** *Non-profit corporations and associations organized for religious, charitable, educational or hospital purposes; liability for negligence:*
>
> *No nonprofit corporation, society or association organized exclusively for religious, charitable, educational or hospital purposes shall, except as is hereinafter set forth, be liable to respond in damages to any person who shall suffer damage from the negligence of any agent or servant of such corporation, society or association, where such person is a beneficiary, to whatever degree, of the works of such nonprofit corporation, society or association; provided, however, that such immunity from liability shall not extend to any person who shall suffer damage from the negligence of such corporation, society, or association, where such person is one unconcerned in and unrelated to and outside of the benefactions of such corporation, society or association, but nothing herein contained shall be deemed to exempt the said agent or servant individually from their liability for any such negligence. This statute has been revised since the insurance issue for this project was dealt with. N.J.S.A. 2A:53A-7 was amended in 1995 by L. 1995, C. 183.*

New Jersey case law examples of N.J.S.A. 2A:53 A-7 show various applications and outcomes, as in the following cases:

- *Pomeroy v. Little League Baseball of Collingswood*
- *Kirby v. Columbian Institute*
- *Jacobs v. North Jersey Blood Center*
- *Peacock v. Burlington County Historical Society*

The NJDEP Division of Parks and Forestry made the conclusion that based on N.J.S.A. 2A:53A-7, any agent or servant of the non-profit NY-NJ Trail Conference would be immune from tort liability for charitable work donated or performed on behalf of the NY-NJ Trail Conference. Therefore, so long as the engineering and design services for the bridge were donated to and were a function of the NY-NJ Trail Conference activity, said servant performing such function would be granted immunity from tort liability, so long as any damage resulting from said servant's action was not a willful, wanton, or grossly negligent act of commission or omission.

Relying on N.J.S.A. 2A:53A-7 had several drawbacks:

- What if the plaintiff was not a beneficiary of the NY-NJ Trail Conference? Chances are that someone misusing the bridge would not be a member. A 1989 tragedy and subsequent 1992 lawsuit highlights the sometimes foolish acts of the populace. On October 28, 1989, a tourist bus stopped at the historic 77-year-old pedestrian suspension bridge over the Little Red River in Cleburne County, Arkansas. Forty tourists disembarked from the bus, mounted the bridge and started to swing it side to side. The cables snapped. Five people were killed and dozens injured. The families of the deceased and injured sued Cleburne County on the basis that the County violated the victims rights to due process and that the County and adjacent landowners were negligent in warning tourists of the hazards of the 77-year-old bridge. The suit included the diner where the tourist bus parked, although no tourist even purchased any food at the diner. Eventually in 1996 the Circuit Court of Appeals ruled in favor of the defendants.

- N.J.S.A. 2A:53A-7 would not prevent improper suits from being filed to which the engineer as a private individual would have to answer to, nor does it provide resources with which to prepare a defense. An innocent person could be bankrupted while a suit is pending.
- Proceeding with the project based on N.J.S.A. 2A:53A-7 would have resulted in a peculiar reversal of the roles. The public-private partnership was based on the NY-NJ Trail Conference providing volunteer technical, administrative, and construction peoplepower to the NJDEP Division of Parks and Forestry in order to assist the NJDEP in closing a missing link in the Appalachian Trail corridor. The bridge is a State structure on State land fulfilling a responsibility of the State. It was not the responsibility of the non-profit NY-NJ Trail Conference to insure a State project.

The 1994 autumn construction season passed by without this dilemma being resolved. No construction took place. With the 1995 construction season rapidly approaching, a solution was needed. To resolve the problem, the volunteer engineer and the firm of Conklin Associates, with whom Mr. Latincsics is employed, was retained by the DBC at the request of the Division of Parks and Forestry to perform as project engineer. A requirement to bid on the engineering of the project was having a one million dollar liability insurance policy. Conklin Associates received a professional fee for their services.

Project Engineering

From 1991 to early 1995, the author served as project engineer in a volunteer capacity. Much of the site assessment, research, field inventory, design, and legwork resulting in the Pochuck Quagmire Bridge was performed in this time period. In late May 1995, Conklin Associates, the firm with whom the author is employed, was retained by the DBC at the request of the Division of Parks and Forestry to finalize the project design and permits. The DBC contract specified a 45-day time limit to ensure the project would meet the short late summer construction window in the quagmire. Among the engineering, survey, and project administration services Conklin Associates performed in this 45 days were the following:

- Finalize geotechnical investigations.
- Three-mile double rod bench run to establish a benchmark in USGS 1929 Datum on the site.
- Verify that the bridge site is in the trail corridor by survey.
- Survey stakeout of the foundation, towers, and anchors.
- Basic hydrologic investigation.
- Foundation and anchorage design.
- Suspension bridge design and plans.
- Detailed material list by quantity and cost.

- NJDEP Stream Encroachment Permit.
- NJDEP Wetlands General Permit #17.
- DBC permit.
- Army Corps of Engineers permit.
- Soil Conservation District waiver.
- Threatened and Endangered Species review.
- Attendance at project meetings.
- Purchasing agent responsibilities.
- Project administration.

The project went to construction immediately after all permits and approvals were granted. During construction, Conklin Associates was retained to provide the following professional services:

- Construction survey support.
- Inspection and acceptance of material.
- Construction supervision and inspection.
- Assistance in project administration to Mr. Powers.
- Cable saddle shop drawings.
- Certification of finished bridge.

The author found the bridge construction to be most enjoyable.

Long-Term Maintenance

The routine maintenance of the bridge consists of treating the CCA lumber with Thompsons Wood Preservative on an annual basis. Another important maintenance task is the annual lubrication of the main catenary cables and suspenders with Prelube 19 HV. This is a high viscosity preservative, wire rope lubricant, and protector. An important characteristic is that it is environmentally sensitive. It is biodegradable, nonhazardous, and nontoxic. Appalachian Trail Committee policy on large bridges is that they should be periodically inspected by the landowning agency partner, Appalachian Trail Committee, or their designees. In this particular case the NJDEP Division of Parks and Forestry is responsible to have the bridge inspected by a P.E. with expertise in suspension bridges. With proper maintenance and inspections, the bridge will serve its 25-year design life.

Project Value Accounting

A detailed breakdown of peoplepower, material, and equipment, as well as summaries of the same, are provided. The purpose of this is two-fold. The first is to document the final cost and secondly from where the peoplepower and funding came. This accounting is valuable information for future projects because it provides an indicator as to the resources that must be dedicated to a suspension bridge of this style and span.

Material

1.	Material purchased by the State of NJ via cash transaction	$22,323	
2.	Material purchased via Forest Service WIT Grant	$10,000	
3.	Material value donated by GPU Energy and others	$3,513	
		$35,836	**(36.4% of total cost)**

Machine Time

4.	Heavy machinery & tool value donated by GPU Energy	$ 7,402	
5.	Trucking provided by the State of NJ	$1,005	
6.	Hand tools purchased by the State of NJ	$992	
7.	Tools provided by Trail Conference	$1,345	
		$10,744	**(10.9% of total cost)**

Work-Hours

8.	1,309 State employee work-hours (25%)	$19,635	
9.	1,150 N.J. Corrections work detail (22%)	$1,100	
10.	2,780 Volunteer work-hours (53%)	$31,074	
	5,239 Total Work-Hours	**$51,809**	**(52.7% of total cost)**

Direct Cash Cost = Above Items: 1 + 2 + 6 + 8 =	$52,969	(54% of total cost)
Donation Value = Above Items: 3 + 4 + 5 + 7 + 9 =	$45,420	(46% of total cost)
Project "Construction Cost"	***$98,389***	

The volunteer-driven, public-private partnership provided a bridge that was estimated to cost $208,000 by the DBC 1985 pre-design study. Adjusting to 1995 dollars and incorporating expenses not envisioned by the pre-design study, it can be stated without reservation that the **true project value is $300,000 or more**. This $300,000 value was built by purchasing $32,323 in material, utilizing donated material, enlisting the aid of resources from the NJ Division of Parks & Forestry, the field know-how and equipment of GPU Energy, and most significantly, the labor and interest of the NY-NJ Trail Conference.

Summary of Construction Costs

	Purchase	Donation
Heavy Equipment		$7,657
Foundation	$8,030	2,202
Towers	775	2,192
Walkway, Rails, Stairs	13,563	
Suspension	9,184	560
Tools	1,168	2,095
Misc.	771	6,590
Total	**$33,491**	**$21,296**

Total Bridge Span	=	146'
Bridge Walkway Width	=	44"
Bridge Square Footage	=	535 S.F.
Total Project Cost per Foot of Span	=	$674
Total Project Cost per Square Foot	=	$184
Total Material Cost per Foot of Span	=	$245
Total Material Cost per Square Foot	=	$ 67
Tool & Labor Cost per Foot of Span	=	$429
Tool & Labor Cost per Square Foot	=	$117
CCA #1 KDAT SYP Lumber Superstructure Cost, Material Only	=	$14,338 @ $98.20/Foot of Span or $26.83/Square Foot

Material and Equipment Cost Breakdown

PF = NJ Division of Parks and Forestry
TC = NY-NJ Trail Conference*

Use & Item	Cash Provided By:		Donations Provided By:	
Foundation				
1.75" Sixplex Swamp Anchors, Ext. Rod, Shackle	TC	$2,166.18		
1.5" Helical Pier Foundations	TC	$778.00		
Guyline Anchors			GPU Energy	$1,302.00
Crushed Stone				
Tensar Geogrid 1400	PF	$598.00	T. Latincsics	$900.00
#18 Rebar	PF	$172.00		
#3 - #8 Rebar	PF	$894.50		
Fiber Form	PF	$672.00		
32 C.Y. Concrete	PF	$2,114.90		
Concrete Pumping	PF	$635.00		
		$8,030.40		$2,202.00
Towers				
Four 40' Class 1 Transmission Poles			GPU Energy	$1,200.00
Four 20' Class 4 Transmission Poles			GPU Energy	$300.00
3" x 10" Timbers	PF	$775.20		
3/4" Bolts, Nuts, Washers			GPU Energy	$280.00
1/2 Circle Spike Grids (48)			GPU Energy	$96.00
1/2" Structural Strand Guy Lines			GPU Energy	$120.00
Four J6270 Pole Band Assembly			GPU Energy	$80.00
Four Foundation Rebar Pole Band Assembly			GPU Energy	$80.00
Twelve Yellow Plastic Guy Line Guard			GPU Energy	$36.00
		$775.20		$2,192.00

* Includes USDA Forest Service Funding

PF = NJ Division of Parks and Forestry
TC = NY-NJ Trail Conference*

Use & Item	Cash Provided By:		Donations Provided By:	
Truss Bridge Walkway, Platforms and Stairs				
21 Milled 6"x6"x10' #2 SYP CCA.40	PF	$1,155.00		
#1 SYP CCA.40 KDAT 19% Lumber	PF	$10,479.00		
Screws, Nails, Bolts, Framing Angles	PF	$1,929.23		
		$13,563.23		
Suspension System				
Cable Saddles (4)	PF	$3,200.00		
Two 200' 1" 6x25 EIP IWRC Wire Rope with Spelter Sockets (4)	PF	$1,393.68	Transport - GPU Energy	$400.00
Four 1-3/4" 24" Turnbuckles	TC	$1,000.00		
Forty-two Piggy Back Clips	TC	$861.00		
1/2" 6"x19" Wire Rope to 30" Threaded Rods	TC	$2,603.52		
Forty-two Square Nuts	TC	$126.00		
Eighty 3"x3"x1/4" Square Galvanized Washers			GPU Energy	$160.00
		$9,184.20		$560.00
Miscellaneous Material				
1"x1" Poly Galv Mesh	PF	$561.30		
Screw Tips, Saw Blades	PF	$200.00		
Bit. Water Proof	PF	$10.00		
		$771.30		
Subtotal:		*$32,323.33*		*$4,954.00*
Access Prep				
Dump Trucks @ $250 - $450/Day				$4,150.00
Backhoe @ $700/Day				$3,850.00
Filter Cloth, Seed			P.Bell	$225.00
Crushed Stone			P.Bell	$636.00
Dock & Steel Plate for Temporary Bridges			PF	$500.00
				$9,361.00**
Heavy Machinery for Tower and Bridge Construction				
Swamp Anchor Track Digger, 17 Hr @ $66/Hr.			GPU Energy	$1,122.00
Digger Truck, 13.5 Hr @ $58.44/Hr				$790.00
Cherry Picker Bucket Truck, 20 Hr @ $58.50/Hr			GPU Energy	$1,170.00
JD710 Backhoe for Foundation X, 21 Hr @ $66/Hr			GPU Energy	$1,386.00
JD450 Bulldozer 28 Hr @ $78/Hr			GPU Energy	$2,184.00
Flatbed Trucks & Dump Body			PF	$1,005.00
				$7,657.00

*Includes USDA Forest Service Funding
**Excluded from the total cost. For details, see: "Project Cost Tabulation Exclusions" on page 88.

PF = NJ Division of Parks and Forestry
TC = NY-NJ Trail Conference*

Use & Item	Cash Provided By:		Donations Provided By:	
Hand Tools and Equipment				
Power Miter Chop Saw	PF	$367.00		
(4) Winch Hoist	PF	$525.00		
High Wire Scaling Ladder			GPU Energy	$400.00
Power Handsaws, Drills, Hand Tools, Generator, Extension Cords, GFI			T.C. P.F.	$1,000.00
Contractor's Table Saw			T. Latincsics	
Hard Hats, Goggles, Gloves, Fall Protection	PF	$100.00		
Kelly Bar Adapter	TC	$37.00		
Torque Indicator			NJ Transit	$345.00
SS175 Drive Tool	TC	$49.00		
Flange to Flange Adapter	TC	$90.00		
Chain Saws, Peavees			GPU Energy	$150.00
Power Brush Cutters			Trail Conference	
Block & Tackle, Pulleys			GPU Energy	$200.00
Transit, Surveyor's Level, Steel Tape, Impact Wrench			Conklin, GPU Energy	
		$1,168.00		*$2,095.00*
Miscellaneous				
On-Site Hospitality (Food & Liquids)			P. Bell	$3,000.00
Project Phone Bills				$400.00
Porta-John				$200.00
Project Administration			T. Latincsics	$2,030.00
Blueprints			Conklin	$100.00
20% Discount by Chance				$500.00
Baldwin Stone Discount				$360.00
				$6,590.00
Total		**$33,491.33**		**$21,296.00**

*Includes USDA Forest Service Funding

Peoplepower Breakdown: Bridge-Specific Construction Only

State Employees				
Wes Powers - Project Manager	468 Hours	@ $15.00/Hr	=	$ 7,020.00
NJ State Park Personnel	793 Hours	@ $15.00/Hr	=	$11,895.00
NJ Forest Fire Service	48 Hours	@ $15.00/Hr	=	$ 720.00
NJ Corrections Work Detail	1,150 Hours	@ $ 1.00/Hr	=	$1,150.00
Subtotal	**2,459 Hours (47%)**		**=**	**$20,785.00**

Volunteers				
Trail Conference Volunteers	2,285 Hours	@ $8.00/Hr	=	$18,280.00
Pete Morrissey, GPU Energy Foreman	175 Hours	@ $29.25/Hr	=	$ 5,120.00
GPU Energy Linemen	225 Hours	@ $25.68/Hr	=	$ 5,778.00
GPU Energy Equipment Operators	62 Hours	@ $22.85/Hr	=	$ 1,417.00
GPU Energy Utility Workers	33 Hours	@ $13.00/Hr	=	$ 429.00
Subtotal	**2,780 Hours (53%)**		**=**	**$31,024.00**
Grand Total	***5,239 Hours***			***$51,809.00***

Peoplepower Breakdown Discussion

As indicated in the peoplepower hour tally, "a bouillabaisse" of people were involved in the bridge construction. These people varied from expert to layperson. The person-hour tally is only that time specifically involved with actual construction of the bridge. It does not include site access preparation, survey work, engineering design, or the administration time leading up to the actual construction or required to mobilize the volunteers. This allows one to utilize the construction person-hour total for comparison and planning purposes. A total of 5,239 hours was spent on the bridge construction, of which 2,780 hours or 53 percent was provided by the volunteer sector. Another 1,309 hours or 25 percent was State Park Service employee time. A NJ Corrections work detail provided the remaining 1,150 hours or 22 percent.

In order to establish the project "construction cost," a dollar value had to be determined for the variety of peoplepower, both volunteer and professional. For the State employees this was easy. A generic average wage per hour regardless of job title was applied to their time. A similar procedure was used for the 495 volunteer hours donated by the GPU Energy volunteers. However in that case, the hourly wage assigned was consistent with their GPU Energy job title. Neither benefits nor overhead were included in the assigned wage.

Assigning a value to the 2,285 volunteer hours provided by the Trail Conference volunteers was a little more difficult. A wide range of tasks were completed by a variety of people with a wide range of skill levels. At least 55 individuals contributed. Trail groups assign volunteer time a value ranging from minimum wage to $8.00 per hour. Given the diversity and sometimes technical tasks for this project, the value of $8.00 per hour was utilized. The 1,150 hours provided by the State Correctional inmates was assigned a value of $1.00 per hour.

The important conclusion from this peoplepower tally is that projects of this nature require peoplepower resources measured in increments of thousands of hours.

Project Cost Tabulation Exclusions

In order for the "bottom line" numbers generated by this report to be utilized for future planning, costs not directly associated with the specific construction of the bridge were excluded from the final tabulation. These expenses could be characterized as unique to this project.

