III.2 CERTAIN ASPECTS OF ALASKA DISTRICT ENGINEERS EXPERIENCE IN AREAS OF MARGINAL PERMAFROST

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In nearly twenty years of engineering and construction experience in Alaska, the Alaska District of the U.S. Corps of Engineers has encountered permafrost in many diverse and extreme topographic locations. The areas of extreme permafrost of course can be readily identified by areas of very low mean annual temperatures and less extreme conditions of snowfall. Non-permafrost areas can be classified as those that are in a marine environment and also those that consistently have extremely heavy snowfall throughout the winter. Between these two extremes a very large portion of Alaska must be considered as potential areas of marginal permafrost.

In the establishment of a new site location or facility, the first consideration has been to try to locate the site on free draining, non-frost susceptible gravels or firm hard rock. Where the site requirements dictate a location on which these conditions cannot be fulfilled, an exploration program is laid out from which the existence or non-existence of permafrost is determined. When there is a possibility of the existence of permafrost as a result of favorable micro-climatic conditions combined with soil conditions such as saturated silts and peats, the permafrost encountered is easily disclosed by augering, churn drill holes or testpits.

The most difficult soils to identify are the unsaturated granular materials which frequently have insufficient moisture to give the degree of strength easily recognizable as a frozen condition. The fact that sands and gravels themselves are frozen in an unsaturated state is not by itself a detrimental condition; however, we find that frequently these materials are actually in a condition of such low density that they will consolidate readily upon thawing. In a natural state, they appear fairly dense and firm because of the strength given them by the thin ice bond.

Our first problem has been to recognize these materials and then to get a satisfactory undisturbed sample from which density and thaw consolidation tests could be run.

Our experience has shown that unsaturated clean sand and silty sand will have sufficient consolidation to cause appreciable differential settlement under an on grade heated structure. When frequent trips are to be made to the site, sensitive thermocouples are installed as a cross check on the thermal profile of the soil for the existence and limits of permafrost; however, soils with depressed freezing points have been encountered which, coupled with the limits of field accuracy of the temperature measuring devices, has made it difficult to determine exactly the limits of the permafrost by this method.

Once permafrost is known to exist in an area, the biggest problem has been to outline the limits of that area and then to build entirely within or outside of those limits. The design and construction of roads, airfields and parking areas on marginal permafrost has been aimed at one of two extremes. One has been to eliminate the permafrost as easily as possible, either by excavation of the detrimental perennially frozen ground or by accelerating or optimizing the thaw conditions which will cause rapid degradation and dissipation of permafrost. When the detrimental perennially frozen soils cannot be economically removed or thawed then the design soil profile will be such as to provide for the continued maintenance of the permafrost. The net heat outflow of the soil must then exceed the net heat inflow. This usually is accomplished by restricting the depth of granular materials and permitting water to accumulate in the lower portion of these materials.

An example of such a design is the runway extension at Galena, in which 8 inches of Portland cement concrete was underlain by 7.3 feet of compacted sandy gravel. This in turn was underlain by a silt permafrost subgrade. Prior analysis showed that 11 feet of granular backfill would be a depth sufficient for continual degradation of the permafrost. On the other hand, 6 feet of granular material would have allowed rather extreme seasonal frost heave and settlement that could cause severe cracking of the Portland cement concrete pavements. A design compromise was reached in which the top of the silt subgrade was 8 feet below the finished pavement surface. This airfield has performed extremely well. There is no detrimental heave or settlement of the Portland cement concrete. Part of the success may be attributed to the subgrade pressures on the silt limiting ice lensing. It could also be due partially to the 8 foot depth providing a rather uniform heave profile at the surface. This is doubtful, however, because the silt subgrade in question is quite susceptible to differential ice lensing conditions.

Unheated structures are treated in the same manner as roads and airfields with the exception that there is usually a snow blanket over the area throughout the winter. Because of this situation they have been more difficult to analyze and have required a more detailed thermal calculation. Where these structures are shaded the snow cover can be eliminated and under such a condition, it is possible to provide a permafrost foundation with an assurance of stability.

Heated structures and their service utilities have provided the greatest challenge and problems in these marginal permafrost areas. The thermal analysis for the structure foundation design is not limited to the conditions directly under the structure but also includes the area immediately adjacent to and surrounding the structure. The area included in the thermal analysis depends on many factors, such as - how marginal is the permafrost, what is the nature of the adjoining soils, and to what depth might the soils potentially thaw and consolidate.

