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SUBJECT WORK OF THE DIVISION OF BUILDING RESEARCH IN NORTHERN CANADA (From The Arctic Circular, Vol. XIV, No. 2, 1961, p. 28-35)

When the Division of Building Research of the National Research Council was established in 1947 it was assigned responsibility for providing a research service to the Canadian building industry. Since this industry is one of Canada's largest, with a broad range of research requirements, the Division's time and effort has from the outset had to be concentrated on selected projects. The policy established was to give particular attention to those problems of building that were of special importance to Canada, which arose because of conditions peculiar to this country, and which could be studied adequately only here. This led, naturally, to studies of building in the north.

Until relatively recently there was very little construction in northern Canada. Before 1920 most building was done by the Hudson's Bay Company and other traders, the Royal Canadian Mounted Police, and the various missions. During the next two decades construction gradually increased, with such notable achievements as the drilling of the first oil well at Norman Wells in 1920, the completion of the Hudson Bay Railway to Churchill in 1929, and the introduction of mining in the Northwest Territories, beginning with the discovery of radium at Great Bear Lake in 1930.

The imperative of war led to a marked increase in the rate of northern building, marked by the construction of the Canol Pipeline, the Alaska Highway, and the airfields associated with the Crimson and

Northwest Staging Routes. In the post-war period there has been the establishment of the Joint Arctic Weather Stations in the far northern islands, developments in gold and uranium and nickel mining and in oil exploration, defence installations including the DEW and Mid-Canada lines, and a major construction program of schools and other administrative buildings. This work has emphasized the distinguishing features of northern building, and in particular has shown the special technical problems of engineering construction in the north to arise mainly from the presence of perennially frozen ground - or permafrost as it is more commonly known - a condition which occurs over nearly one-half of the land area of Canada.

DBR'S EARLY WORK

Before the war there was virtually no organized knowledge of permafrost problems in North America. A major source of information was to be found in Russian publications, but increasing activity in Canada's north soon demonstrated the need for permafrost information related specifically to Canadian conditions. Accordingly a Permafrost Section was established within the Division in 1950, and work was begun that same summer on a survey of the performance of buildings over permafrost in the Mackenzie River valley. This survey was carried out jointly with the Directorate of Engineer Development of the Department of National Defence and was followed the next summer with an expedition to the Northwest Territories, made in cooperation with the Arctic Section of the Defence Research Board and Purdue University, to examine the application of air-photo interpretation methods to preliminary site surveys. These assessments showed the need for studies of site selection methods and of factors affecting the construction and performance of foundations in permafrost, studies which now form two of the three broad lines of permafrost research being currently undertaken by the Division. The third is a study of the distribution, occurrence, and properties of permafrost in Canada.

Since many aspects of permafrost research could be studied adequately only in the field, the Division in 1952 established a northern research station at Norman Wells to provide a field base. The Mackenzie valley area was chosen because it had shown evidence of some of the worst soil and permafrost foundation problems in the north; Norman Wells was selected because of its central location in this region, its excellent transportation service by barge and air, and the presence of the Imperial Oil Company, whose friendly cooperation has been of particular value. Initially, the Division was in rented quarters but in 1956 these were replaced by two new buildings, providing accommodation for six to eight research workers, and a combined soil mechanics laboratory, workshop, and garage for special soil studies and equipment.

The detailed work of the Permafrost Section has included the development of special drilling and soil sampling techniques to investigate the properties of perennially frozen soils, and the continuing compilation of data on building performance in relation to soil and permafrost conditions. Some of the early phases of this work were carried out at the townsite of Aklavik and demonstrated the unusually poor nature of the permafrost of that area. This was an important factor in the ultimate decision to relocate the town.

In 1954 the entire northern staff of the Division was diverted to assist the government team assigned the task of selecting an improved location for Aklavik. This provided a valuable opportunity to use air-photo interpretation methods in preliminary permafrost investigations and to give a practical test to the drilling and sampling techniques which had been under study. These included somewhat unusual field photographic procedures for recording details of ice formation in frozen soil samples in summer without recourse to costly refrigerated equipment for sample storage and transport.

INUVIK

The town of Inuvik now built at this new site has provided an excellent base for further studies of permafrost. These have included observations of the effect on permafrost of the construction of various facilities associated with a town, such as roads, airstrip, building foundations, and services as well as detailed assessments of their performance in this area of continuous permafrost. A careful record has been kept of the original permafrost conditions to permit a comparative assessment of any changes that may occur.

