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.