Photo 40. 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).

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.

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, at Wawayanda State Park. Photo courtesy of Mr. Stephen Klein, Jr.
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.

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