The first such expense was the access prep to the site. This will vary significantly from project to project. As listed in the detailed breakdown, Mr. Bell and his contractor friends donated $9,361 of machine time and material as well as 180 person-hours of labor. The second item is the miscellaneous items, which varied from the cost of soft drinks for the workers to the value of the blueprinting. These 100 percent donated items totaled approximately $6,590. Adding in the donated amount of $16,221 would bring the respective totals to the following:

Total Project Construction Cost	=	**$ 114,610**	
Direct Cash Cost	=	**$ 52,969**	**(46%)**
Donation Value	=	**$ 61,641**	**(54%)**

The third and fourth items not included in the cost tabulation are the project planning, administration, and engineering design. These processes date back approximately four years. The NY-NJ Trail Conference undertook the project leadership role in 1991, with Ms. Lutkenhouse, a professional staff member, serving as Project Director. A significant amount of time and resources was dedicated to the project. The engineering legwork leading to the final design was a volunteer endeavor by Mr. Latincsics. Among the purposes of this long-winded report is an attempt to compile the lessons learned in the Pochuck Quagmire to benefit future projects. Suspension bridges will continue to be a solution to long-span problem crossings.

Preliminary Project Cost Estimates

It is very helpful in preliminary project planning to be able to identify project cost on a “ballpark” level. The previous accounting should be helpful in this regard. This thought process shall be taken one step further by comparing the material costs of the Pochuck Quagmire Bridge to three other trail suspension bridge projects of the 1990s. Each project was unique in the problems it had to overcome, the standards to which it was built, and the resources available to the project owner. The variety in the projects allows one to establish a range in material costs for general planning purposes.

The first comparison project is the Smokey Angel Snowmobile Bridge (SAB) over the West Branch of the Sebasticook River in Hartland, Maine. The SAB is a 190-foot span by 5.4-foot wide bridge constructed in 1992 as a link in a snowmobile corridor. A photograph is provided in Appendix H. Similar to the Pochuck Quagmire Bridge, the SAB was constructed as a volunteer community project by the Smokey Angel Snowmobile Club. It also made adaptive use of readily available material. It was the recipient of a USDA Forest Service, Wood In Transportation grant. The SAB project engineer, Mr. Robert Doane, provided good practical advice and inspiration to the Pochuck Quagmire Bridge.

The second and third comparison projects are the Tye River and Hastings Trail Bridge projects. Both involve the reconstruction of the cable suspension system and the walkway of damaged bridges. In each case, the existing foundations are reutilized. The project expenses deal specifically with just the superstructure. The Tye River Bridge (also known as Cripple Creek) is one of the Appalachian Trail Suspension Bridges. It is located a short distance off the Blue Ridge Parkway south of Rockfish Gap. The bridge has a 148-foot span and a 26-inch wide walkway. It was originally constructed in 1972. The bridge appears to be the model for the later bridges in George Washington and Jefferson National Forests. Due to deterioration, the suspenders, walkway, and rail system were replaced in 1992 in a joint project between the Virginia Tidewater Trail Conference and the ATC Konorock Professional Trail Crew with the benefit of Forest Service supervision. This was another volunteer driven project.

The Hastings Trail Bridge in White Mountain National Forest, Maine, was reconstructed in the late summer of 1997. Because the existing foundation was reused, and there is a paved road to the site, the work was limited to the reconstruction of the towers, cables, and timber walkway. Since the river crossing is a critical link in a New Hampshire to Maine snowmobile corridor, the bridge width was expanded to 5.5 feet. The span is 179 feet, 7 inches. The bridge has been constructed to USDA Forest Service specifications and is a "showpiece" facility similar to the Lincoln Woods Trail Bridge. The project was put out to public bid by professional construction companies. The construction bids varied from $150,000 to $315,000, with the majority clustered around $185,000. The low bid of $142,675 was awarded the project. The superstructure material has a market value of approximately $66,500.

	Pochuck Quagmire Bridge	Smokey Angel	Tye River	Hastings Trail
Dimension	146 feet by 44 in.	190 feet by 65 in. plus ramps	148 feet by 27 in.	179.6 feet by 66 in.
Material Costs	$35,836 or $245/ft	$32,474 or $171/ft		$66,500
Heavy Equipment Costs	$7,657	$4,056 plus donations		
People-Hours	5,239	2,800	2,400	
Walkway Material Costs	$17,313 or $118/ft	$14,000 or $96/ft	$60,000 or $334/ft	
Project Cost	$98,400*	$59,4000*	$28,000	$142,675
*includes value of volunteer labor				

Because the Pochuck Quagmire Bridge and SAB share many similarities, and both bridges were "from scratch," comparison of the material costs is helpful.

Material costs for the Pochuck Quagmire Bridge and SAB projects are in the same general range, but the Pochuck Quagmire Bridge did require higher material costs for the following reasons:

- Most items tend to cost more in the New York Metropolitan area.
- The resourcefulness and community spirit of the Downeast Yankees behind the Smokey Angel Bridge put even the Pochuck Gang to shame. For example,
    - The SAB primary cables were donated by a ski lift company in Vermont. Pochuck Quagmire Bridge paid $1,394 for 400 linear feet of proof tested 6 x 25 wire rope with spelter sockets.
    - The material for the 28-foot SAB pylons were donated by a paper company. A local machine shop donated the use of their facility, allowing skilled volunteers to fabricate the towers and cable saddles. Pochuck Quagmire Bridge paid $3,200 for the fabrication of the cable saddles.
    - The Pochuck Quagmire Bridge primary catenary cables terminated in spelter sockets, chain shackle, and turnbuckles at all four ends. The turnbuckles alone cost $1,000. The SAB had the benefit of a skilled volunteer welder who substituted lower cost alternatives and wire rope clips.

- The Pochuck Quagmire Bridge engineer specified CCA.40 #1 KDAT 19% SYP for the dimensional lumber. This specialty item cost the Pochuck Quagmire Bridge $10,479. The SAB used CCA.40 #2 SYP from five different lumber companies donating 50 percent of the lumber.
- Both projects had significant foundation expenses. Interestingly, concrete costs the same in Maine as in New Jersey. This may be explained by the fact that the higher density of concrete plants in New Jersey results in more competitive pricing and lower transportation costs. The extremely poor subsurface Pochuck Quagmire Bridge soil conditions led to an innovative but extensive foundation system made up of the reinforced concrete snowshoe, geogrid, helical piers, and helical anchors. As previously explained, these innovations saved the project at least $14,000 in concrete costs. But the Pochuck Quagmire Bridge foundation system still cost $8,000. The SAB appears to have had more suitable subsurface conditions and, therefore, utilized a more conventional system with approximately 200 tons (100 CY) of concrete. This had a market value of $7,500, but 50 percent was donated. Both sides of the SAB river were accessible by vehicles, so the SAB project did not have to rent a concrete pumper as did the Pochuck Quagmire Bridge.
- Due to the construction codes in New Jersey, the Pochuck Quagmire Bridge is built to a more restrictive standard. The Pochuck Quagmire Bridge was designed for a live load of 78 PSF, while the SAB utilized a live load of 22.6 PSF. The higher standard led to higher material costs. For example, the SAB utilized 4-inch by 4-inch cross stringers, while the Pochuck Quagmire Bridge used 6-inch by 6-inch. The cost difference is significant.

To wrap up this line of thought and to provide some practical meaning to the array of figures provided, based on the Pochuck Quagmire Bridge, a concept “ballpark” project market cost can be estimated as follows:

- Identify the superstructure material costs based on the span, the bridge width, cablework, and towers. Double this figure for the completed value. Call this (A).
- Sitework, foundation cost, erosion control, and cleanup will equal (A) above. Call this (B).
- Engineering, survey work, soil borings, environmental studies, and project administration may equal at least 20 to 40 percent of A + B.

Planning purposes cost estimate = 1.2 to 1.4 x (A + B).

This is a simplistic estimate. It is up to the project planner to add in the additional costs for the normal and expected challenges.

Project Volunteers

Following is a full listing of the project volunteers. Photo 87 on page 92 is a partial group picture.

NY-NJ Trail Conference

Barry Beaver, Allen Bell, Paul Bell, Peter Bidoglio, Gene Bove, Allan Breach, Bob Busha, Bob Boyle, Paul Campbell, Doug Castellana, Jonathan DeCoste, Paul DeCoste, Dave Dougert, Joe Dowling, Rob Eldridge, Ann Fitzgerald, Terry Gallagher, Ron Geredien, Dave Giordano, Rudy Haas, Tom Hass, Hank Hagedorn, Doug Henckl, Rob Hill, Bob Jonas, Robert Kirchmer, Steve Klein, Andrew Latincsics, Bernadette Latincsics, Shauna Latincsics, Tibor Latincsics, George Lightcap, Harold Lott, Gregory Ludwig, Kevin Maher, Tom Majenski, Chris Mazza, Jason Meissner, Bob Messerschmidt, Martha Olsen, Jim Palmer, Walt Palmer, Sandy Parr, Steve Petshaft, Charles Rosien, Glenn Scherer, Helmut Schneider, Bill Shapiro, Dean Shemenski, Bev Shuppon, John Siebert, Steve Steele, William Stoltzfus, Jim Walsh, Dick Warner, and St. Thomas Episcopal Church of Vernon

GPU Energy

Michael Andrews, William Begraft, James Boyer, Robert Dixon, John Farr, John Johnson, Jeffrey Jordan, John Karcher, Alan Krosencky, Robert Hill, William Hulmes, Lou Merkooloff, Claude Morrissey, Peter Morrissey, Tim Parsons, Jeff Rowen, George Rowen, James Ward, Gary Weaver, Paul Williams, and Joel Wisnowski

Saint Benedicts Prep School - Newark, New Jersey

Students: Carlos Alverez, Matt Coleman, Terrance Eason, Kevin Harris, Boris and David Moyston, Peter Muniz, Terence Rivera, David Rodriguez, Jose Rosado, Jose Suarez, and Hector Vasquez
Faculty: Mike Friedman and Matt Higgins

Mountainview Correctional Facility

at High Point State Park; Detail 11 (Inmate Work Program)

Assistance and Support

NJ Assemblyman Walter J. Kavanaugh, Jack Penn, John Mulvihill, Mary Esposito, Anne Lutkenhouse, Herbert Schlesinger, P.E., the Appalachian Trail Conference, and the National Park Service

Photo 87. Project volunteers. Top Row; Left to Right: Wes Powers, Dick Warner, Greg Ludwig, Walt Palmer, Charlie McCurry, Alan Breach, Hank Hagedore, William Stoltzfus, Dean Shemski, Anne Lutkenhouse, Pete Morrissey, Paul Williams, Claude Morrissey. **Bottom Row; Left to Right:** Tibor Latincsics, Glenn Scherer, Paul DeCoste, Helmut Schneider, Chris Mazza, Dave Giordano, Paul Bell. *Photo courtesy of Ms. Marcy Dubinsky.*

New Jersey Department of Environmental Protection

State Park Service - Region III
Judy Babcock, Bill Hamilton, Charlie McCurry, Wes Powers, and Jimmy Scholts

NJ Forest Fire Service - Division A
Harold Lott

Occupational Health & Safety
Don Gates, Mary Rudakewych, and Lisa Weitz

Bureau of Inland Regulation
Sandy Adapon, Paul Drake, Steve Jacobus, and Gene McColligan

State Forestry Services
Edward Lempicki

New Jersey Treasury Department - Division of Building and Construction

Dale Smith, R.A.

USDA Forest Service

Dave Benevitch, Ed Cesa, Kasey Russell, Lanny Simmons, William Talley, and Terry Smith

Corporate Partners

A.B. Chance, Conklin Associates Engineers and Land Surveyors, Doran Sling & Assembly Corporation, GPU Energy, Mountainview Construction, R.S. Phillips Steel, Torsilieri Inc., R.J. Hill, Baldwin Quarry, and Fischer Thompson

20-20 Hindsight

As with most complex projects, all the project partners had a greater appreciation of the project upon its completion. Following is a listing of post construction "20-20 hindsight" comments as well as thoughts on improvements for future designs.

- A common question by reviewers of draft copies of this case study was why were the tower poles embedded in the soil as opposed to being mounted on concrete pedestals atop a concrete footing. The second alternative, as used in the USDA White Mountain National Forest, may result in a more durable structure or at least the concrete foundation can be re-utilized as is the case with the Hastings Trail Bridge. The answer is that the construction of the towers and foundation was performed by volunteer workers from GPU Energy and the NY-NJ Trail Conference. The construction was centered around a very short construction window utilizing GPU Energy standard procedures. Mounting non-uniform circular poles on an elevated concrete pedestal or wall is not standard utility company practice. Embedded utility poles have an effective life of 25 years or more. A concrete pedestal system should be considered if project resources allow.
- Attaching a 30-inch or 36-inch diameter reinforced concrete septic tank cover to the base of the tower poles with a lag screw would have increased the basal bearing area of the poles in the soft soil. This would have assisted when the poles were installed on a temporary basis.
- The exposed end grain at the top and bottom of the poles should have been sealed. This could be something as simple as bituminous roof tar with a plastic bag or more sophisticated like the coatings used on marine pilings.
- It should be investigated to see if a bridge socket can be attached directly to the square shaft of a Chance® Helical Anchor. This would simplify the anchorage attachment.
- The pros and cons of the various suspender configurations or combinations thereof as discussed on pages 60-63 should be considered.
- If a swaged threaded rod is used in the suspender assembly, such as in the Pochuck Quagmire Bridge, incorporating the rod as a component of the stiffening truss would be a major improvement.
- The Pochuck Quagmire Bridge stiffening truss does not act as an ideal load distribution member when a point load is directly over a cross-stringer. This could be remedied by making the suspender connections at the top of the stiffening truss, but this would be at the expense of the simple and effective cross-stringer connection.

- If possible, keep the cable saddles simple and uniform.
- Two-inch by six-inch decking was used on the Pochuck Quagmire Bridge. A suitable alternative is 1 1/4-inch by 6-inch decking. Using 2-inch by 4-inch dimensional lumber with a healthy gap would improve the aerodynamics of the walkway deck. For very long bridges or bridges in a windy location, open grating should be considered for the walkway.

Conclusion

The primary project goal of providing a safe, practical, durable, cost-effective bridge over the Pochuck Creek in order to relocate the Appalachian Trail from a dangerous 2.1 mile roadwalk into the protected trail corridor was achieved.

A cost-effective and practical design meeting all the project goals, as well as the limited resources of the project partners, was prepared. The Pochuck Creek was spanned by using common construction material in a creative and innovative manner. The construction was implemented by a unique public-private partnership. The primary project goal of providing a safe, practical, durable, cost-effective bridge over the Pochuck Creek in order to relocate the Appalachian Trail from a dangerous 2.1 mile roadwalk into the protected trail corridor was achieved. Other benefits or technical items demonstrated by this project are as follows:

- The bridge is a very visible and effective demonstration of modern timber bridge technology on a National Scenic Trail.
- Design standards for timber pedestrian suspension bridges were investigated. This project and case study publication has initiated a nationwide dialogue among engineers with an expertise in small scale suspension bridges. This technology transfer will benefit the public.
- This project documents that utilization of CCA treated lumber for bridges is not limited to short-span stringer bridges or truss bridges. This project clearly shows long-span lumber walkway suspension bridges are practical. This shall add to the recognition of CCA lumber as a proven construction material.
- The project introduced Chance® Helical Anchors and geogrid to the Appalachian Trail as alternatives or enhancements to traditional foundations. These are especially useful in environmentally sensitive areas or projects with poor access.
- The project shows that the Americans With Disabilities Act design standards can be attained in a cost-effective, practical manner, even in a remote, difficult location.
- A major project can be constructed with minimal environmental impact.
- The project initiated a meaningful dialogue and partnership between the USDA Forest Service, NJDEP, the Appalachian Trail Partners, and the local community.
- The rustic bridge complements and blends with the primitive Appalachian Trail experience.
- The design and construction followed a “conservation ethic” by utilizing donated and previously purchased material as well as the in-house talents of the project partners.

- The project complied with the NJDEP Wetlands and Flood Hazard Area Rules and Regulations.
- The bridge provides a fabulous elevated observation platform for environmental and floodplain education, wildlife and bird observation, and a wood turtle Geographic Positioning System tracking station. All this is achieved while protecting the fragile quagmire ecosystem.
- The Pochuck Quagmire Bridge has been called a remarkable achievement that underscores the success of public-private partnerships along the Appalachian Trail. The project is a good example of organizations and individuals working together to tackle a project beyond any one organization's resources.

Appendix A — Health and Safety Plan, Pochuck Bridge Construction Project

Submitted by

Mary Rudakewych, Program Manager
NJDEP Office of Occupational Health and Safety
September 11, 1995

Introduction

Project Description

Construction of a pedestrian suspension bridge across Pochuck Creek in the Appalachian Trail corridor.

Phases of Construction	Performed by
• Placement of bridge anchors	GPU Energy
• Erection of poles with guy cables	GPU Energy
• Framing of poles	GPU Energy
• Suspension of cables	GPU Energy
• Excavation for concrete footings	GPU Energy, volunteers
• Pouring concrete footings	Parks employees, inmates
• Installation of reinforcing rods	Parks employees, volunteers
• Prefabrication of frame sections	Parks employees, volunteers
• Suspension of frame sections	Parks employees, volunteers
• Construction of access platforms	Parks employees, volunteers
• Cutting and installation of decking	Parks employees, volunteers
• Prefabrication and installation of stairs	Parks employees, volunteers
• Site grading and drainage	Parks employees, GPU Energy

Scope of Safety Plan

Construction of the bridge will be performed by a variety of crews at various times. Crews will be composed of different combinations of crew members, depending on the phase of construction and work required. Crew members may consist of the following: GPU Energy (formerly JCP&L) employees, Appalachian Trail Conference members (volunteers), Division of Parks and Forestry employees, public citizen volunteers, private contractor volunteers, and Department of Corrections prison inmates.

This Safety Plan applies to all phases of construction and work performed by: Parks employees, Trail Conference members, all volunteers, and prison inmates.

This Safety Plan does not apply to work performed by employees of GPU Energy as those phases of construction are performed under the direction and supervision of a company designated senior project and safety manager and are under the jurisdiction of safety rules and work procedures normally used by GPU Energy.

The purpose of this safety plan is to identify the potential hazards associated with job activities and possible on-site conditions and to provide safety and health guidelines to address those specific hazards and to assist all concerned in complying with applicable standards as identified in this document or during subsequent site inspections.

