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.
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.

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
of bituminous foundation waterproofing 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 pentachlorophenol 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.

The students from Saint Benedicts Prep School of Newark, New Jersey, photo 21, deserve kudos for their hard work.
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.

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.

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.
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.

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
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 sparram 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.

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.