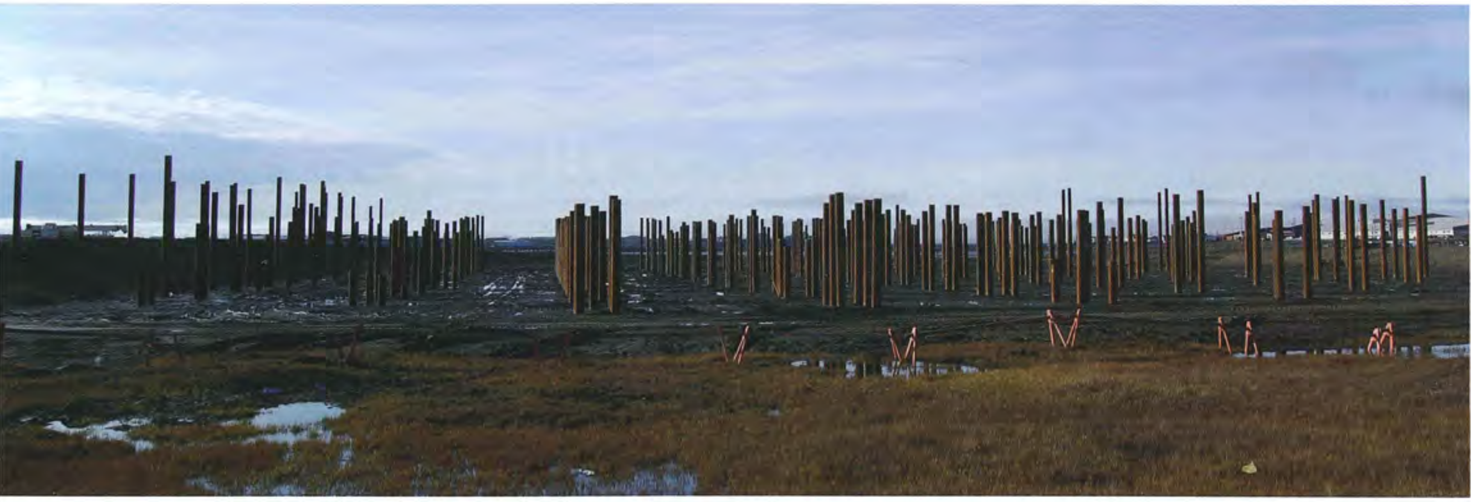
Joel Ulring, P.E. and Heather Brooks, E.I.T. – Golder Associates, Inc.
Gina Beim, P.E. – Pile Dynamics, Inc.

DYNAMIC PILE TESTING AT THE SAMUEL SIMMONDS MEMORIAL HOSPITAL, BARROW, ALASKA

The city of Barrow, Alaska, is one of the northernmost cities in the world and is the farthest north population center in North America. Nearby Point Barrow is the nation's northernmost point. Situated 320 miles (515 km) north of the Arctic Circle and roughly 1300 miles (2,100 km) south of the North Pole, its climate is cold and dry, and is officially classified as polar.

The new 109,000 square foot Samuel Simmonds Memorial Hospital being constructed in Barrow is supported on 356 driven steel pipe piles of 12.75-inch outer diameter and 0.5-inch wall. The piles are embedded from 33.25 to 48.25 feet in bonded and unbonded permafrost.

The word "permafrost" is shortened from "permanently frozen ground". According to the 1998 Glossary of Permafrost and Related Ground-Ice Terms, published by the Permafrost Subcommittee of the Associate Committee on Geotechnical Research of the National Research Council of Canada (all definitions cited in this article are from this Glossary), "permafrost is ground (soil or rock) that remains at or below 0°C (32°F) for at least two years (three years by a Russian definition)". The definition is on the basis of temperature – while "all perennially frozen ground is permafrost, not all permafrost is perennially frozen". Bonded permafrost is permafrost "in which the soil particles are cemented together



by ice". Permafrost is otherwise called "unbonded". High salt content lowers the freezing point of water; therefore highly saline soils may be "unbonded permafrost".

Installing foundations in permafrost is a well documented challenge, with its own standard (ASTM D5780 - 10 Standard Test Method for Individual Piles in Permafrost under Static Axial Compressive Load) and extensive literature dealing specifically with the subject.