This Safety Plan was developed on the basis of an initial site inspection visit and information obtained about construction plans from Wes Powers, the designated Site Project Manager, and is a revision of the Safety Plan submitted for review by Gregory Marshall, Director, Division of Parks and Forestry.

Organizational Responsibilities

Site Project Manager and Safety Officer

The designated Site Project Manager and Safety Officer for this project is Wes Powers. The Site Project Manager is responsible for coordination and direction of all site activities necessary to complete the construction project, including implementation of the Safety Plan.

The Industrial Hygiene and Safety Unit of the Office of Occupational Health and Safety shall serve as advisor and consultant to the Safety Officer on all health and safety related issues.

As the on-site Safety Officer, the Site Project Manager is responsible for the following:

- Conduct site evaluations to assess potential hazards.
- Enforce the Safety Plan and have authority to stop operations if personnel safety is jeopardized.
- Maintain all records required relating to the Safety Plan.

- Ensure that safety training is provided as required.
- Provide hazard information to on-site workers.
- Inform Industrial Hygiene and Safety staff of work in progress and status of construction project phases.
- Coordinate response activities during an emergency.
- Conduct safety meetings at the beginning of each work shift.

In an advisory capacity, the Industrial Hygiene and Safety Unit will conduct site visits at the beginning of each new construction phase to review the need for changes to the Safety Plan as the project progresses.

Hazard Assessment

Construction of the bridge can be divided into two main types of activities occurring at two different locations as follows:

- SITE A — Woodworking and prefabrication of frame sections at Wawayanda maintenance shop area.
- SITE B — Assembly and erection of bridge components at the Pochuck Creek site.

Different hazards are associated with each work site relating to the work performed as well as site conditions. The hazards will therefore be addressed in a site specific manner.

SITE A — Wawayanda Maintenance Shop Area

Job description

Woodworking and prefabrication of frame sections will occur outdoors near the Wawayanda maintenance shop and will require the use of electrical power tools such as skill saws, saber saws, and power cut-off saws. Workers will cut lumber which has been treated with wood preservatives. Seven sections of the frame, each twenty feet long, will be pre-constructed at Wawayanda to insure proper fit, and then disassembled and transported to the construction site for re-assembly and suspension at the bridge.

Hazard identification

a. *Use of power tools*

Improper use of power tools can result in serious injury such as cuts and amputations, as well as exposing employees to electrical hazards. Employees assigned to use such tools must demonstrate past experience in handling power tools and understand the hazards of woodworking. Electric power tools used in an outdoor environment must be used with a Ground Fault Circuit Interrupter (GFCI).

b. *Lifting, carrying, and manual loading*

Sprains, strains, and back injuries are the most common injuries resulting from improper lifting. All employees involved in lifting, carrying, and loading must be given training in proper lifting techniques. Manual lifting should be avoided as much as possible, and use of devices to assist in lifting should be used. Team lifting should also be encouraged when applicable.

c. *Health Hazards*

Potential for exposure to wood dust through inhalation, chemical wood preservative through skin contact or inhalation, and noise are of concern. All of these hazards will need further evaluation at the time woodworking begins for assessment of severity of exposure in order to recommend appropriate personal protective equipment. Material Safety Data Sheets (MSDSs) from the manufacturer of the wood preservative must be obtained and kept on site at Wawayanda in order to be made available for employee information.

d. *Personal Protective Equipment required at SITE A*

The following equipment should be available for distribution to workers engaged in woodworking: gloves, eye goggles or face shields, ear plugs, and dust masks.

Respirators may be required if additional industrial hygiene evaluation indicates they are needed.

Employees are required to provide and wear their own heavy construction type foot-wear.

SITE B — Pochuck Creek Bridge Construction Site

Job Description

Disassembled components of frame sections will be transported, unloaded, and re-assembled at this location. The frame section will then be lifted, positioned, and secured to construct the bridge. Two access platforms with stairs, one at each end, will also be constructed. Bridge decking, which has been pre-cut, will also be installed. The site will be graded for proper drainage. This phase of construction will involve the use of earth moving equipment, rigging equipment for lifting, and ladders.

Hazard Identification

a. *Fall Protection*

Fall protection such as ropes, harnesses, and retractable reels will be required for any person assigned to climb the unfinished bridge to secure the frame section during installation. Fall protection is also required when climbing support poles for any reason or when working at heights above 6 feet without the benefit of guardrails.

b. *Material Handling*

Rigging equipment used for material handling such as chains, slings, hoists, or wire rope must be inspected daily before use.

Hard hats must be worn whenever there is a danger of objects falling overhead or of being struck by moving objects or equipment.

Heavy duty construction-type foot wear provided by the employee must be worn by all persons on the construction site.

Workers required to do manual lifting must receive appropriate training.

c. *Electrical Hazards*

Ground Fault Circuit Interrupters shall be used for all electrical power tools at the site.

d. *Health Hazards*

Poison Ivy is endemic to this area. Employees must be informed that it is present in order to avoid contact. Insect bites including ticks are also of concern. Therefore workers must wear long pants.

e. *Personal Protective Equipment required at SITE B*

Hard hats, construction-type foot wear (provided by employee), eye protection, gloves, dust masks, and depending on levels of exposure - ear plugs or respirators

Applicable Occupational Safety and Health Administration Standards

Occupational Safety and Health Administration (OSHA) Standards which may apply at either or both location are as follows:

Safety and Health Regulations for Construction PART 1926

Subpart C - General Safety and Health Provisions 1926.20 - 1920.23
Safety training, record keeping, first aid and medical attention

Subpart D - Occupational Health and Environmental Controls 1926.50 - 52
Medical Services, sanitation, occupational noise exposure

Subpart E - Personal Protective Equipment and Life Saving Equipment
1926.95 - 1926.107
Foot protection, head protection, eye and face protection, hearing protection, safety belts, life line or lanyards, safety nets, working over or near water, respiratory protection

Subpart F - Fire Protection and Prevention 1926.150 - 151

Subpart G - Signs, Signals, and Barricades 1926.200 - 203

Subpart H - Material Handling, Storage, Use, and Disposal 1926.250 - 251

Subpart I - Tools - Hand and Power 1926.300 - 304
Hand, power, and woodworking tools

Subpart K - Electrical 1926.400 - 405
Assured equipment grounding

Subpart M - Fall Protection 1926.503

Subpart N - Cranes, Derricks, Hoists, Elevators, and Conveyors 1926.550, 1926.552
Material Hoists, personnel hoists

Subpart X - Stairways and Ladders 1926.1053

General Work Practices

The following work practices shall be adopted and implemented throughout the construction project:

The work area at the bridge construction site will include three separate zones: Right Bank, Left Bank, and Support Zone. The support zone will consist of an area outside the right and left bank zones. Eating, drinking, and smoking will be permitted in the support area.

All construction and inspection work performed on site will be done using the “buddy system.” Prior to beginning the work each day, buddies or work teams will be assigned. Team members will keep in contact with each other at all times, and report any hazards or injuries to supervision on site.

Inspected fire extinguishers shall be kept in designated areas in a proper quantity.

Warning signs will be affixed in readily visible locations near work areas and will include “Caution - Authorized Personnel Only.”

No food, beverage, or tobacco products may be present or consumed in the Bridge Erection Area (right or left bank zones). Smoking will only be permitted in the designated smoking area.

All emergency and first aid equipment will be placed in a designated, readily accessible area.

A two-way radio system will be located on site at the construction area.

All proper personal protective equipment shall be worn.

Training

All employees who work at a particular job site or task will have been trained in the associated hazards as per this Safety Plan. Employees will be informed of the following:

Applicable OSHA standards pertaining to their job.

Required use of personal protective equipment.

Potential health hazards.

Potential fire hazards.

Potential electrical hazards.

Potential woodworking tool hazards.

Procedures to follow in the event of an emergency.

Safety meetings for the purpose of training will be conducted at the beginning of each work shift or whenever new employees arrive on the job site.

Emergency Response and First Aid

The Site Project Manager is responsible for directing response activities during an emergency. These responsibilities include:

- Assessing the emergency situation and determining the required response measures.
- Notifying the appropriate response teams of the specific actions to be taken.
- Determining and coordinating the on-site personnel actions for the emergency.
- Contacting and coordinating appropriate governmental authorities.
- Completing the Supervisor Injury Report form immediately after an accidental injury has occurred.

Injured employees (except inmates) must complete the First Report of Injury or Illness form (RM2) and contact the Center for Occupational Medicine within 24 hours of the accident event.

At least one qualified person competent in both American Red Cross First Aid and Cardiopulmonary Resuscitation (CPR) techniques will be part of the work force on site.

A complete first aid kit will be readily available on site. The kit must include written instructions on how to contact Parks management to report an incident and to seek assistance.

If a serious injury occurs, the local hospital or first aid squad will be summoned to evacuate the injured or ill person.

Emergency Telephone Numbers

Project Manager:
Wes Powers
Office: (201) 827-6200
Home: (201) 948-3382

Appalachian Trail Conference:
Paul DeCoste
Office: (201) 764-4481

Hospital:
St. Clair's Riverside Medical
Franklin, New Jersey
(201) 827-9121

Call Vernon Township - 911
for fire, police, ambulance, or other emergency response

Appendix B — American Association of State Highway Transportation Officials (AASHTO) Guide Specifications

In July 1996, the AASHTO Subcommittee on Bridges prepared a standard specification entitled "AASHTO Guide Specification for Design of Pedestrian Bridges." The guide specifications were adopted and published by AASHTO in 1997. The purpose of the guide is to serve as a voluntary standard for bridges which are part of highway facilities but carry primarily pedestrian and/or bicycle traffic. The guide specifications set forth minimum requirements which are consistent with current practice. Modifications may be necessary to address local conditions, such as snow load. Portions of the draft guide specification which deal with design loads follow, with the guide commentary in italics. As is the case with all references, the reader is advised to obtain a full copy. AASHTO can be contacted at 444 North Capital Street, N.W., Suite 249, Washington, D.C. Phone: 202-624-5800.

Guide Specifications for Design of Pedestrian Bridges

1.1 GENERAL

These guide specifications shall apply to bridges intended to carry primarily pedestrian and/or bicycle traffic. Unless amended herein, the existing provisions of the AASHTO Standard Specifications for Highway Bridges, 16th Edition shall apply when using these guide specifications. Either the Service Load Design or Strength Design (Load Factor Design) methods may be used.

1.1 GENERAL Commentary

This Guide Specification is intended to apply to pedestrian and bicycle/pedestrian bridges that are part of highway facilities; and thus, provide realistic standards that ensure structural safety and durability comparable to highway bridges designed in conformance with the AASHTO Standard Specifications for Highway Bridges. This specification should apply equally to all bridge types and construction materials, including steel, concrete, and timber.

The term primarily pedestrian and/or bicycle traffic implies that the bridge does not carry a public highway or vehicular roadway. A bridge designed by these specifications could allow the passage of an occasional maintenance or service vehicle.

This Specification allows the use of the service Load Design or Load Factor Design methods as provided by the AASHTO Standard Specifications. It is not presently for use in conjunction with the AASHTO Load and Resistance Factor Specifications.

1.2 DESIGN LOADS

1.2.1 Live Loads

1.2.1.1 Pedestrian Live Load

Main Members: Main supporting members, including girders, trusses, and arches, shall be designed for a pedestrian live load of 85 pounds per square foot of bridge walkway area. The pedestrian live load shall be applied to those areas of the walkway so as to produce maximum stress in the member being designed.

If the bridge walkway area to which the pedestrian live load is applied (deck influence area) exceeds 400 square feet, the pedestrian live load may be reduced by the following equation:

$$W = 85\left(0.25 + \left(15 \big/ \sqrt{A_1}\right)\right)$$

where "W" is the design pedestrian load (psf), and A is the deck influence area (square foot,) which is that deck area over which the influence surface for structural effects is different from zero.

However, in no case shall the pedestrian live load be less than 65 pounds per square foot.

Secondary Members: Bridge decks and supporting floor systems, including secondary stringers, floorbeams, and their connections to main supporting members, shall be designed for a live load of 85pounds per square foot, with no reduction allowed.

1.2 DESIGN LOADS Commentary

1.2.1 Live Loads

1.2.1.1 Pedestrian Live Load

The 85 lb/s.f. pedestrian load, which represents an average person occupying 2 square feet of bridge deck area, is considered a reasonably conservative service live load which is difficult to exceed with pedestrian traffic.

When applied with AASHTO service load allowable stresses or group 1 load factors for load factor design, an ample overload capacity is provided.

Reduction of live loads for deck influence areas exceeding 400 square feet is consistent with the provisions of ASCE 7-95 "Minimum Design Loads for Buildings and Other Structures," and is intended to account for the reduced probability of large influence areas being simultaneous maximum loading. For typical bridges, a single design live load value may be computed based on the full deck influence area and applied to all main member sub-components.

The 65 pounds per square foot minimum load limit is used to provide a measure of strength consistency with the new Load Resistant Factor Design (LRFD) specifications, which use 85 pounds per square foot combined with a lesser load factor than used under the Load Factor Design (LFD) specs.

Requiring an 85 pounds per square foot live load for decks and secondary members recognizes the higher probability of attaining maximum loads on small influence areas. Designing decks also for a small concentrated load, for example 1 kip, may be considered where the bridge may be subject to equestrian use or snowmobiles.

1.2.2 Wind Loads

A wind load of the following intensity shall be applied horizontally at right angles to the longitudinal axis of the structure. The wind load shall be applied to the projected vertical area of all superstructure elements, including exposed truss members on the leeward truss.

For Trusses and Arches: 75 pounds per square foot
For Girders and Beams: 50 pounds per square foot

For open truss bridges, where wind can readily pass through the trusses, bridges may be designed for a minimum horizontal load of 35 pounds per square foot on the full vertical projected area of the bridge, as if enclosed.

A wind overturning force shall be applied according to Art. 3.15.3 of the Standard Specifications for Highway Bridges.

1.2.2 Wind Loads Commentary

The AASHTO wind pressure on the superstructure elements are specified, except that the AASHTO minimum wind load per foot of superstructure is omitted. The 35 lb/s.f. value applied to the vertical projected area of an open truss bridge is offered for design simplicity, in lieu of computing forces on the individual truss members. The specified wind pressures are for a base wind velocity of 100 miles per hour, and may be modified based on a maximum probable site-specific wind velocity in accordance with AASHTO Art. 3.15.

1.2.3 Combination of Loads Commentary

The load combinations, allowable stress percentages for service load design and load factors for load factor design as specified in Table 3.22.1A of the Standard Specifications for Highway Bridges shall be used, with the following modifications:

Wind on Live Load, WL, shall equal zero.
Longitudinal Force, LF, shall equal zero.

1.2.3 Combination of Loads Commentary

The AASHTO wind on live load force seems unrealistic to apply to pedestrian loads, and is also excessive to apply to the occasional maintenance vehicle which is typically smaller than a design highway vehicle. The longitudinal braking force for pedestrians is also neglected as being unrealistic.

The AASHTO Group Loadings are retained to be consistent with applying the AASHTO Service Load and Load Factor design methods without modifications.

1.3. DESIGN DETAILS

1.3.1 Deflection

Members should be designed so that the deflection due to the service pedestrian live load does not exceed 1/500 of the span.

The deflection of cantilever arms due to the service pedestrian live load should be limited to 1/300 of the cantilever arm.

The horizontal deflection due to lateral wind load shall not exceed 1/500 of the span.

Appendix C — Materials List

Item	*Quantity*
Access prep 1 1/2" stone	30 c.y.
Foundation 3/4" stone	15 c.y.
Filter cloth	100 s.y.
Geogrid UX 1400	224 l.f.
Concrete, 4000 psi fiber mix	15 c.y.
#18 rebar - 14' long	2
#6 rebar - 15' long	48
#6 rebar - 11' long	36
#6 rebar - 4' long	56
#6 rebar - 90 dowel - 3' legs	40
#6 rebar - 90 dowel - 18" legs	40
6" x 6" temperature wire fabric	1 roll
Fib bituminous water proofing	5 gal.
Chance® square shaft double helical pier 10" & 12", or equivalent, with 10' shaft and eye nut	8
Chance® square shaft pisa swamp anchor sixplex helix 8"-10"-12", 14"-14"-14", 1 3/4" rod	4
1 3/4" square shaft extension rods 10'	12
1 3/4" square shaft extension rods 7'	4
1 3/4" square shaft extension rods 5'	4
Shackle assembly	4
Primary 1" galvanized EIP IWRC wire rope with 1" open spelter sockets and 1 3/4" x 24" turnbuckle at each end	2

Item	Quantity
Suspender assemblies (thimble, piggyback, flemish loop-threaded stud)	42
Cable saddles	4
1/2" galvanized steel strand high strength grade	750 l.f.
teco or equivalent single curve spike grids	80
3/4" bolts with washers & nuts, varying lengths, 18" +	60
3/8" x 8" hot dipped galvanized machine bolts platform	(6) (8) = 48
Walkway verticals	(7) (46) = 322
Walkway diagonals	(7) (44) = 308
Staircase	(8) (16) = 128
	806 + 94 = 900
3/8" x 10" hot dipped galvanized machine bolts	(3) (12) = 36
Overhead 2" x 4"	(2) (2) (21) = 84
Inclined 2" x 4'	120 + 30 = 150
1/2" x 8" hot dipped galvanized machine bolts - lower chord	(6) (2) (8) = 72 + 10 = 82
3/8" x 4" hot dipped galvanized machine bolts	(124) + 20 = 144
5/8" oval eye hot dipped galvanized eyebolt	14
8' yellow plastic guy guard	12
4" x 4" x 1/2" h.d. square washer 1 1/8" dia. hole	100
5/8" x 8" galvanized lag screw	16
3/4" x 8" galvanized lag screw	16
1/2" x 10" galvanized lag screw	50
Class I span 40' syp transmission poles	4
Class I span 20' syp transmission poles	4
All lumber to be #1 SYP CCA 40 KDAT 19% MC, unless otherwise noted.	
6" x 6" timbers - 10' long - #2 or better	20 + 5 = 25
2" x 10" bridge chords - 20' long	14 + 2 = 16

Item	*Quantity*
2" x 6" bridge joists - 20' long	28 + 3 = 31
2" x 6" hand rail components - 20' long	28 + 3 = 31
2" x 6" bridge decking - 10' long	130 + 14 = 144
2" x 6" platform decking - 8' long	36 + 4 = 40
2" x 10" platform joists - 18' long	16 + 2 = 18
2" x 10" platform headers - 10' long	4
2" x 12" platform joists - 18' long	4
2" x 12" stair joists - 22' long	8
4" x 6" posts - 8' long - bridge walkway	36 + 8 = 44
4" x 6" posts - 8' long - platform & stairs	12 + 2 = 14
2" x 8" top rail - 10' long	32 + 4 = 36
4" x 4" diagonals - 8' long	44 + 8 = 52
2" x 4" angle & tops - 8' long	112 + 18 = 130
Stair rails - 2" x 6" - 12' long	32 + 4 = 36
Stair rails - 2" x 8" - 12' long	8 + 2 = 10
Hand rail, with brackets	80 L.F.
3" x 10" #2 or better, MC 25 CCA 40 timber - 10' long	12 + 1 = 13
3" x 10" #2 or better, MC 25 CCA 40 timber - 12' long	4 + 1 = 5
3" x 10" #2 or better, MC 25 CCA 40 timber - 14' long	4 + 1 = 5
Simpson heavy duty joist hanger model HU 210	32 + 4 = 36
Simpson heavy duty joist hanger model HU 210-2	4
Simpson heavy duty joist hanger model HU 212-2tf	4
Simpson H1 hurricane clips	120

Item	*Quantity*
Simpson H2.5 hurricane clips	120
Simpson l50 framing anchors	150
Simpson TA-10 staircase angle with lag screws	76 + 6 = 82
Simpson joist hanger nails N20AE6	10 boxes
2 1/2" ceramic coated bugle head square drive deck screws	50 lbs.
3" ceramic coated bugle head square drive deck screws	50 lbs.
Gilbert & Bennett 1" x 1" 16 gauge 48" x 100' gbwm product #259063 wire 400'	(4 rolls)
#8, #10, #12 hot dipped galvanized spiral shank nails	20 lbs. Each
#8, #10, #12 hot dipped galvanized ring shank nails	20 lbs. Each

Appendix D — Tools

Safety tools

Safety tools to be defined and enforced by safety officer provided by the State of New Jersey. To include, but not limited to, non-skid boots, protective clothing, hard-hats, cotton and leather gloves, ear protection, safety belts and fall protection, sun and insect protection lotion, eye protection goggles, and GFI extension cords.