The initial phase of the program has been observation of construction procedures and establishment of suitable instrumentation on the structures to be studied. To follow the performance of most of the major structures including the powerhouse, hostel, school, and oil storage tanks, elevation reference points have been marked on the pile foundations. This has entailed setting a series of elevation bench marks throughout the townsite to which these structures are referenced. In addition, three specially designed deep bench marks were installed in drilled holes to a depth of 50 feet to serve as reliable permanent datum points. These are themselves under observation to determine their effectiveness, since the design of precise bench marks in permafrost areas is still not well established.

Studies have also been made of the refreezing of piles placed in steamed holes. Records of steaming and driving details, boiler water and fuel consumption, ground temperatures, and pile movements during the freeze-back period were obtained for piles both singly and in groups; these were aimed at providing an estimate of the time required before piles are sufficiently anchored by refreezing for erection of the superstructure. Results to date indicate that, in an area such as Inuvik, sufficient refreezing occurs within approximately eight weeks from the time of pile placement, provided that the piles are sufficiently embedded in the permafrost and that excessive disturbance of the site has been avoided during the piling operations. It is not therefore necessary in these areas to leave piling over an entire winter to obtain sufficient refreezing.

Observations of ground temperatures to depths of 30 feet are being carried out by means of thermocouple installations under buildings, utilidors, bridges, sections of road, and the airstrip. Those at the airstrip are of particular interest indicating that, four years after construction began, the original ground at the bottom of the 8-foot rock fill remains frozen. Temperature measurements are also being obtained in undisturbed natural areas to depths of 30 feet and two special installations have been made to depths of 100 feet to permit an assessment of long-term changes in the permafrost. The depths of natural thaw in various soil types and under varying surface cover conditions have been measured at selected points in the townsite by means of hand probings.

The major part of the construction program at Inuvik is now over and the Division's instrumentation in the area is complete. Further work will be confined to regular collection and analysis of ground temperature readings, with periodic visits to observe and assess the performance of the various structures.

KELSEY DYKE STUDIES

Another area in which the Division has been active is in northern Manitoba at the site of the Kelsey hydro-electric plant on the Nelson River. This plant, built for the Manitoba Hydro-Electric Board to supply power to the new nickel mining town of Thompson, is in an area of discontinuous permafrost where frozen soil occurs in scattered patches and is close to melting. These conditions are common near the southern boundary of permafrost and often prove more troublesome for construction than those in the more northerly regions, where permafrost is continuous and several degrees colder.

The Division therefore welcomed the opportunity to initiate in 1958 a study of the performance of a sand-filled dyke over permafrost at the Kelsey plant. Thermocouple cables have been installed in the reservoir formed by the raised river level and in the dyke itself. Similar cables in an undisturbed area of the site serve as reference points. The dyke has been instrumented with settlement gauges to follow any soil movement resulting from the thawing effect of the reservoir. The soil in this area is a varved clay of unusual interest, containing varying quantities of ice in layers up to 8 inches thick. The water level was raised to its final elevation in the reservoir in November 1960, but there has as yet been no indication of significant thawing effects on the frozen ground beneath. Observations indicate that the mean ground temperature for the area is about 31°F.

The thawing effect of water in contact with permafrost is an important consideration in many construction projects in permafrost regions. Both the rate and depth of thaw are questions of importance to the engineer, as was recognized in the design of the Kelsey project, and yet these are not readily answered with the information now available. One method of improving knowledge and of providing guidance for future engineering design is by studying the present level of permafrost under natural bodies of water in the north such as lakes and rivers. Such a study was begun by the Division in the spring of 1961 in the Mackenzie delta, not far from Inuvik, where drilling was done to determine the permafrost profile under several small lakes and a river channel.

The difficult construction conditions caused by discontinuous or sporadic permafrost are also much in evidence at Thompson, some fifty miles to the southwest of the Kelsey hydro-electric plant. In order to broaden its work in these fringe areas of permafrost the Division has recently initiated a program of field observations of construction at this townsite.

PERMAFROST DISTRIBUTION

Paralleling this work on the problems of construction in permafrost areas has been the compilation of information on the occurrence and distribution of permafrost in Canada, particularly for defining the southern limit of permafrost. This information in the form of ground temperature records or, more commonly, direct observations of permafrost occurrence, has been obtained from many sources including references in the technical literature, reports from individuals or agencies in the north, and the Division's own field studies, and is being recorded in card index form and on large-scale maps. Recently a Permafrost Questionnaire has been prepared for circulation under the auspices of the Permafrost Subcommittee of the Associate Committee on Soil and Snow Mechanics to appropriate groups in the north.

