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Brown, R. J. E.

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by

R. J. E. BROWN

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A REVIEW OF PERMAFROST INVESTIGATIONS IN CANADA*

R. J. E. BROWN

National Research Council, Ottawa

PERMAFROST, a term used widely to describe perennially frozen ground, is a thermal condition of materials in the earth's crust such as soil and rock, the temperature of which remains below 32°F continuously for a number of years. Permafrost underlies about one-fifth of the land area of the world and about one-half of the land area of Canada, comprising the Yukon and Northwest Territories and the northern parts of all the provinces except New Brunswick, Nova Scotia, Prince Edward Island, and the island of Newfoundland.

The great extension of building operations which has taken place in northern Canada since the second world war has brought to the fore the problems peculiar to construction in this vast area. In recognition of this, the Division of Building Research of the National Research Council of Canada has, since its inception in 1947, considered the problem of building in the North to be one of its major responsibilities. Early studies showed that one of the special problems of engineering construction in northern areas arises because of the presence of permafrost. The major construction works carried out in northern Canada during the second world war, such as the Alaska Highway and the Canol project, drew particular attention to the engineering difficulties caused by permafrost. There was very little organized knowledge of the subject in North America at that time although a major source of information was to be found in Russian publications. Because of the great extent of permafrost in northern Canada, it was recognized that this phenomenon was a most important factor in northern development and in 1950 a small Permafrost Section was formed within the Division of Building Research.

A start at permafrost research was made the same year when the Division joined forces with the Directorate of Engineering Development of the Department of National Defence in sponsoring an expedition to the Mackenzie River valley in the Northwest Territories. The object of this small expedition was to obtain information on the construction and performance of buildings on permafrost. More than two hundred buildings were inspected, and their condition suggested the need for a critical review of site selection methods and the need for research on suitable building foundations in permafrost areas containing fine-grained soils with high ice contents, which are subject to extensive settlement on thawing.[1]

Believing that the use of aerial photographs could simplify and reduce the costs of preliminary site surveys, the Division of Building Research joined the Defence Research Board and Purdue University in an expedition to the Northwest Territories during the summer of 1951. Purdue University, working under contract with the U.S. Corps of Engineers, had five years' air photo interpretation experience in Alaska and was anxious to extend its investigations to northern Canada. The findings of this expedition justified the belief in the applicability of air photo interpretation methods for preliminary site surveys in permafrost areas.

These and other research needs, which could be fulfilled only by actual field investigations, prompted the Division to establish in 1952 a Northern Research Station at Norman Wells on the Mackenzie River about ninety miles south of the Arctic Circle. The choice of this site was prompted by the widespread occurrence of permafrost in the area, the transportation service by boat and air, and the cooperation offered by Imperial Oil Limited, which operates an oil refinery there. The operation of the research station is seasonal, extending from June to early October.

Since 1950, the Division's permafrost research has been conducted along two

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broad fields of study.[2] The first is concerned with acquiring knowledge of the nature of permafrost and its distribution in Canada, which are vital prerequisites to successful construction. The second is concerned with construction techniques and building performance in permafrost areas and the development of site selection methods and equipment.

Information on the distribution of permafrost in Canada is being gathered continuously from a variety of sources including the technical literature, reports from others operating in permafrost areas, circulation of a questionnaire to appropriate groups in the North, and direct field observations. Emphasis has been placed on the determination of the southern limit of permafrost but observations from the entire permafrost region are also being recorded. With the several hundred observations of the occurrence of permafrost in northern Canada now available and plotted on maps, the location of the southern limit and the approximate division between the continuous and discontinuous permafrost zones are becoming increasingly evident.[3]

Accompanying the collecting of permafrost information by these means is the continuing study of the basic factors affecting its distribution and continued existence in order to improve the ability to predict its occurrence. Such work involves investigations of the basic climatic and terrain components of the energy exchange at the earth's surface that affect the occurrence of permafrost.[4] Field studies of some of these components were conducted at the Northern Research Station in 1959 and 1960, including measurements of evapotranspiration and radiation through the vegetative cover, and ground temperature beneath the cover. Closely allied with these studies is the continuing collection of ground temperature observations from thermocouple cables installed to various depths at scattered points across the permafrost region.

Since 1954, a major project has been the study of permafrost and engineering facilities at Inuvik, N.W.T., located on the east flank of the Mackenzie River delta, thirty-five miles east of Aklavik, N.W.T., in the zone of continuous permafrost. The building of this entirely new community was prompted in part by investigations conducted at Aklavik in 1953, which showed the soils and permafrost conditions in that area to be unusually poor from the construction standpoint.[5] The development of Inuvik[6] has provided a unique opportunity to observe the effect on permafrost of the construction of the various facilities associated with a town and the detailed assessment of the performance of the facilities themselves, including roads, airstrips, building foundations, and services. The initial phase of this project was concerned with the observation of construction procedures and the establishment of suitable instrumentation and reference points on the structures so that their performance could be observed and assessed in the future. The reference points were placed on all major structures to determine, by means of level surveys, any movements that may occur; thermocouple cables have been installed at various locations to measure ground temperatures.

The construction of the Kelsey hydroelectric plant on the Nelson River in northern Manitoba for the Manitoba Hydro Electric Board provided an opportunity to begin a study of dyke construction in an area of discontinuous permafrost. Beginning in 1958, thermocouple cables were designed, fabricated, and installed to observe the effect of the raised river level on the thermal regime of the permafrost and settlement gauges were installed in the sand-filled dykes to record their performance.