Prefabrication crew

Table saw, handles 5.5" timbers
Radial arm saw, handles 5.5" timber
Drill press for 1", 1/2", and 3/8" holes
Chop saw for 3 1/2" and 1 1/2" lumber
Pressure treated lumber saw blades
Extra drill bits
Screw guns, extra square drive tips, batteries, chargers
Circular saws, hand drills
GFI extension cords, power strip
Squares, tape measures, chalk line
Safety goggles, ear protection
C-clamps, i.d. 7" and larger
Wire snips
Saw horses (numerous)
Typical hand tools
Ratchet, open and power wrenches

Excavation and backfill crew

Two 14' x 18' x 4' tower excavations
Two 7' x 18' x 4' platform excavations
Two 8' x 7' x 4' stair platform excavations
Backhoe
Shovels, picks, hoes, rakes
Wheelbarrows
Vibratory plate compactor
Large tarp, poles, rope, stakes for shade
Hand tools to construct forms
Hay mulch, seed

Concrete crew

Knee-high rubber boots
Shovels, concrete hoes
Rebar wire, snips, rebar bender
Tarp for shade/rain cover
Trowels
Typical hand tools
Concrete chute
Power mixers
Emergency lighting
Stakes for geogrid

Platform and stair framing crew

Scaffolding
Saw horses, planks
Ladders
Screw guns (extra tips, batteries, chargers)
Wrenches
Generator, extension cords
Hand tools

Bridge assembly crew

Ladders
Scaffolding
Safety harness, fall protection
Hand tools
Screw guns, with extra batteries, chargers
Screw gun square drive tips
Cotton gloves
Cargo hoisting block and tackle meeting load requirements

Appendix E — Sources of Information on Material

Helical anchors

A.B. Chance® Company
210 North Allen
Centralia, MO 65240-1395
(314) 682-8414

Atlas Systems, Inc.
3114 Waterford Rd.
Independence, MO 64055
(800) 325-9375

Wire rope and fittings

Bilco Wire Rope and Supply Corporation
265 Pennsylvania Avenue
Hillside, NJ 07205
(908) 351-7800

Bridon American
101 Stevens Lane
Exeter, PA 18643
(717) 822-3349

The Crosby Group, Inc.
P.O. Box 3128
Tulsa, OK 74101-3198
(918) 834-4611

Structural wood connectors

Simpson Strong Tie Connectors
1450 Doolittle Drive
P.O. Box 1568
San Leandro, CA 94577
(415) 562-7775

Spike grids and structural wood fasteners

Cleveland Steel Specialty
14400 South Industrial Avenue
Cleveland, OH 44137
(800) 251-8351

CCA .40 southern yellow pine

Southern Forest Products Association
P.O. Box 641700
Kenner, LA 70064-1700
(504) 443-4464

Treated douglas-fir

Western Wood Preservers Institute
601 Main Street, Suite 405
Vancouver, WA 98660
(360) 693-9958

Appendix F — References

A.B. Chance® Company. Chance® Encyclopedia Of Anchoring. Centralia, Missouri

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American Association of State Highway and Transportation Officials. 1992. Standard Specifications for Highway Bridges. 15 ed. American Association of State Highway and Transportation Officials, Washington D.C.

American Concrete Institute. 1983. Building Code Requirements for Reinforced Concrete (ACI 313-83) American Concrete Institute. Detriot, Michigan.

American Forest and Paper Association. 1991. ANSI/NFoPA NDS - 1991 National Design Specification for Wood Construction. Revised 1991 Edition. American Forest & Paper Association, Washington, D.C.

American Forest and Paper Association. 1991. Design Values for Wood Construction, Revised Supplement to the Revised 1991 Edition National Design Specification. American Forest & Paper Association, Washington, D.C.

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American National Standards Institute. 1992. American National Standard for Wood Poles - Specifications & Dimensions. American National Standards Institute, New York.

American Society of Civil Engineers. 1932. Transactions.Paper No. 2029 - Preliminary Design Of Suspension Bridges - 1932. New York: American Society of Civil Engineers

American Society of Civil Engineers. 1943. Paper No. 2243 - Rigidity & Aerodynamic Stability Of Suspension Bridges - 1943. New York: American Society of Civil Engineers

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Building Officials and Code Administrators International, Inc. 1993. The BOCA® National Building Code/ 1993. Building Officials and Code Administrators International, Inc, Country Club Hills, IL.

Doran, R. 1992. Bilco Wire Rope & Supply Corp., General Catalog. Bilco Corp., Hillside, NJ.

Federal Emergency Management Agency. 1986. Floodproofing Non-Residential Structures. Federal Emergency Management Agency, Washington D.C.

Gimsing, N.J. 1998. 2nd Edition. Cable Supported Bridges, Concept and Design. John Wiley & Sons, Inc. New York.

Hoyle, R.J., F.E. Woeste. Wood Technology in the Design of Structures. Iowa State University Press, Ames, IA.

Joslyn Manufacturing Company. 1991. Products for the Utility Industries, General Catalog. Joslyn Manufacturing Co., Franklin Park, IL.

Lai, G.C.. 1985. Phase 1 Pre-Design Study. DBC Project No. P375 Bridges on Appalachian Trail, Wallkill River, Pochuck Creek. Gar Chew Lai Engineers, North Haledon, NJ.

Merriman, T., T.H. Wiggen. 1911, 5th edition 1946. American Civil Engineers' Handbook. John Wiley & Sons, Inc., New York.

Merritt, F.S., M.K. Loftin, J.T. Ricketts. 1995. Standard Handbook for Civil Engineers, 4th Edition. McGraw-Hill, New York.

Navel Facilities Engineering Command. 1986. Foundations & Earth Structures, Design Manual 7.02. U.S. Government Printing Office, Washington D.C.

New Jersey Dept. of Community Affairs. 1993. Chapter 23, Uniform Construction Code Regulations. Office of Administrative Law, Trenton, NJ.

Occupational Safety and Health Administration. Regulations 29 Cfr 1926.1. OSHA.

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Roebling's Sons Div. 1959. Suspension Bridge Technical Data. J.A. Roebling's Sons, Trenton, NJ. (out of print)

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TECO (Timber Engineering Co.) 1973. Design Manual for TECO Timber Connector Construction. TECO, Colliers, WV.

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Urquhart, L.C. 1959 Civil Engineering Handbook, Fourth Edition. McGraw-Hill Book Co. Inc., New York.

US Architectural & Transportation Compliance Board. 1994. Recommendations for Accessibility Guide Lines: Recreational Facilities and Outdoor Developed Areas. Access Board, Washington D.C.

USDA Forest Service. 1992. Timber Bridges, Design Construction, Inspection and Maintenance. USDA Forest Service, Washington D.C.

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USDA Rural Electrification Administration. 1972. Transmission Line Manual. U.S. Government Printing Office, Washington D.C.

USDA Rural Electrification Administration. Transmission Lines Design Manual For High Voltage, REA Bulletin 1724 E-200. U.S. Government Printing Office, Washington D.C.

United States Steel. Wire Rope Engineering Handbook. (out of print). United States Steel, Bethelem, PA.

Western Wood Preservers Institute. 1995. Best Management Practices for the Use of Treated Wood in Aquatic Environments. Western Wood Preservers Institute, Vancouver, WA.

Wire Rope Technical Board. 1993. Wire Rope Users Manual, 3rd Edition. Wire Rope Technical Board, 3246 Fall Creek Highway, Suite 190, Granbury, TX 76049-7979.

Appendix G — Literature Listing

It has been said that a civilization can be judged by the manner in which the people built their bridges and treated their wastewater. The Roman Aquaducts are a good example. The great suspension bridges of the world are icons of the nations in which they are located, as is the case of the Golden Gate and Brooklyn Bridges. So it is not surprising that a body of literature has developed celebrating bridges. For the most part, these are not technical texts, but rather the history of the world's great bridges, their builders, and the saga behind each. The author of this case study found the following books to be very informative, entertaining, and each contained an informative bibliography.

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Billington, D.P. 1983. The Tower and the Bridge, The New Art of Structural Engineering. Basic Books, Inc., New York.

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Vogel, R.M. 1971. Roeblings Delaware and Hudson Canal Aquaducts. Smithsonian Institution Press, City of Washington.

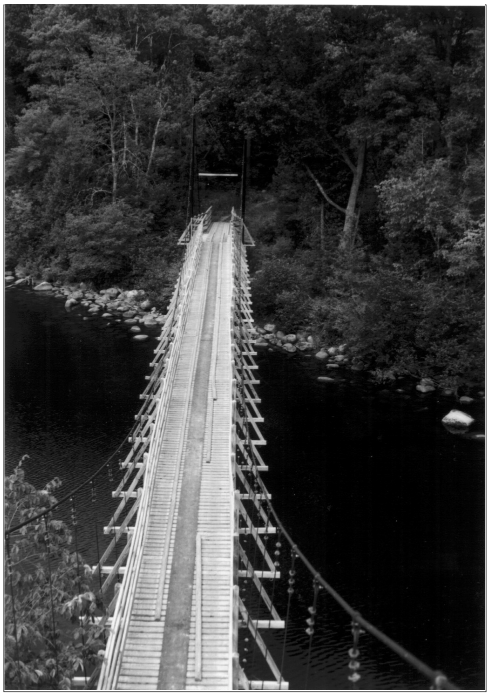
Appendix H — Examples of Other Pedestrian Suspension Bridges in the United States

Bridge Name: Wire Bridge
Location: Carrabassett River
New Portland, Maine
Main Span: 198’-5”
Photographer: Tibor Latincsics

Bridge Name: Cranberry Lake
Location: Allamuchy State Forest
Sussex County, New Jersey
Main Span: 345.5’
Photographer: Bernadette Conroy

Bridge Name: Great Gulf Access
Location: Great Gulf Trail
White Mountain National Forest, New Hamphire
Main Span: 160’
Photographer: Tibor Latincsics

Bridge Name: Kimberling Creek Bridge
Location: Appalachian Trail
Thomas Jefferson National Forest, Virginia
Main Span: 136’
Photographer: Tibor Latincsics



Bridge Name: "Smokeys Dream"
Location: Sebasticook River
Hartland, Maine
Main Span: 190'
Photographer: Tibor Latincsics

Bridge Name: Hastings Trail Bridge
Location: White Mountain National Forest, New Hampshire
Main Span: 180'
Photographer: Jay Sylvester

Bridge Name: Eagle Mountain
Location: Clearwater National Forest, Idaho
Main Span: 138'
Photographer: Merv Eriksson

Bridge Name: Warm Springs Creek
Location: Clearwater National Forest, Idaho
Main Span: 230'
Photographer: Merv Eriksson

Bridge Name: Mocus Point
Location: Clearwater National Forest, Idaho
Main Span: 200'
Photographer: Merv Eriksson

GENERAL NOTES

1) Project Owner: NJDEP, Natural & Historic Resources, Division of Parks & Forestry; Mr. Jim Hall, Assistant Commissioner. 5 Station Plaza, 501 East State Street, Trenton, NJ 08625

2) These plans are provided as an addendum to the Pochuck Creek Timber Suspension Bridge Case Study. They are presented as a general planning tool. These plans are not a design standard or specification. Utilization of these plans by other organizations or consultants is prohibited without the explicit approval of the NJDEP, Natural and Historic Resourses, Division of Parks and Forestry.

3) All dimension lumber, 2"–4" thick and 4" x 6" are Southern Yellow Pine #1 CCA .40 KDAT MC 19% meeting A.W.P.A. Standards C1 and C2, unless otherwise specified.

4) All 3" x 10" lumber and 6" x 6" timbers are Southern Yellow Pine #2 or better CCA .40 meeting A.W.P.A. Standards C1 and C2.

5) All connectors, screws, nails, spike grids, bolts, clips, joist hangers, and wire rope are hot dipped galvanized or equivalent meeting A.N.S.I. Standards. Walkway decking screwed with galvanized square drive 3" bugle head deck screws.

6) Twin Primary Wire Rope is 1" 6 x 25 Galvanized EIP IWRC, Suspenders are 1/2" EIP IWRC 6 x 19 galvanized wire rope (11.5 ton nominal breaking strength).

7) All construction to complies with the following unless otherwise noted: B.O.C.A. National Building Code 1993 Timber Construction Manual, A.I.T.C., Building Code Requirements for Reinforced Concrete A.C.I.–318. Floodproofing Non–Residential Structures FEMA 102–1986, AASHTO Pedestrian Rail Standard 2.7.3.2.1, NJDEP Flood Hazard Rules & Regulations, NJAC 7:13–1.1, NJDEP Freshwater Wetlands Act, NJAC 7:7A, Conditions of Stream Encroachment Permit 1922–93–0001.1 & Freshwater Wetlands Permit 1922–93–0001.2, Soil Erosion & Sediment Control Act, NJSA 4:24–3 & 4:24–42.

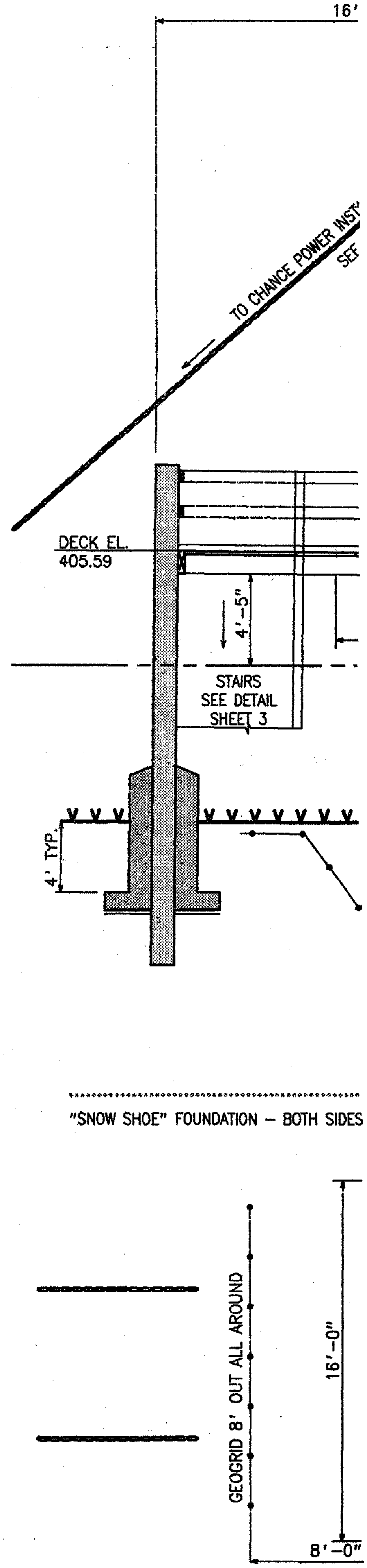
8) All decking was installed bark side up. All joists and stringers installed with camber up.