A typical building located on a silt subgrade was analyzed to a distance of 30 feet on the south side of structures, 10 feet on the north side and an intermediate value on the east and west sides. As much of the exploration as possible for such structures has been undertaken in early winter to evaluate the depth of thaw from the previous summer as well as the new seasonal frost. These values are not used directly in analysis but provide a basis for estimating the micro-climatic situation on which to base a re-analysis of the disturbed area.

The Bethel AC and W site provides an example of a wood pile foundation in which the holes were augered 30 feet deep with a minimum diameter 4 inches larger than the butt diameter of the piles installed. Freezing coils were attached to the piles. The piles were installed in early winter. The gravelly sand slurry used around those piles was frozen evenly the full length of the pile by circulating a refrigerant through the coils installed on the piles. This prevented or reduced confining pressures and as a result there was no noticeable movement of the pile on freezing.

The Bethel Communications Towers were constructed on driven 14 BP 73 and 12 BP 53 piles with a design depth of 30 feet and a maximum depth of thaw of 10 feet. A two inch pipe was attached between the web and flange. This pipe was for potential use as a refrigerant line in case degradation of the permafrost occurred.

Difficulty was anticipated with the channelling of water around the steel piles and possibly thawing the frozen ground to a greater depth adjacent to the steel pile. To prevent this, a shallow auger hole filled with a sand-bentonite mixture was dug at the pile location prior to pile driving. A mixture of 1/3 bentonite and 2/3 sand by weight was used as backfill. This sand-bentonite mixture serves several purposes. As the sand-bentonite mixture is practically impervious it prevented the concentration of water adjacent to the pile. Its large capacity for absorption of water increased its latent heat capacity to decrease the depth of thaw adjacent to the pile.

In cases where deformation of eccentric piles caused refusal at a depth less than specified an oil and wax mixture was poured between a 4 to 6 foot deep steel shell and the pile. The oil and wax mixture prevented adhesion of the active frost layer to the pile thereby preventing seasonal ice jacking of the short piles.

Table 1 is a listing of a number of sites on marginal permafrost in Alaska showing the variation in soil and weather conditions and describing the type of foundation and treatment used.

A limited amount of permafrost exists in the Anchorage area and further south at higher altitudes. On the other hand, soils without permafrost exist throughout interior Alaska including deep deposits of unfrozen, unsaturated silts on south facing slopes in the Fairbanks area. One of the most exacting analytical problems is the recognition or prediction of the existence and limits of these marginal permafrozen materials.

TABLE 1

	Glennallen	Campion	Bethel	Unalakleet	NE Cape
Elevation (ft)	1572	350	173	14	78
Latitude	62°N	64.7°N	60.8°N	63.9°N	63.3°N
Mean Annual Temperature (°F)	27	23.7	29.6	26.2	22
Highest Recorded Temperature (°F)	91	89	86	86	68
Lowest Recorded Temperature (°F)	-65	-64	-52	-50	-36
Maximum Freezing Index - Degree Days	6000	6805	4682	5678	4444
Maximum Thawing Index - Degree Days	3282	3540	3192	2984	1349
Mean Annual Precipitation (in.)	11.7	13.59	18.17	11.28	19.0
Mean Annual Snowfall (in.)	48.6	55.1	62.2	34.5	81.8
Average Wind Velocity (mph)	7	7	10	12	13
Soil	Till sometimes covered with clean outwash gravel or sand.	Silt and sandy silt	Silty fine sand subgrade - silt surface.	Broken sedimentary rock, ice content decreasing with depth.	Boulder, cobbles, sand, silt, and peat; frozen and non-frozen ground occur in combination.
Type of Foundations	Ventilated concrete foundations, ventilated structures on rail piles, timber mat foundations, natural refrigeration, post and pad foundation.	Ventilated foundations on granular fill, ventilated on grade foundations; natural refrigeration, post and pad foundation.	Steel and wood piles, post and pad foundation, timber mat tank foundation.	Remove ice laden rock on grade construction.	Remove or avoid permafrost or use wood and pipe piles on permafrost.

Discussion

In reply to a question by G.S.H. Lock, the author stated that temperature measurements were taken at the bottom of a 400 foot borehole beneath a building. The surface temperature was found to be 34°F by extrapolation and the surface water was close to freezing.

R.S. Taylor asked what size of boulders were being moved in the soil by frost action. Long replied that test-pits showed that boulders up to 8 feet in size were being moved at Granite Mountain. These boulders are too small to provide bearing. R.S. Taylor added that there are areas in northern Canada where granite blocks are being moved by frost action.

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