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.”

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

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