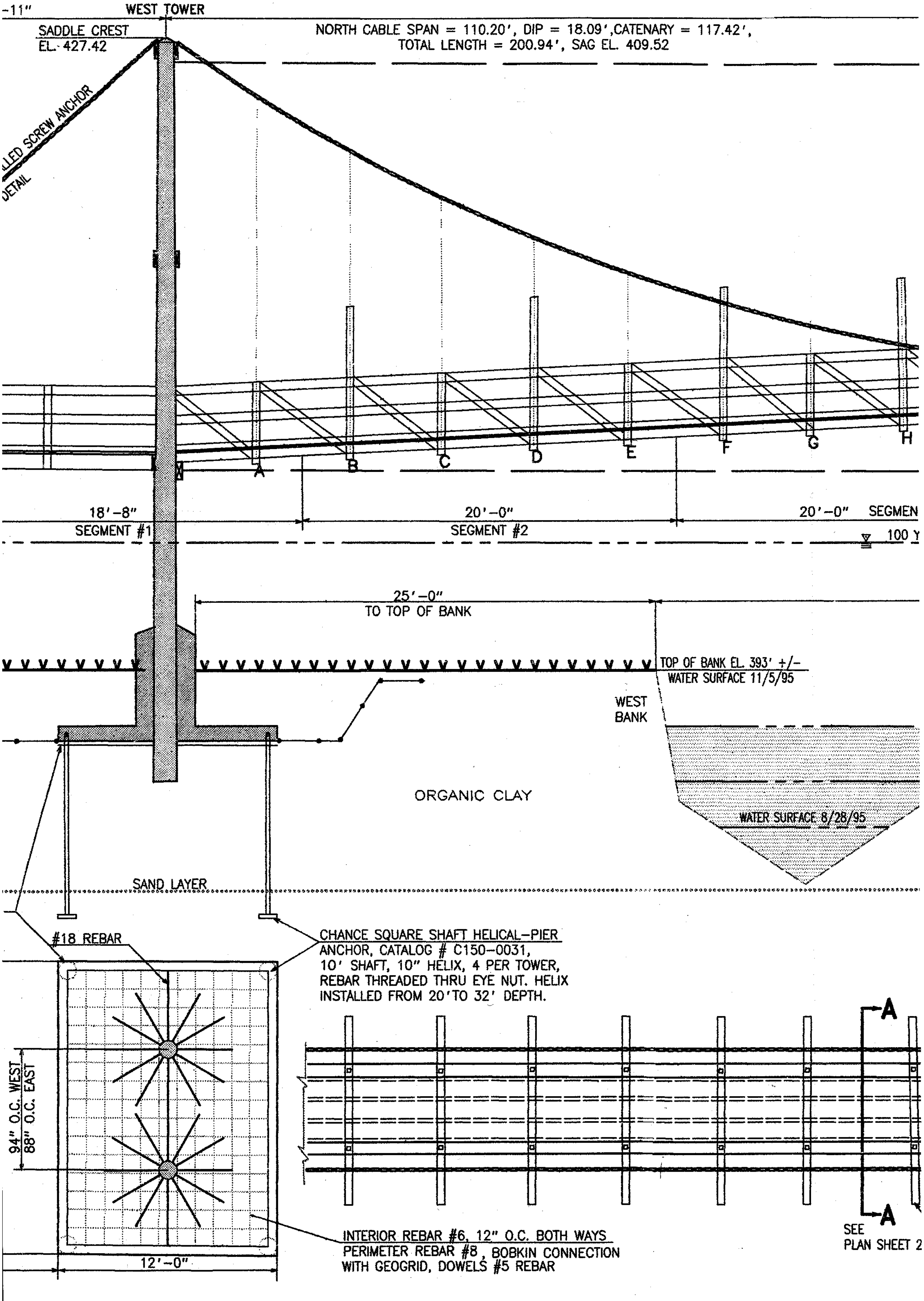
9) Vertical Datum N.G.V.D. 1929

10) Waywayanda Quad Sheet
N 875,000, E 2,053,600
Walkill–Hudson River Watershed

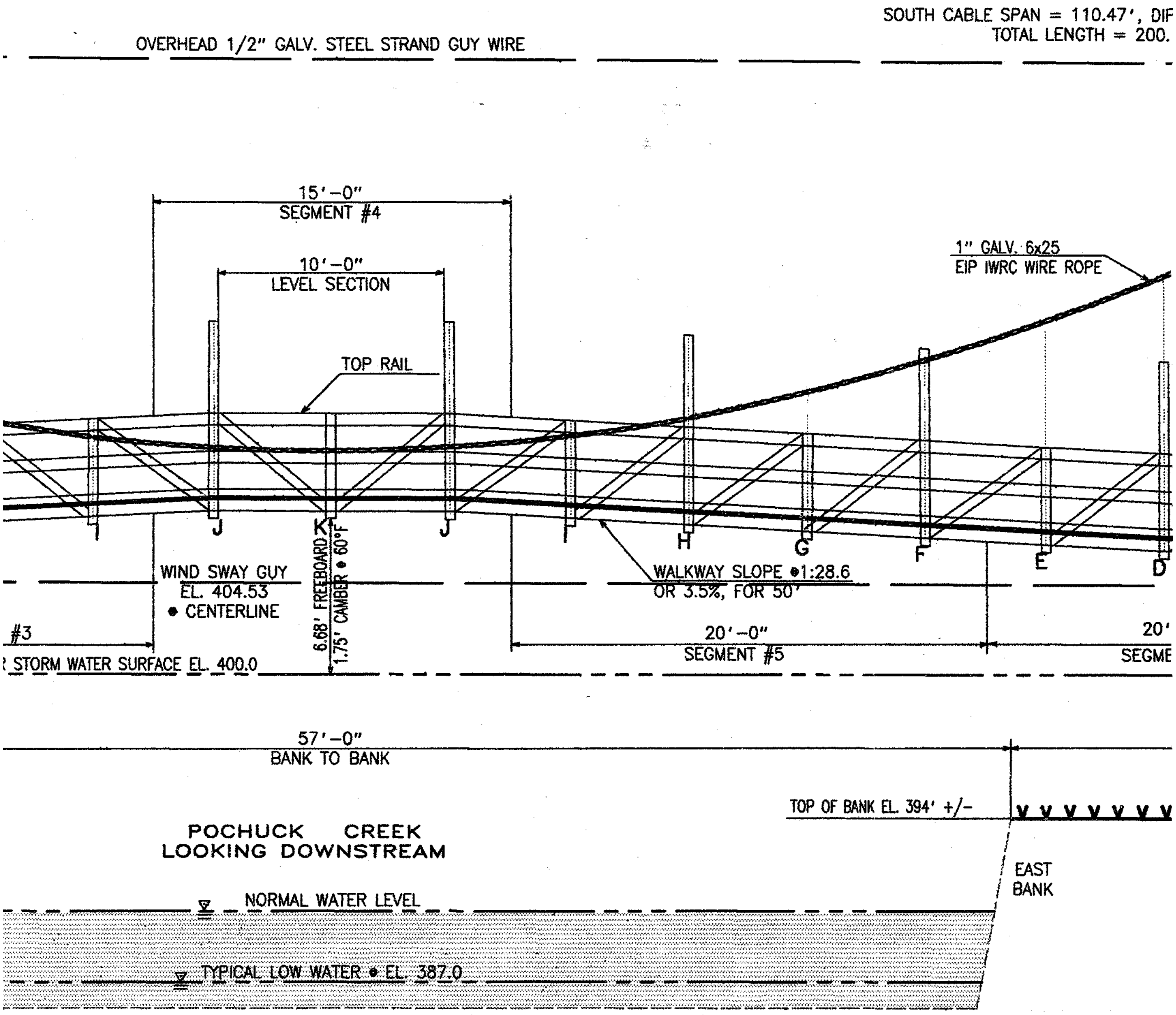
11) Pochuck Creek is a nondeliniated water course. Project designated 100 year water elevation is 400.0

12) Use of these plans for construction purposes is prohibited without the explicit approval of Tibor Latincsics, Conklin Associates, P.O. Box 282, Ramsey, N. J. 07446, (201) 327 0443.



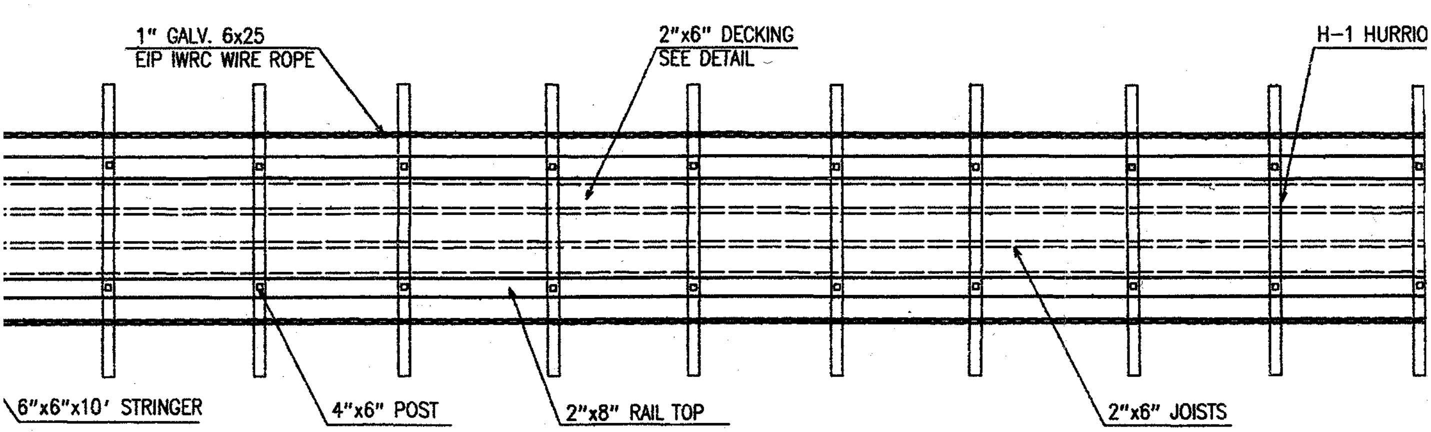

-11"
WEST TOWER
SADDLE CREST
EL. 427.42
NORTH CABLE SPAN = 110.20', DIP = 18.09', CATENARY = 117.42',
TOTAL LENGTH = 200.94', SAG EL. 409.52
LLED SCREW ANCHOR
DETAIL
A
B
C
D
E
F
G
H
18'-8"
SEGMENT #1
20'-0"
SEGMENT #2
20'-0"
SEGMEN
100 Y
25'-0"
TO TOP OF BANK
TOP OF BANK EL. 393' +/-
WATER SURFACE 11/5/95
WEST
BANK
ORGANIC CLAY
WATER SURFACE 8/28/95
SAND LAYER
#18 REBAR
CHANCE SQUARE SHAFT HELICAL-PIER
ANCHOR, CATALOG # C150-0031,
10' SHAFT, 10" HELIX, 4 PER TOWER,
REBAR THREADED THRU EYE NUT. HELIX
INSTALLED FROM 20' TO 32' DEPTH.
94" O.C. WEST
88" O.C. EAST
12'-0"
INTERIOR REBAR #6, 12" O.C. BOTH WAYS
PERIMETER REBAR #8, BOBKIN CONNECTION
WITH GEOGRID, DOWELS #5 REBAR
A
A
SEE
PLAN SHEET 2

POCHUCK QUAGMIRE BRIDGE

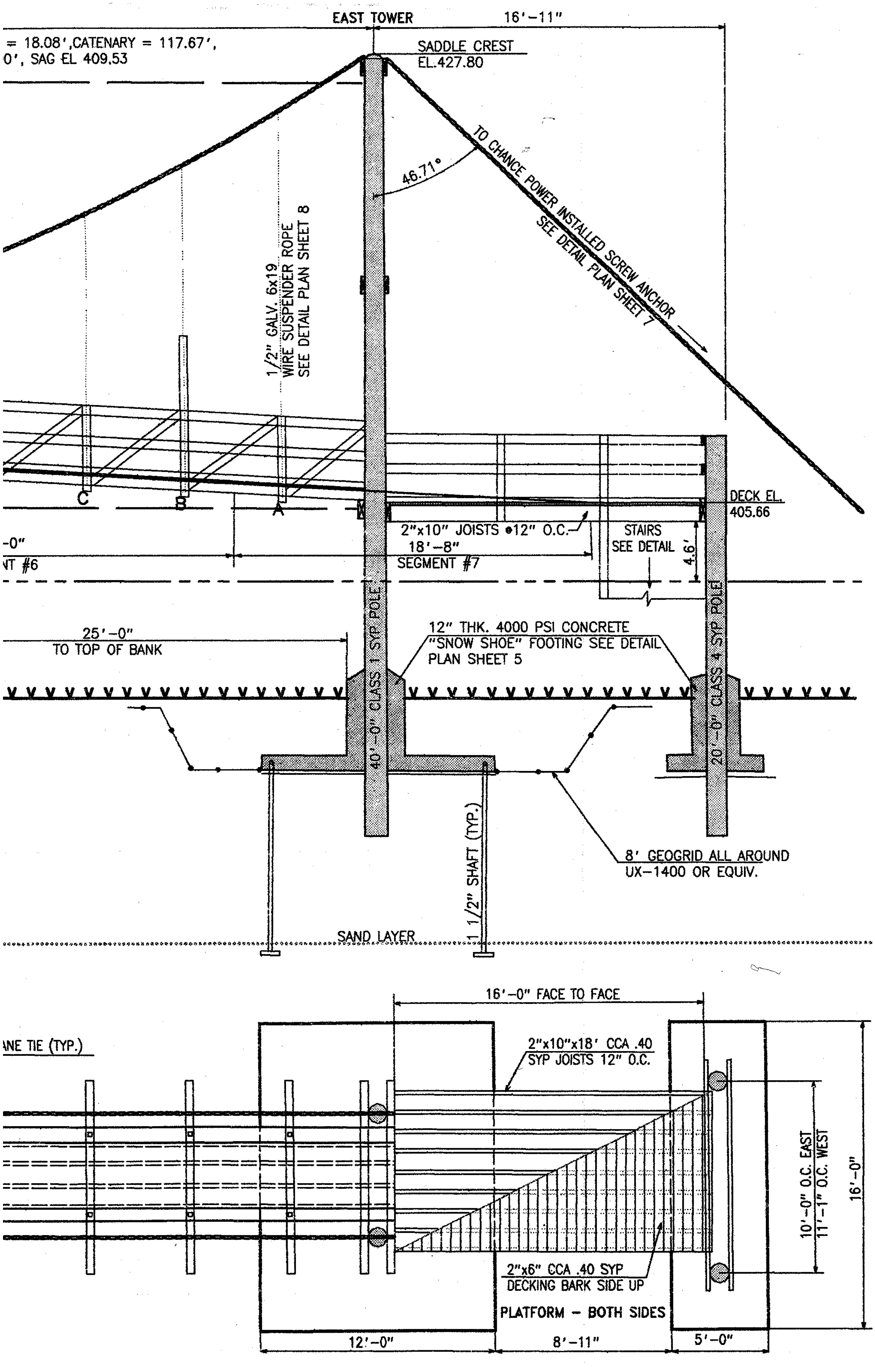


PROFILE VIEW

NOT TO SCALE



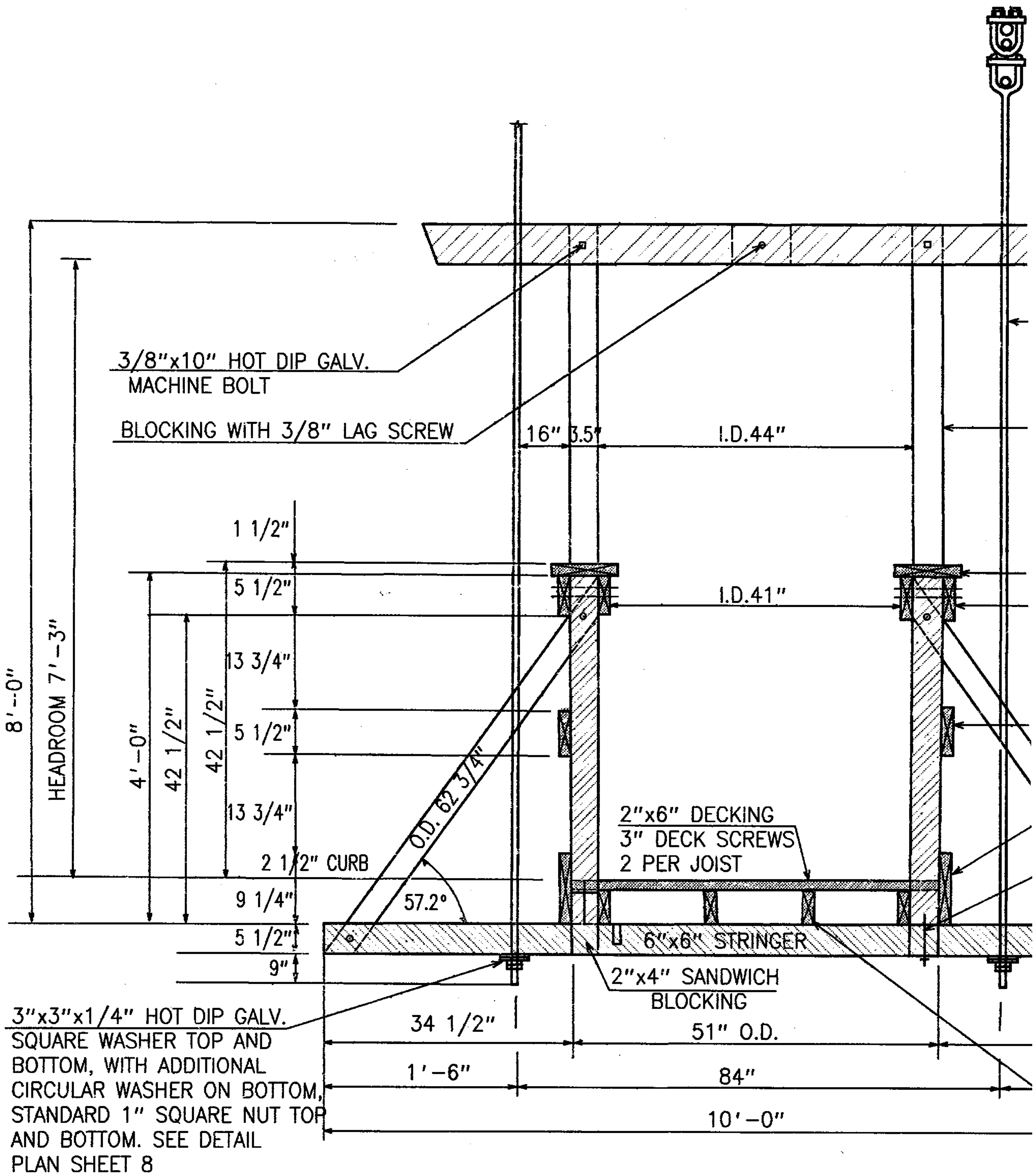
PLAN VIEW


EAST TOWER
16'-11"
= 18.08',CATENARY = 117.67',
0', SAG EL 409.53
SADDLE CREST
EL.427.80
TO CHANCE POWER INSTALLED SCREW ANCHOR
SEE DETAIL PLAN SHEET 7
46.71°
1/2" GALV. 6x19
WIRE SUSPENDER ROPE
SEE DETAIL PLAN SHEET 8
C
B
A
DECK EL.
405.66
2"x10" JOISTS @12" O.C.
18'-8"
SEGMENT #7
-0"
NT #6
STAIRS
SEE DETAIL
4.6'
25'-0"
TO TOP OF BANK
12" THK. 4000 PSI CONCRETE
"SNOW SHOE" FOOTING SEE DETAIL
PLAN SHEET 5
40'-0" CLASS 1 SYP POLE
20'-0" CLASS 4 SYP POLE
1 1/2" SHAFT (TYP.)
8' GEOGRID ALL AROUND
UX-1400 OR EQUIV.
SAND LAYER
16'-0" FACE TO FACE
ANE TIE (TYP.)
2"x10"x18' CCA .40
SYP JOISTS 12" O.C.
10'-0" O.C. EAST
11'-1" O.C. WEST
16'-0"
2"x6" CCA .40 SYP
DECKING BARK SIDE UP
PLATFORM - BOTH SIDES
12'-0"
8'-11"
5'-0"

