MINING EXPERIENCE WITH PERMAFROST

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This Company has been engaged in mining in permafrost areas since 1935. In that time five producing mines have been established in the Yukon and Northwest Territories, mostly within 150 miles of the Town of Yellowknife and all of the underground type. The author has been employed in this work since 1953.

Most of these mines have been located in areas of Precambrian rock where overburden is generally shallow or absent thus minimizing the permafrost problems. Where permafrost has been encountered, various methods have been used depending on local conditions and experience. This paper describes permafrost problems and methods employed to overcome them in connection with foundations, power lines, roads, airstrips, sewage disposal and underground mining.

PLANT AND EQUIPMENT FOUNDATIONS

All possible advantage is taken of exposed bedrock when choosing sites for buildings and machinery. Occasionally this is not feasible and in such cases one of three courses of action is usually followed. If the overburden appears to be shallow, perhaps 15 feet or less, the surface insulating vegetation is stripped in the early Spring. The frozen ground is removed as it thaws until solid rock is reached. Cribbing may be required to support the walls of the excavation. Thawing has also been accelerated by fires or the heated cooling water from machinery. In one case where the building was small, and some movement could be tolerated, three timber mats were laid down in a triangular pattern on the undisturbed ground surface. Two steel beams were set on these mats; the floor joists were fastened to the beams, and the building was erected. This is merely the common three point suspension method. The building shifted considerably but not to the point where its usefulness was impaired. In other cases techniques developed at Inuvik, N.W.T., and similar places have been used.

POWER LINES

Sixty-five miles of hydro-electric power lines have been constructed and maintained. These lines have been built with single wooden poles, about 15 per cent of which are standing in muskeg on permafrost. These poles are supported by setting them in a rock-filled log crib 8 feet square by 4 feet high. Similar rock-filled cribs 4 feet square by 4 feet high are also built at the same time. They are located about 25 feet away from the power line and at right angles to it. Anchors are set in the smaller cribs and the pole is guyed to these anchors. The cribs last approximately 15 years.

Each Spring the peat on the south side of these cribs thaws first. The crib sinks toward that side causing the pole to tilt. Generally, the pole only moves off vertical by 10° to 15° and not every pole moves. Movement may be hampered by the guy wires. If the pole is not straightened, the leaning increases and the line will collapse in one or two years. This problem is handled by sending out a two-man crew and a cook in August. A block and tackle is rigged on the pole, some rock is removed, and guy wires loosened if necessary. The tie wires that fasten the power cables to the insulators may also have to be loosened. The pole is then pulled back to vertical, all wires tightened and the rock replaced in the crib. The pole will be serviceable for another year. The crew covers about 15 miles per week, checking the line for other difficulties at the same time.

ROADS

Our work has required construction of several hundred miles of winter (or snow) roads and about 90 miles of all-weather roads have had to be constructed. Snow roads carry about 80 per cent of the freight load and are the best example of the occasional usefulness of permafrost. These roads follow lakes and the valleys between lakes to avoid steep grades as much as possible.

The route for a new road will be inspected during the previous summer by light aircraft. When approximately 8 inches of ice has formed on the larger lakes, a light custom-made truck with extra large tires is driven slowly over the route. Ice is tested for thickness ahead of the truck. This work flattens the snow and destroys its insulating qualities. A drag is pulled behind the truck to smooth the road. The road-making truck is driven back and forth over the road several times. The snow freezes hard and smooth, and on lakes the ice beneath thickens rapidly. As soon as 24 inches of ice is available, a truck-mounted snowplow goes along the road. It plows the road, on lakes only, bare of snow for a width of approximately 50 feet. Shortly afterwards, hauling with semi-trailers begins. The first loads will be approximately 10 tons. Within 2 weeks there will be sufficient ice to carry 25 ton loads. By Spring the ice under the road may be 6 feet thick. Where the road is straight, as on lakes, speeds of 50 miles per hour are possible. These roads have a life of about 90 days.

About 35 miles of all-weather road were constructed from clay that was perennially frozen near the ground surface. This road was built by bulldozing trees and clay from the sides of the road to make an embankment about 4 feet high. At first it was wet and soft, passable only to tracked vehicles. It soon dried and became quite passable. One of the company's mining properties in mountainous terrain in the Yukon Territory required about 45 miles of all-weather road. This was constructed almost entirely on side hills and encountered intermittent stretches of permafrost. These frozen areas made the road nearly impassable during the first summer. By the following July, they had thawed and dried and became usable. If such conditions are encountered again, log corduroy would be laid as soon as possible and covered immediately with gravel to reduce the rate of thaw. Four miles of road were also constructed on the tundra over a mixture of sand and clay soils. Ample supplies of crushed rock and gravel were available to make an embankment 2 feet high by 15 feet wide. Care was taken not to disturb the natural surface; this road was usable immediately and has now been in service for 5 years.

AIRSTRIPS

Three airstrips have been constructed at the company's mines in the past 12 years. One was made by placing tailings on a muskeg area. The sand from the tailings was carried by water through a pipeline to the deposition point and a layer 4 to 10 feet thick was placed to obtain a level surface. The water drained rapidly and it appears that the permafrost table rose to 3 or 4 feet below the airstrip surface the following winter and has remained there. The strip is 150 feet wide by 3, 500 feet long. A layer of gravel 3 inches thick and 50 feet wide was laid down the centre. For 10 years this strip has been in satisfactory year-round use except for about 10 days each Spring. It does not exhibit frost boils or other surface disturbances at any time.