In 1960, a study of permafrost distribution and foundation problems was initiated at Thompson, Manitoba, the site of a new mining and smelting development of the International Nickel Company of Canada, which uses the power generated at Kelsey. At the town, located four hundred miles north of Winnipeg near the southern fringe of the permafrost region, perennially frozen ground occurs in scattered patches and its temperature is close to 32°F. Construction operations are complicated because of the difficulty of predicting the occurrence of individual permafrost islands and also because disturbance or removal of the protective insulating moss cover generally causes the thawing of the underlying frozen soil containing ice layers, resulting in large-scale settlements of struc-

tures. Because of the Division's interest in determining the climatic and terrain factors affecting the distribution of permafrost and in studying construction problems encountered in the southern fringe of the permafrost region, of which the Thompson area is typical, an observation programme is continuing.[7]

The studies at Kelsey led to the realization of the paucity of information concerning the magnitude of the thawing effect of water in contact with permafrost. As a first approach and in an attempt to provide some information on this effect, a drilling programme was carried out in April 1961 to determine the present level of permafrost under a small lake in the Mackenzie River delta near Inuvik. The strong thawing effect of the lake was borne out by the presence of thawed ground under the lake to a depth of several hundred feet.[8]

Permafrost investigations have been carried out in other areas at various times. In 1954, a hole was drilled to a depth of forty feet in a pingo near the Mackenzie River delta revealing the existence of a large body of massive ice within this peculiar landform.[9] In 1955, a permafrost distribution survey was conducted along the Mid-Canada Line. In 1958, an intensive drilling and sampling operation was carried out at Fort Simpson, N.W.T., on the Mackenzie River, where permafrost is discontinuous, to obtain information on the occurrence of permafrost, soil types, and ice content in cleared and uncleared areas.[10] In the same year, two holes were drilled to two hundred feet at Norman Wells in which thermocouple cables were installed to determine the depth and long-term performance of permafrost in the area. In 1961, a 200-foot thermocouple cable to measure ground temperatures was installed in a drill hole at the site of a proposed asbestos mining development in continuous permafrost near Sugluk in northern Quebec. During the past three years, the Division has been assisting the McGill Subarctic Research Laboratory and the Iron Ore Company of Canada in studying the distribution of permafrost in the iron mines at Schefferville, P.Q. In 1962, a permafrost distribution survey was carried out in northern Alberta to be followed in future years by similar investigations in the northern parts of other provinces.

To facilitate the investigation of permafrost, techniques have been under study for some years. Special drilling and sampling techniques have been developed to obtain undisturbed cores of perennially frozen ground and record the soil type and ice segregation. The possibility of utilizing geophysical methods for subsurface exploration in permafrost areas was investigated during the summer of 1958. Field studies were conducted at Norman Wells, Fort Simpson, and Inuvik to evaluate the use of a portable refraction seismograph and an earth resistivity device in determining the depth to permafrost. A detailed study of the factors affecting the measurement of ground temperatures in permafrost areas with particular emphasis on the use of thermocouples and various types of reading instruments was initiated in 1961 in an attempt to improve the reliability and accuracy of such measurements. The preparation of a guide to a field description of permafrost is nearing completion. This guide is intended for use by engineers in the field to achieve a simple and uniform description of permafrost in site investigations of potential construction areas.

The large body of permafrost literature now available is under continuous scrutiny and reviews of several aspects have been undertaken. These include reviews of benchmarks, tower construction, and pile foundations in permafrost areas, and the strength characteristics of frozen ground.[11] Continual review is being made of the extensive Russian literature on permafrost and selected papers have been translated. There is now an active exchange of permafrost literature between the National Research Council and the Academy of Sciences of the U.S.S.R.

A 25-minute colour film, *Building in the North*, was produced for the Division by the National Film Board early in 1961. The film describes the special characteristics of the North, such as terrain, climate, and short construction season, and emphasizes the need for careful planning and adequate site investigations prior to the start of any construction work.

In addition to the Division of Building Research, there are a number of other agencies involved in studying various aspects of permafrost. These include: Defence Research Board (muskeg and

permafrost, physical properties of frozen soils); McGill University (permafrost in Schefferville iron mines); Geological Survey of Canada (permafrost in Quaternary deposits, groundwater in permafrost regions); Geographical Branch (patterned ground studies, geomorphological studies in permafrost areas); Institute for Northern Studies (vegetation and permafrost); Department of Transport (climatic aspects of permafrost, Meteorological Branch; airfield design in permafrost regions, Construction Branch); Department of Public Works (construction in permafrost areas). Most of these agencies, including the Division of Building Research, are represented on a Permafrost Subcommittee sponsored by the National Research Council, which meets periodically to discuss current and proposed investigations. In addition to these fundamental and engineering interests, there are numerous building contractors, oil companies, and mining companies who are concerned with permafrost in their northern operations. The Division is privileged also to have close liaison with the Cold Regions Research and Engineering Laboratories (formerly Snow, Ice and Permafrost Research Establishment) of the U.S. Corps of Engineers, which have been conducting permafrost investigations for many years. In April 1962, the Permafrost Subcommittee sponsored the First Canadian Conference on Permafrost, which was attended by 160 delegates from across Canada and the United States.

It is evident that permafrost research in Canada has come a long way from its modest beginnings more than a decade ago. During this period, much information on the scientific and construction problems associated with permafrost has been gathered. Many problems still await solution and permafrost research must continue to expand in conjunction with increased construction and other activities in northern Canada.

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