PLAN SHEET 1

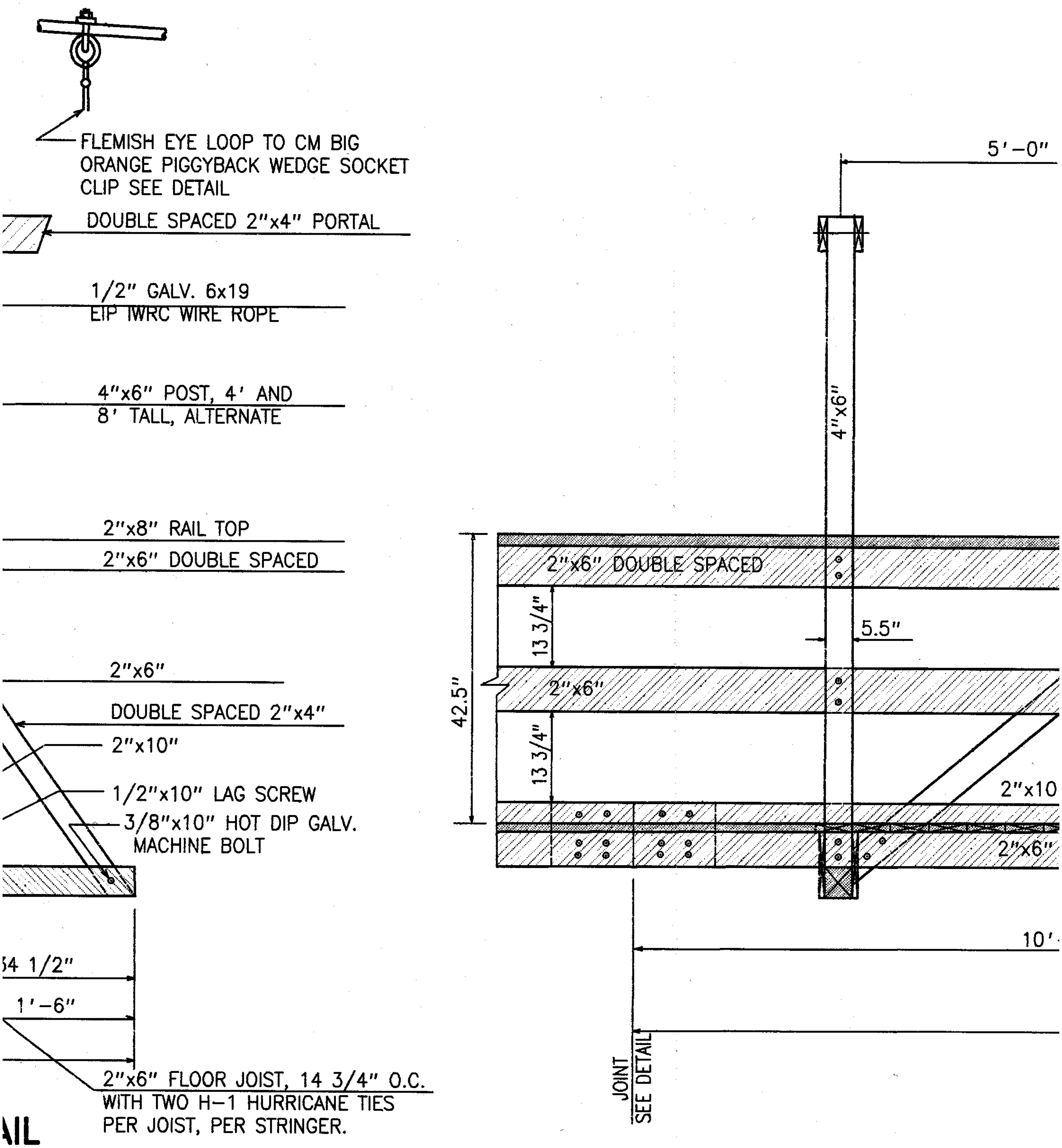
TIBOR LATINCSICS
PE 32444

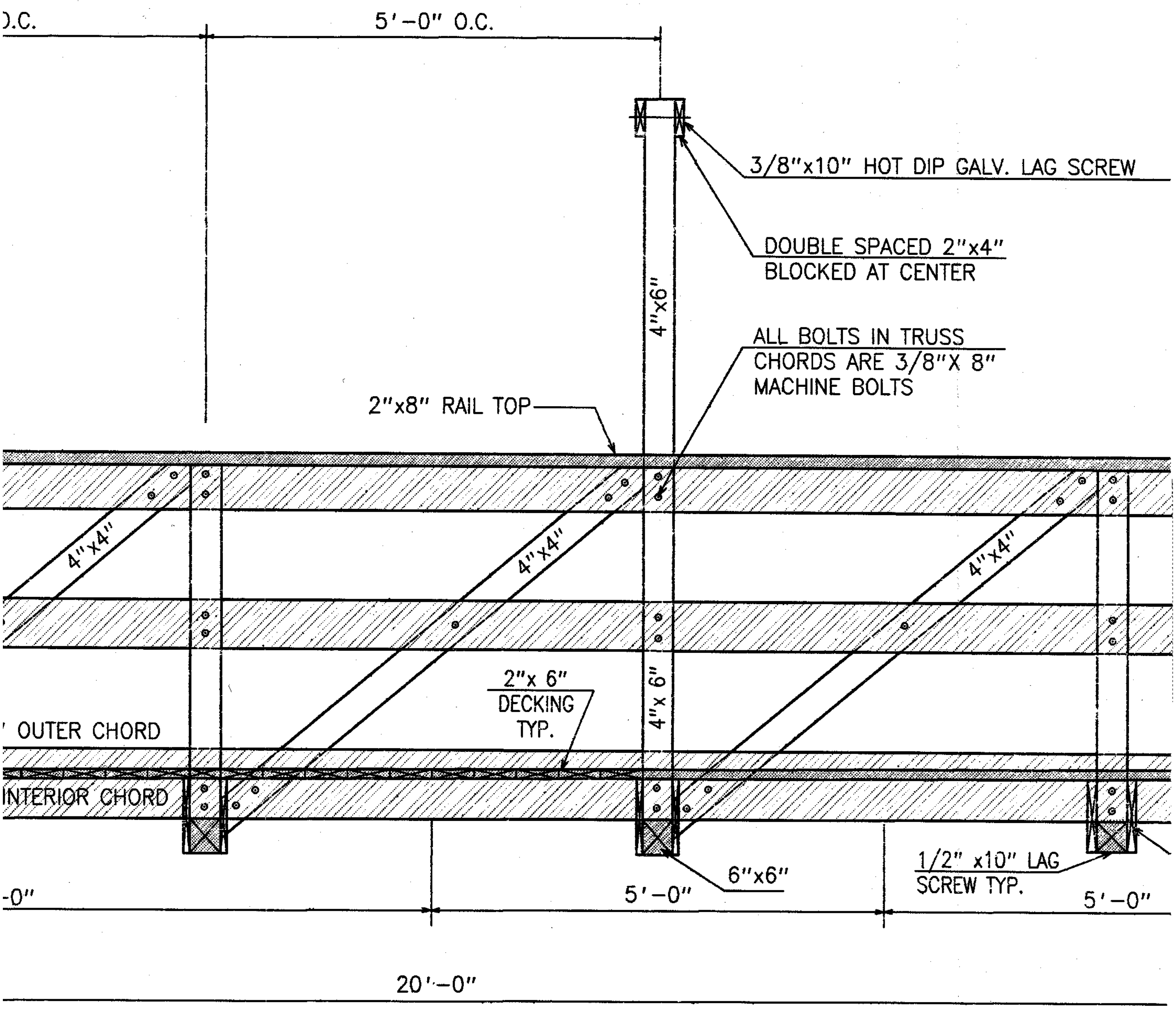
CONKLIN ASSOCIATES
P.O. BOX 282
RAMSEY, NJ 07446
(201) 327 0443



WALKWAY CROSS SECTION A-A DET

NOT TO SCALE

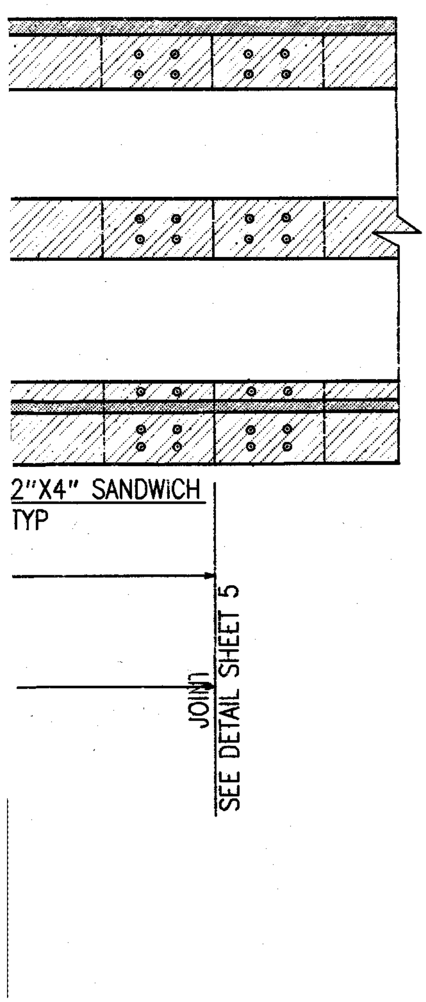

FLEMISH EYE LOOP TO CM BIG ORANGE PIGGYBACK WEDGE SOCKET CLIP SEE DETAIL
DOUBLE SPACED 2"x4" PORTAL
1/2" GALV. 6x19 EIP IWRC WIRE ROPE
4"x6" POST, 4' AND 8' TALL, ALTERNATE
2"x8" RAIL TOP
2"x6" DOUBLE SPACED
2"x6"
DOUBLE SPACED 2"x4"
2"x10"
1/2"x10" LAG SCREW
3/8"x10" HOT DIP GALV. MACHINE BOLT
4 1/2"
1'-6"
2"x6" FLOOR JOIST, 14 3/4" O.C. WITH TWO H-1 HURRICANE TIES PER JOIST, PER STRINGER.
AIL
5'-0"
4"x6"
2"x6" DOUBLE SPACED
13 3/4"
5.5"
42.5"
2"x6"
13 3/4"
2"x10
2"x6"
10'-
JOINT
SEE DETAIL