The second airstrip was made from perennially frozen clay. Trees and moss were first bulldozed off the area. The clay surface consisted of frost mounds about 2 feet in diameter by 1 foot high. This turned into a quagmire and no further work was done for two months. By then the clay had dried and hardened enough to permit grading. Fall came at this time freezing the airstrip and the following summer it was lightly gravelled and performed satisfactorily thereafter.

The third airstrip was located on a gravel esker in the tundra. The gravel was dry and did not contain ice. After levelling, this strip was the best of the three. Its surface is about 20 feet above the surrounding terrain and it blows relatively clear of snow in winter. Being dry it is usable throughout the year and will accommodate aircraft up to Hercules size.

PIPELINES

All plant buildings including residences are steam-heated from a central heating plant. The pipelines that carry the steam, condensate, cold water and sewage are contained in wooden boxes between buildings. They are generally about 18 inches high by 2 to 3 feet wide. Steam lines are insulated but condensate lines are unprotected. In some cases the boxes have been filled with sawdust, in others the interior was lined with paperboard and a one-inch layer of insulation was fastened to the lid of the box. Both types have proven satisfactory. The sawdust-filled box presents a modest fire hazard but the sawdust ensures protection from freezing due to boiler failure, for perhaps as long as 48 hours.

SEWAGE DISPOSAL

All sewage lines are laid to provide natural drainage if possible. They are carried in the same boxes as steam and water lines or where these are not available in their own box with a steam line beside the sewage line.

Sewage line discharge into septic tanks, of adequate size, constructed of steel or wood. They are housed in a building sufficiently large to permit access on all sides. The building is steam heated, with the condensate discharging into the septic tank. This maintains the tank at 90 to 100° and ensures adequate bacterial action. Septic tanks are located where they can discharge downslope. The steepest available slope is most desirable.

The tank overflows, almost constantly, through a wooden pipe onto the ground. Tree branches or similar snow catching trash is piled around the discharge pipe. This has proven adequate to prevent freezing both in forested areas and in the tundra, and the entire arrangement has been free of difficulties.

UNDERGROUND WORK

Permafrost in the mines has varied to a maximum thickness of 950 feet at Tundra Mine located 50 miles north of the treeline.

At Discovery Mine the permafrost was about 250 feet deep when mining commenced. On one occasion the mine had to be closed down for a lengthy period because of flooding when all openings became filled with ice. When it was reopened, there was fortunately a small pond nearby which was quite warm, probably 40° to 45°F. Water was siphoned from the pond into the mine and pumped out again causing the ice to melt rapidly. This mine has now been in operation for 22 years. There is no sign of permafrost anywhere and it is assumed that it has receded 5 to 10 feet from the walls of the excavations.

At Tundra Mine, the permafrost was both a convenience and a nuisance. It was convenient because it effectively prevented surface water from entering the mine, thus lightening the pumping load and saving electricity for other uses. Rock temperatures are around 32°F varying from 28°F at a depth of 175 feet to 33°F at the 1,100 foot horizon. Underground excavations are made by drilling 1 1/2 inch diameter holes, loading these with explosives and detonating the charges. The holes are drilled with a percussion-type drill similar to a pavement breaker. Water supplied through aluminum or iron paper lines 1 to 2 inches in diameter is used with these machines to suppress dust. Cooling water was used from the diesel engines and air compressors, which had a temperature of about 140°F when it entered the mine and about 50°F when it reached the rock drills. When the drills were not in use, valves were opened slightly at the end of each line to ensure continuous flow. Heat from this source was enough to thaw the walls of any excavation. They would remain thawed as long as active work was proceeding.

DIAMOND DRILLING

The main problems with diamond drilling in permafrost are the freezing of cooling water en route to the drill and freezing of the rods in the hole. Usually the only preventative for these hazards is constant vigilance. Drilling water is obtained from the nearest lake usually less than 1,500 feet distant. In winter it is drawn from 5 to 10 feet below the ice where its temperature may be 35°F. It passes through an oil-fired heat exchanger which raises the water temperature to, perhaps, 45°F, and through 1 inch diameter rubber hose to the drill. It is essential that the water pump and the heat exchanger work continuously. As long as both are operating, the hose line will remain open. In summer the heat exchanger is left out of the system and less vigilance is required. Care must also be taken to avoid leaving the rods in the hole without water being pumped through them and without the rods being turned. Sometimes calcium chloride is added to the drilling water to lower the freezing point just before it enters the drill. This allows some latitude in leaving the rods in the hole.

In two cases, mine shafts that had been idle many years have been reopened. The permafrost was only about 100 feet thick at both locations. A hole was drilled through the ice and a string of 1 inch diameter pipe was inserted. This was extended until the bottom end of the pipe was at least 100 feet below the ice. Compressed air was blown through the pipes at about 60 to 70 pounds pressure. This brought up warm water which melted the ice quite rapidly. At the same time warm cooling water was discharged from diesel engines onto the top of the ice and pumped out again. This technique was quite satisfactory and much easier than blasting and shovelling the ice.

Our company's experience leads us to believe that permafrost problems usually can be overcome by thought and tenacity. Permafrost conditions are just something native to an area and the accompanying problems should not be overrated. It is essential to have good, reliable equipment with some spare heat capacity, patience, and an open mind toward trying out new ideas. It is desirable to use the permafrost to advantage but, if this is impossible, it will provide an excellent opportunity to test one's ingenuity.