In spite of these aids and even with the fullest cooperation of those in the north, this way of obtaining a picture of permafrost distribution in Canada is inevitably a long-term project. The Division has therefore begun a study of the climate and terrain factors that, jointly, influence the ground thermal regime and hence the occurrence and continued existence of permafrost. It is only with such knowledge that the limited observations of permafrost now available can be used to predict permafrost occurrence in other areas. This work, started in 1959, has been mainly carried out at Norman Wells and has already indicated some significant differences in evapo-transpiration, net radiation, and ground temperature readings between some types of vegetative cover.

GENERAL PERMAFROST INVESTIGATIONS

Closely allied to these studies of permafrost occurrence have been a number of general scientific investigations of permafrost as a natural phenomenon. These have been largely concerned with the study of ground temperatures at depths greater than are normally affected by engineering construction and are aimed at demonstrating whether permafrost in Canada is static or changes with time.

The first of these installations consisted of two 200-foot deep holes at Norman Wells, completed in 1958 and instrumented with thermocouple cables. The two 100-foot deep ground temperature installations made at Inuvik in 1959 are being supplemented by a 200-foot deep hole in the Mackenzie delta. Temperature observations have also been made in pingos, those peculiarly shaped mounds found along the western arctic coast near Tuktoyaktuk.

INSTRUMENTATION

In all this work, the Division has spent much time developing and improving equipment, field operating techniques, and instrumentation. Methods of measuring ground temperatures have been constantly reviewed in an attempt to develop a system which has the desired accuracy and reduces to a minimum the possibilities of observer error. This latter requirement is of particular importance since volunteer or part-time observers are serving in many of the Division's field studies. In the method now used, the thermocouple wires are encased in an oil-filled plastic tube to protect them from moisture and from damage during installation. A special electronic direct temperature reading instrument has been adapted for field use throughout the year with a portable gasoline-fed generator for power.

Another project has been the development of methods of obtaining information on subsurface soil conditions in permafrost. This has dealt mainly with refinements of drilling techniques in frozen ground but recently geophysical methods for determining the depth to permafrost have been considered and field studies have been carried out with a portable shallow refraction seismograph and an earth resistivity measuring device. The reliability of the information obtained with either instrument appears to depend to a large extent on the experience of the interpreter, and prior knowledge of subsurface conditions is necessary for effective use. Both instruments seem to be mainly useful for supplementing subsurfaces information obtained from boreholes where the permafrost table is too deep or soil conditions too difficult to be readily probed by hand.

NORTHERN HOUSING

Building activity in northern Canada has also created much interest in superstructure design. Although experience has clearly demonstrated that conventional wood-frame building systems can give satisfactory service as heated building enclosures, the high cost of construction in the north has sparked a search for more economical systems.

One result has been an increased emphasis on prefabrication techniques, and the Division has undertaken a number of studies on northern housing to meet the demand for information on these and other aspects of superstructure design. Technical and economic evaluation of prefabrication methods for northern use have been made, based on visits to Canadian prefabricators and surveys of the performance of these buildings in the field. The study has suggested significant economies with some of the light-weight fully prefabricated units now on the market. The stressed skin frame units offer 50 per cent reduction in weight and considerably greater reduction in site erection time over conventional construction, and have received the widest acceptance of the prefabricated systems proposed. The recently developed plastic core structural sandwich units, which are even lighter in weight, have not yet realized the low cost potential of which they appear capable. A comprehensive report on these findings has been prepared.

An earlier phase of the Division's study of northern housing dealt with the high cost of fuel and demonstrated that a much greater thickness of insulation than is normal in southern Canada can be justified on an economic basis for all heated northern buildings.

In all this work the overriding importance of economics in any practical assessment of building techniques in the north has been evident. The careful documentation of the costs of northern construction in terms of their three main components - transportation, labour, and materials - is greatly needed.

The prime objective of all of the Division's work is the provision of information. In the first instance, this may mean simply that the Division acts as a channel for information from other sources, assembling and organizing it in a form suitable for effective use by industry. Where the available information appears inadequate, actual research in the laboratory or in the field may be undertaken to fill the gap. It is largely this aspect of the northern work that has been described in some detail here. In both instances, however, the aim is the publication of information. Only when this has been done, and the information put into the hands of those who can use it, can the research studies be considered effective and the work complete.