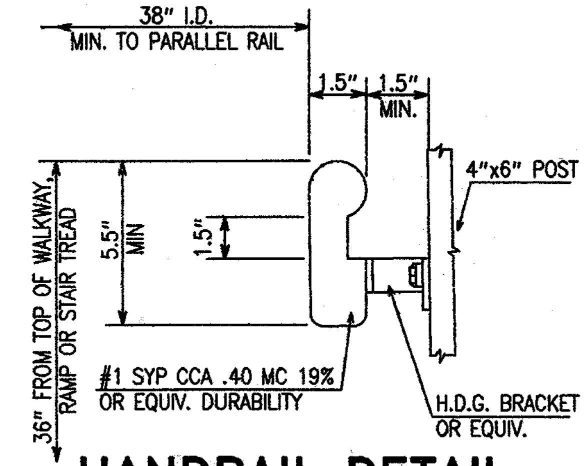


WALKWAY TRUSS SEGMENT DETAIL

NOT TO SCALE

PLAN SHEET 2



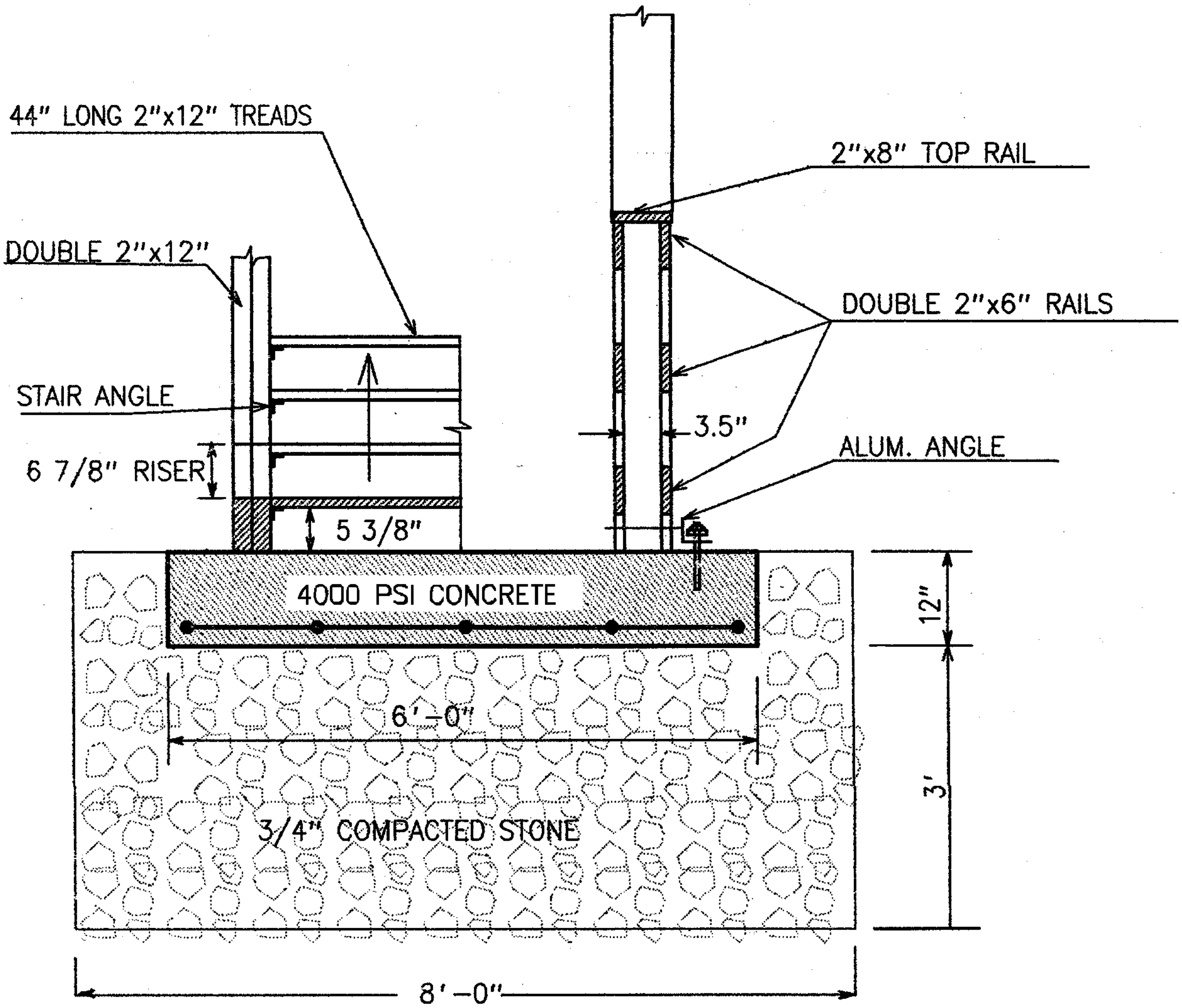


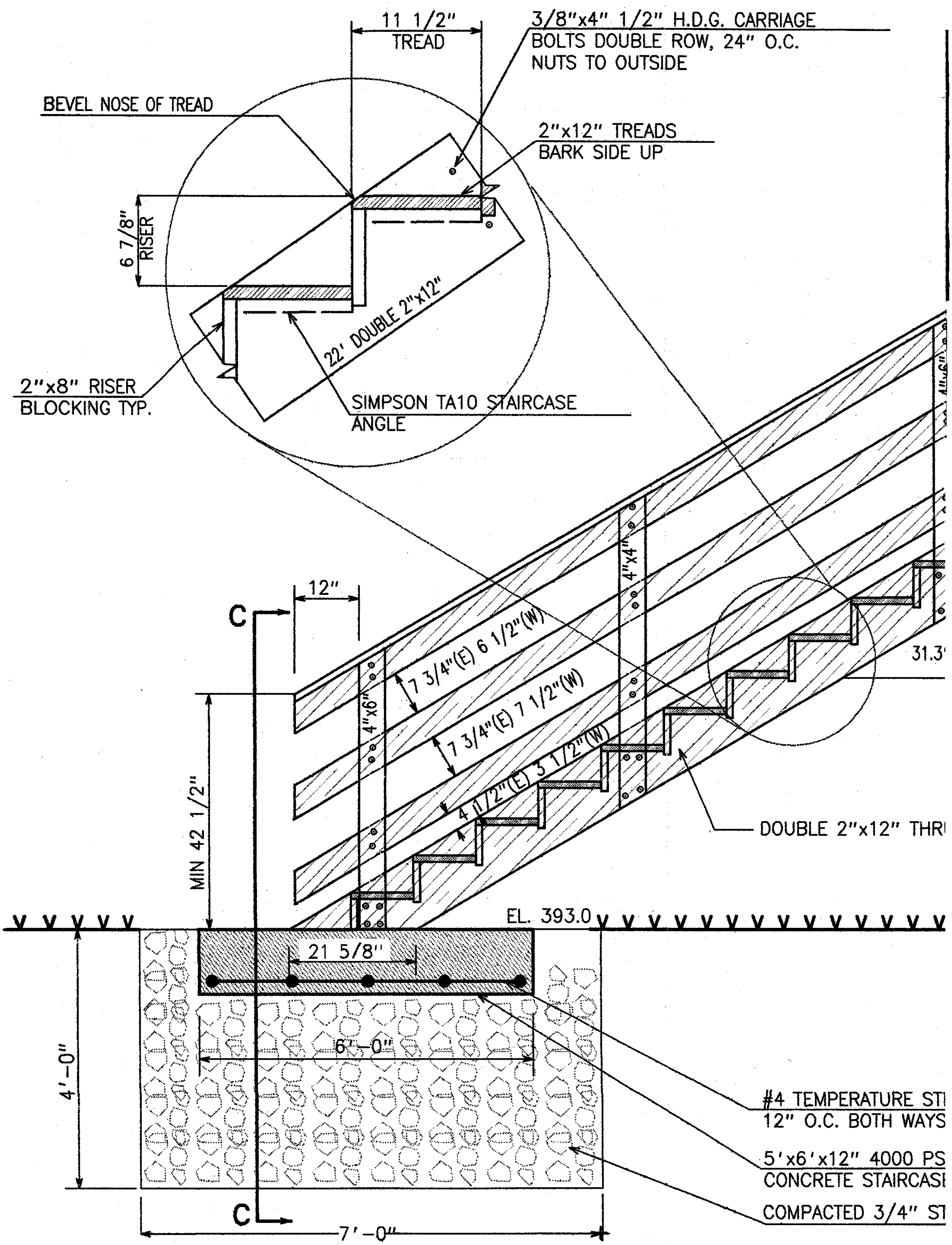
HANDRAIL DETAIL

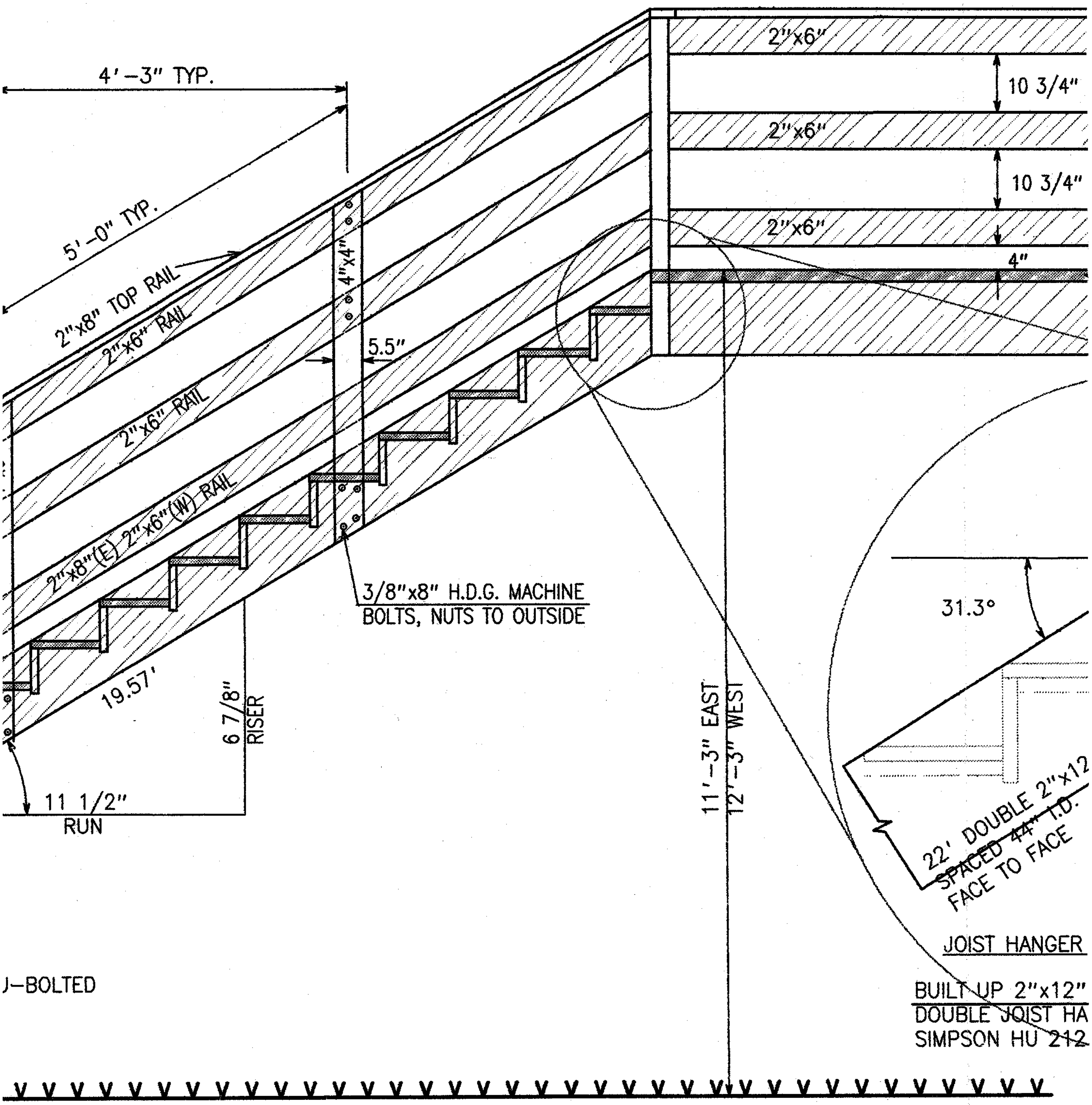
NOT TO SCALE

STAIR SECTION C–C

SCALE 1"= 2'




11 1/2"
TREAD
3/8"x4" 1/2" H.D.G. CARRIAGE
BOLTS DOUBLE ROW, 24" O.C.
NUTS TO OUTSIDE
BEVEL NOSE OF TREAD
2"x12" TREADS
BARK SIDE UP
6 7/8"
RISER
22' DOUBLE 2"x12"
2"x8" RISER
BLOCKING TYP.
SIMPSON TA10 STAIRCASE
ANGLE
12"
C
4"x6"
4"x4"
7 3/4"(E) 6 1/2"(W)
7 3/4"(E) 7 1/2"(W)
4 1/2"(E) 3 1/2"(W)
MIN 42 1/2"
DOUBLE 2"x12" THR
EL. 393.0
21 5/8"
6'-0"
4'-0"
7'-0"
#4 TEMPERATURE ST
12" O.C. BOTH WAYS
5'x6'x12" 4000 PS
CONCRETE STAIRCAS
COMPACTED 3/4" S
C



STAIR DETAIL

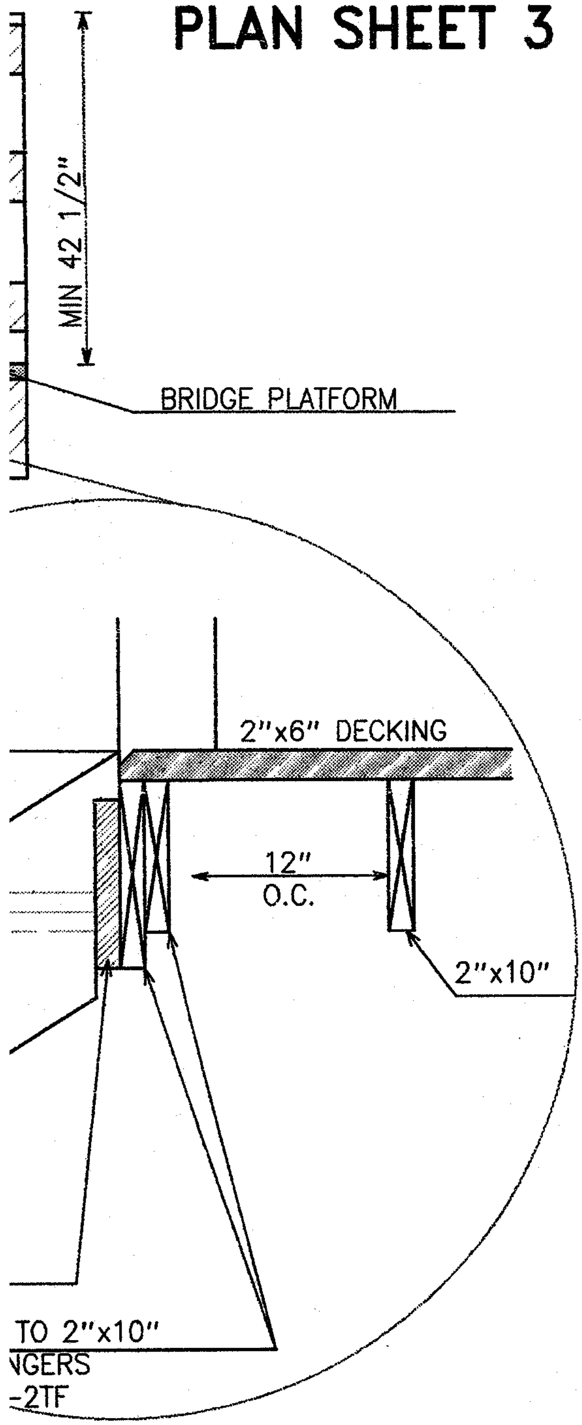
SCALE : 1"=2'