The subsurface soil profile of Barrow Hospital is presented in the table below:

Depth at Base of Layer	Soil Type
1.5 to 3 feet	Gravel (GP-GM)
8 to 13 feet	Silt (ML)
23 feet	Silt and Silty Sand (ML, SM)
32.5 to 33 feet	Silty Sand (SM)
38 to 43 feet	Sand (SP-SM, SM)
49 feet	Silt and Silty Sand (ML, SM)

The subsurface is permafrost throughout the soil profile with a ground temperature of 16°F; however, there is an unbonded zone ranging from 20 to 49.3 feet. The unbonded zone is the result of a hyper-saline soil condition. Measured salinities ranged from 90 to 130 parts per thousand in this zone; approximately 2 to 4 times the salinity of seawater. Salinities throughout the remainder of the soil profile ranged from 0 to 30 ppt.

In permafrost areas with little to no salinity, geotechnical engineers determine the embedment and capacity of piling, based on the "adfreeze bond" that results in an allowable settlement over the design life of the foundation. As salinity increases, the creep of the adfreeze bond increases, decreasing the capacity of the pile.

An adfreeze bond is the bond created when water freezes around a structure and adheres to it; it is an ice bond between the permafrost and the pile. The strength of the adfreeze bond is "the tensile or shear stress required to separate two objects that are bonded together by ice".

The creep of an adfreeze bond is the movement or settlement of the pile under constant load. There are three stages of creep; each stage is dependent on the amount of load. Primary creep, the first stage, is characterized by a decelerating rate of creep. Secondary creep is characterized by a constant creep rate. The final stage is tertiary creep, an accelerating creep rate. The creep rates are dependent on permafrost temperature and the volume of ice within the soil. The ultimate capacity of the adfreeze bond is usually greater than the capacity that can be sustained without significant movement.

Geotechnical engineers design piling in permafrost to stay within the parameters of secondary creep for the design life of the structure. In addition, due to the creep properties of piles in permafrost, geotechnical engineers design for the constant, or sustained, load of the structure - usually the dead load, snow load and a portion of the live load. Transient loads like wind and seismic are taken into account when looking at the design by determining the total adfreeze capacity. These loads will not affect the creep or movement of the piling.

The sustained design load for each pile of the Barrow Hospital was 70 kips. The goal of the design was to bear the pile within the unbonded permafrost zone to develop an unfrozen design capacity with limited creep movement.

Duane Miller Associates, now Golder Associates, from Anchorage, AK, performed Dynamic Foundation Testing with the Pile Driving Analyzer® (PDA, manufactured by Pile Dynamics, Inc) on several of the piles. PDA testing had two purposes: to determine the internal stress of the pile and thus decide whether pilot holes would need to be drilled in the permafrost for pile installation, and to provide documentation of the pile capacity.

Pilot holes filled with hot water are sometimes used by piling contractors to warm the permafrost soil and make pile driving feasible where it would otherwise be impossible; the water also helps improve the adfreeze bond between pile and soil. Pile driving monitoring with the PDA revealed that driving stresses were acceptable, leading the engineers to conclude that drilling of pilot holes was not necessary for pile installation.

Dynamic foundation testing was then conducted during a re-strike, approximately 3 days after initial driving. Following field measurements with the PDA, CAPWAP® analyses were performed. While the PDA gave useful information on driving stresses and soil resistance at the time of monitoring, the CAPWAP analysis provided bearing capacity, resistance distribution and a simulated static load test. CAPWAP-calculated pile capacities ranged from 250 to up to 390 kips, and the piles were accepted.

A static load test was conducted to confirm the capacity of the piles. In general there is good correlation between capacities from static load tests and capacities obtained with CAPWAP. In this case, however, the static load test, the ultimate capacity of the pile by the Davisson failure criterion was not reached during the static load test (24 hour load of 200 kips).

Just as the Barrow Hospital is a critical facility to the North Slope Region, providing health care services to the native Inupiat people and others of the North Slope region, an area larger than Washington State, so is the need to provide properly designed and tested foundation systems to support these facilities in these harsh isolated locations. The project is expected to be completed in 2013. ■

GOLDER ASSOCIATES, INC.

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Pile Dynamics, Inc. is a world renowned developer and distributor of quality assurance / quality control systems for the deep foundations industry. Its line of products extends well beyond the Pile Driving Analyzer used in this project and includes testing and monitoring equipment for drilled, augered and driven piles. PDI instruments are used in more than 100 countries throughout the world.