EEL REINFORCING

E PAD

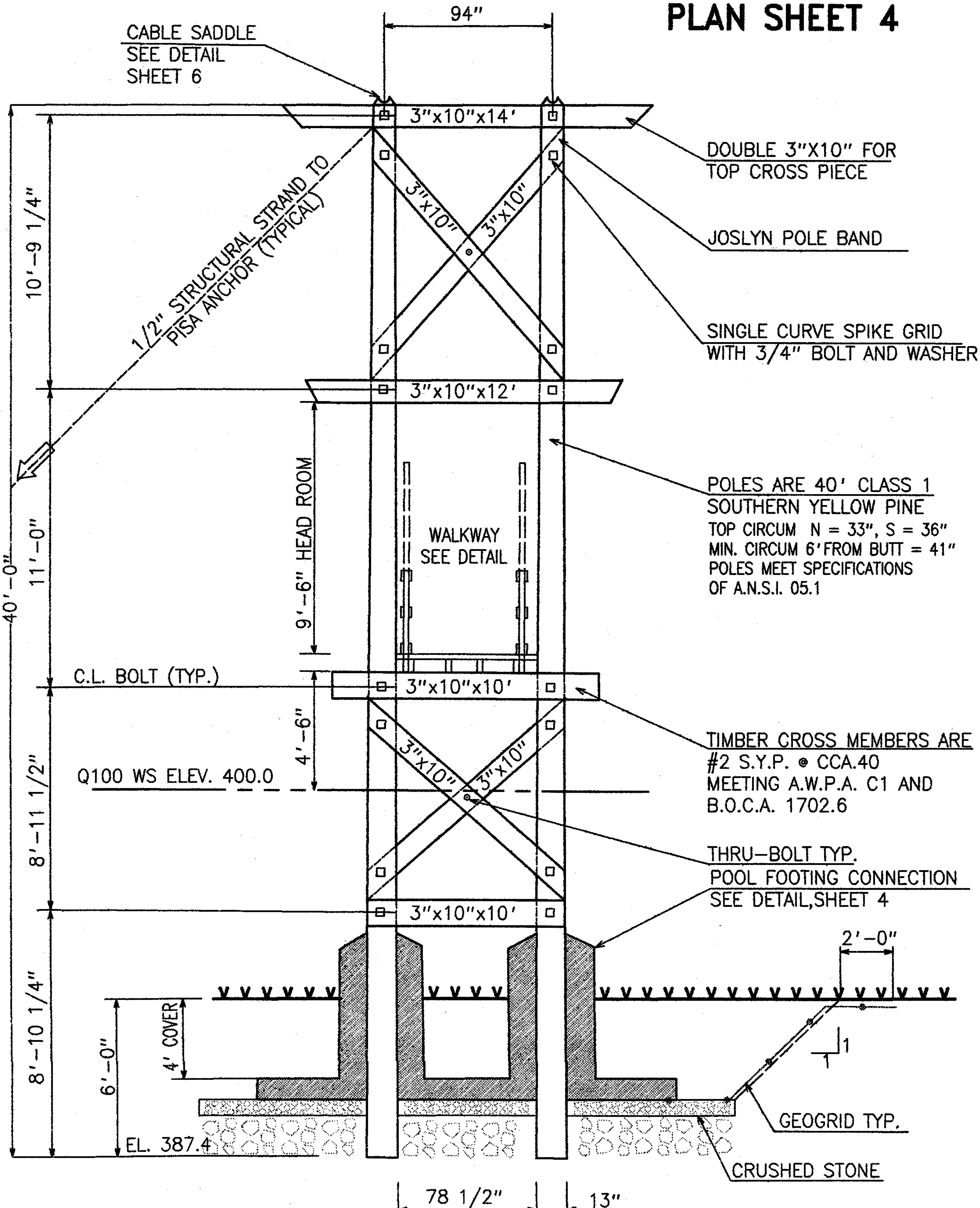
ONE

PLAN SHEET 3



MIN 42 1/2"
BRIDGE PLATFORM
2"x6" DECKING
12"
O.C.
2"x10"
TO 2"x10"
NGERS
-2TF

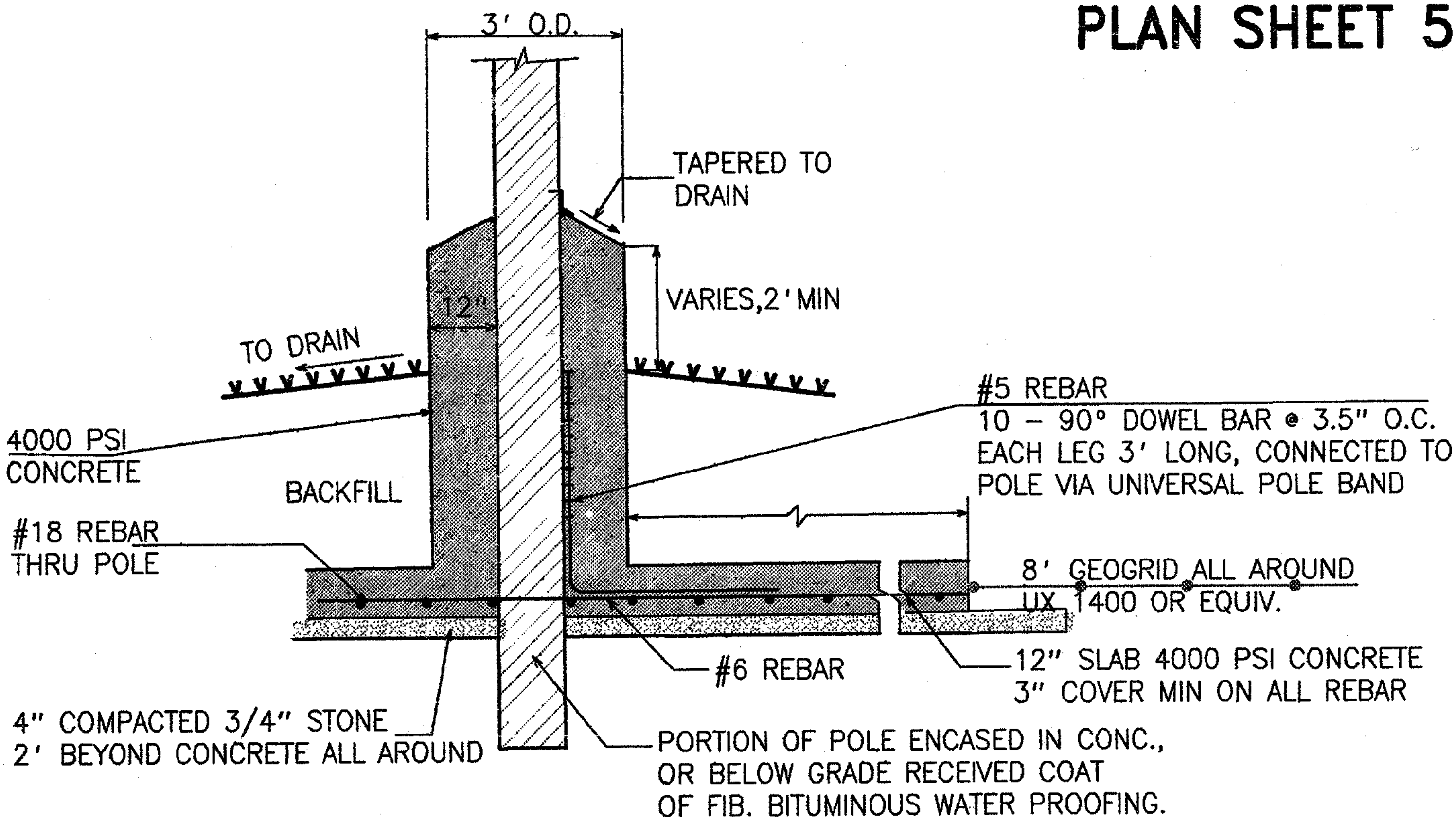
PLAN SHEET 4



WEST TOWER, RIVER VIEW

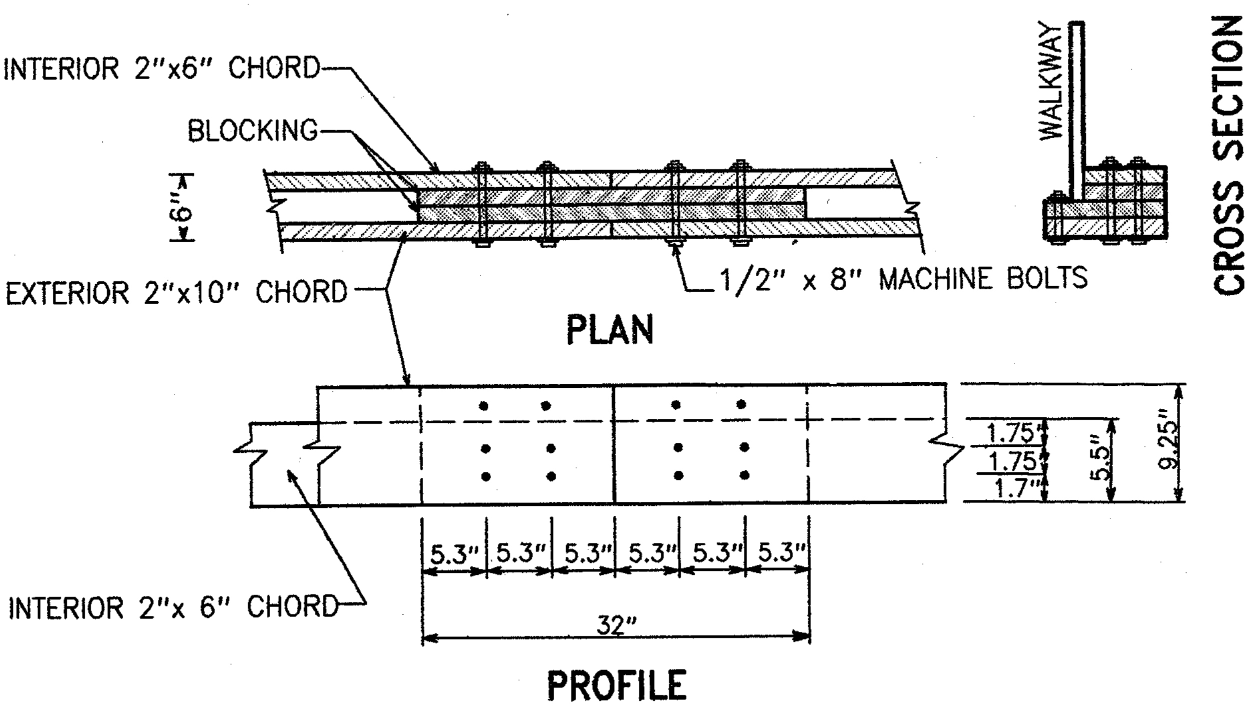
SCALE: 1" = 5'

PLAN SHEET 5



POLE FOOTING CONNECTION

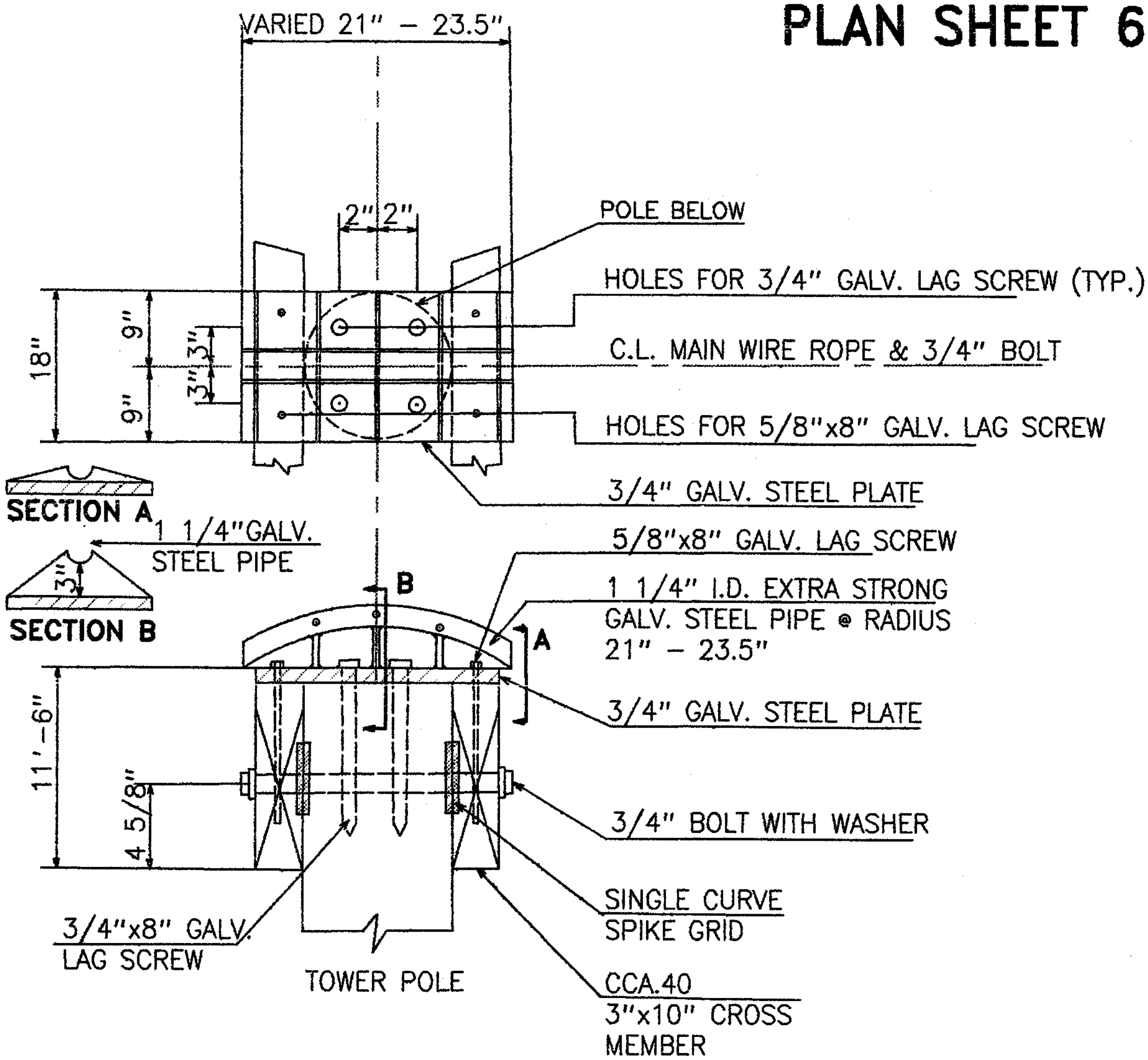
SCALE: 1"=2'



LOWER CHORD JOINT DETAIL

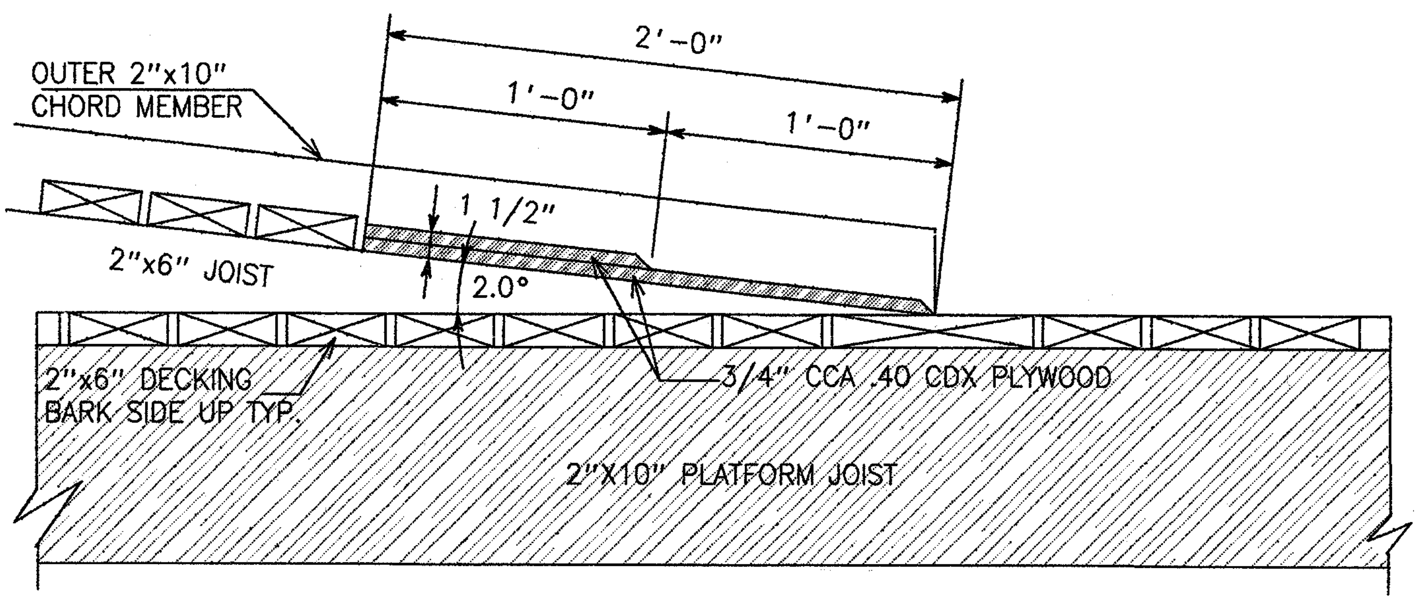
NOT TO SCALE

PLAN SHEET 6



CABLE SADDLE DETAIL

NOT TO SCALE

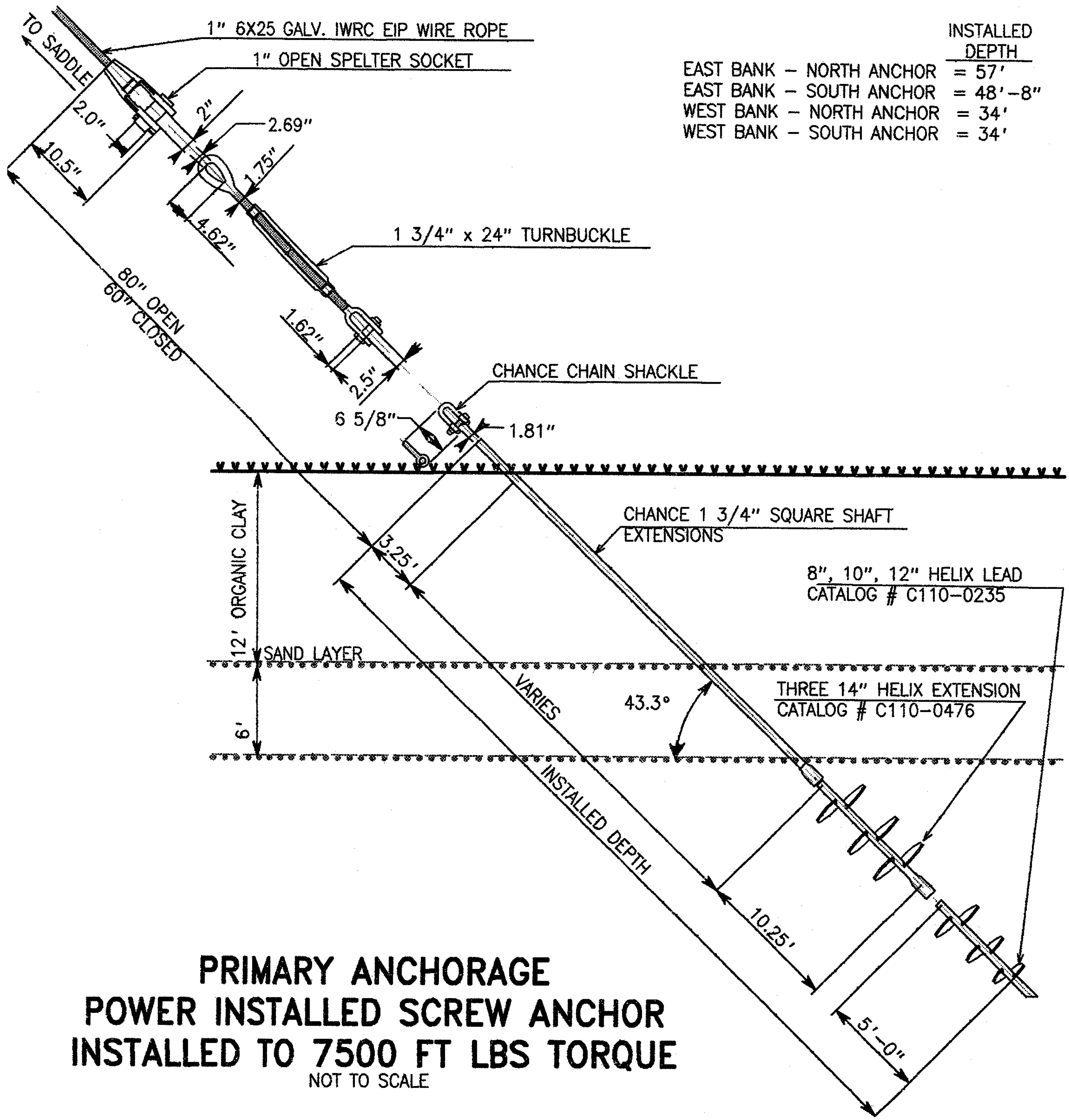


WALKWAY EDGE DETAIL

NOT TO SCALE

PLAN SHEET 7

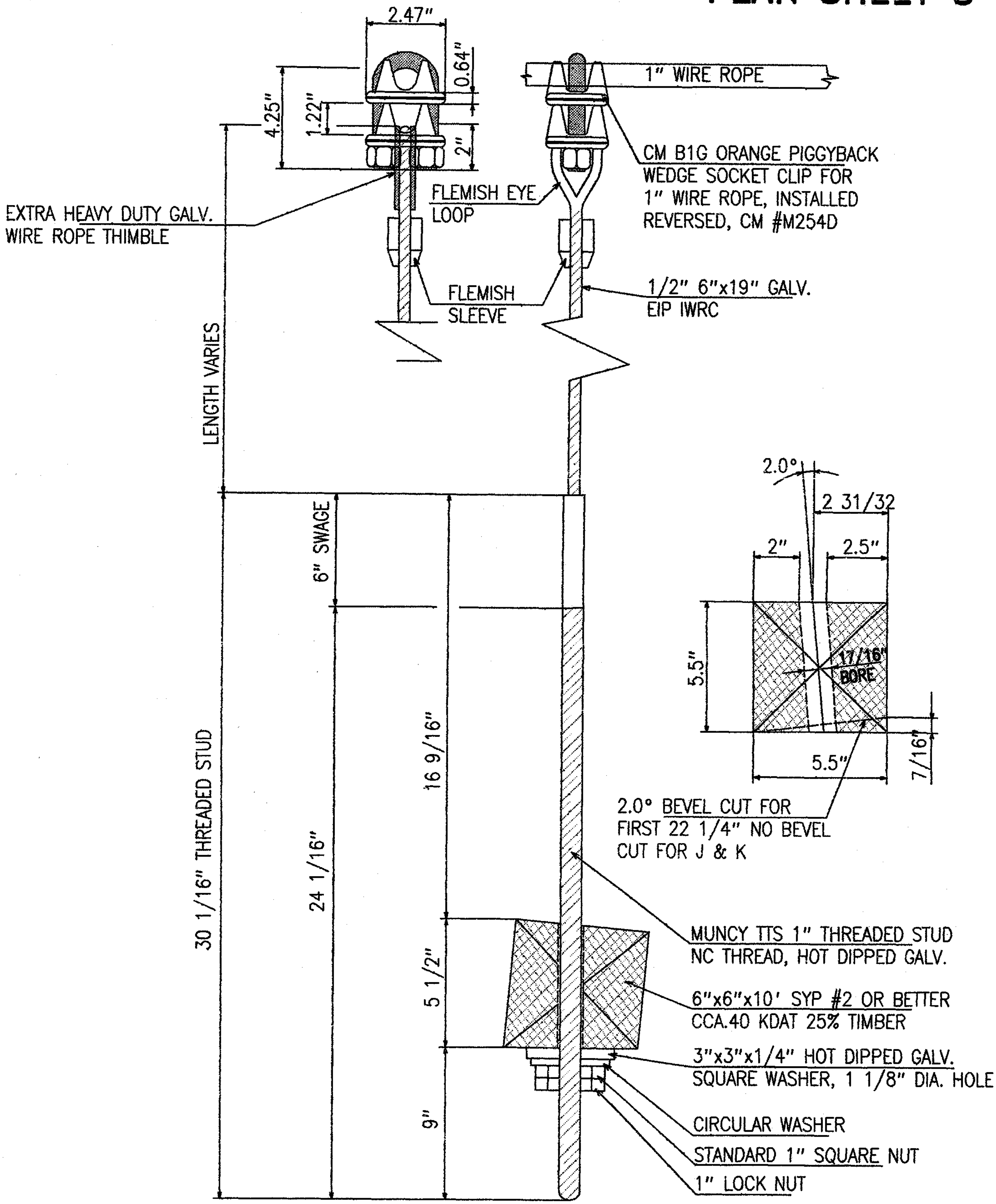
	INSTALLED DEPTH
EAST BANK – NORTH ANCHOR	= 57′
EAST BANK – SOUTH ANCHOR	= 48′-8″
WEST BANK – NORTH ANCHOR	= 34′
WEST BANK – SOUTH ANCHOR	= 34′



PRIMARY ANCHORAGE
POWER INSTALLED SCREW ANCHOR
INSTALLED TO 7500 FT LBS TORQUE

NOT TO SCALE

PLAN SHEET 8



CROSS STRINGER SUSPENDER DETAIL

NOT TO SCALE