III. 4. FOUNDATION PROBLEMS AT FORT McPHERSON, N.W.T.

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During the period from July 1956 to December 1958, the Department of Public Works was responsible for the construction of several buildings at Fort McPherson, N.W.T. The construction of these buildings was complicated by the presence of permafrost throughout the entire area covered by the project. This paper deals with the problems encountered in placing the foundations for these structures.

The settlement of Fort McPherson is located on the Peel River at latitude 67° 30' N and longitude 135°W. Fort McPherson is approximately 1,200 miles northwest of Edmonton, 60 miles south of Aklavik and 60 miles north of the Arctic Circle.

Although Fort McPherson is not actually in the Mackenzie River delta, the general conditions of temperature and precipitation are similar. The settlement is located on the right or east bank of the Peel River, and the river flows almost due north at this point. Actually, the settlement is located on a rise of land which is an island at high water level in the Peel River. This island is roughly triangular in shape. It is approximately 7,000 feet long in the north-south axis and approximately 3,000 feet wide at the base to the south. The settlement is generally 50 to 60 feet above the average river level and the whole area is approximately 80 to 100 feet above sea level.

Fort McPherson is in a permafrost area and the estimated thickness of permafrost is 1,000 feet. On the project site, at depths varying from 9 to 16 feet, a hard grey to black shale was encountered. Test pits dug on the site gave completely inaccurate information of the depth to this shale. This grey black shale, when taken from the bottom of an excavation, is very hard and appears to be quite durable. It does not weather well and, when allowed to dry, breaks into literally thousands of small pieces. These pieces in turn, if subjected to traffic, will quickly disintegrate to rock flour.

The overburden on the project site was rotten shale, badly fragmented, due to frost action. Between the depths of 6 inches and 3 1/2 feet, large ice lenses were encountered. In places, these were nearly pure ice with only hair-line traces of silt running through them.

The surface cover in the area is moss which has an amazing insulation value. In many areas, permafrost occurred directly beneath a moss cover only 6 inches thick. In areas not cleared, there were generally small birch. In the low-lying areas around the lakes and

creeks, there was a very dense growth of alders and spruce. The spruce grows in fairly dense stands and 30 foot piles with 12 inch butts and 8 inch tips were cut for the garage and wharf foundations within 1 1/2 miles of the settlement.

The Fort McPherson project consisted of the following group of structures:

100-Pupil Hostel, approximate floor area - 30,000 square feet
3-Classroom Addition to the existing school
4-Apartment Teacherage
A Generator House
A Warehouse
A Walk-in Freezer
An Ice House
4-Bay Garage
A Bulk Oil Storage Tank - 10,000 barrel capacity.

These buildings were placed on four types of foundations.

(i) The hostel and generator house were constructed on concrete piers with reinforced concrete beams poured monolithically.
(ii) The 3-classroom addition to the school, 4-apartment teacherage, walk-in freezer, and warehouse were constructed on concrete piers using laminated timber beams.
(iii) The garage was placed on timber piles, the only structure at Fort McPherson with the exception of the wharf to be placed on piles.
(iv) The ice house was placed on mud sills on a shale pad placed directly over the moss. The bulk oil storage tank was also placed on a shale pad approximately 6 feet in depth.

As stated previously, test pits were dug on the site which proved to be completely inaccurate. For example, in the area of the walk-in freezer, a test pit was dug which indicated hard shale at approximately 9 feet 8 inches. Shale was not encountered until a depth of 16 feet when the actual excavations were made for the foundations. In the area of the boiler house, the test pit indicated that shale would be encountered at 9 feet, and again, shale was not reached until a depth of 16 feet at the time of construction. These two examples will give some indication of the inaccuracy of the test pits.

During preliminary planning, it was proposed that the hostel would be constructed on piles similar to the hostel erected at Inuvik, N.W.T. As a result of the test pits, however, the design was changed to concrete piers as it was felt that there was not sufficient overburden on the shale to place piles.

The first construction crew members arrived on the site in

mid-July 1956, approximately one week before the scheduled arrival of the first barges loaded with materials.

With a very short construction season ahead, the aim was to get as many buildings closed in as possible before winter began. Aggregate for concrete was to be hauled by one of the transportation companies on the Mackenzie River system, from a gravel beach at the mouth of the Peel River about 40 miles downstream from Fort McPherson. This gravel was to be loaded and hauled as soon as shipping started.

As a result, the excavations for the piers had to be started immediately to be ready to place concrete when the gravel arrived. The gravel did not arrive as scheduled and the problem arose of preventing thawing of about 100 excavations approximately 4 feet by 4 feet by 11 feet deep. This proved impossible and the large ice lenses, referred to previously, melted and literally poured into the holes. This was probably a fortunate occurrence because these lenses would have thawed perhaps under any circumstances and would have created even greater problems after the structure was erected. It did create, however, a new problem at the time of construction.

It became obvious, with the excavation of the first holes, that large quantities of backfill were going to be required. Material excavated from the holes contained less than 50% solids and did not even provide enough material to backfill the holes to one-third of their depth. This, coupled with the thawing of the large ice lenses, put demands on the limited equipment available. It became almost impossible to provide the quantity of fill required in the time available. This lack of equipment to handle adequate amounts of backfill complicated the backfilling of the holes at a later date, because it became necessary to drag the fill material under the concrete beams which had already been poured. In other words, the concrete work proceeded much faster than the holes could be backfilled.

Three methods of excavation were used for placing concrete piers. The first was with pick and shovel. The second was with air compressor and jack hammers, and the third was with open pit excavation using jack hammers to break out the material and dragline to remove the excavated material.

The pick and shovel was used at the very start of construction before the equipment arrived on the site. This was obviously a very slow process but it was considered justified because of the short construction season.

When the equipment finally arrived, the process of digging the

holes was changed to the use of air compressor and jack hammers, and the native labourers became quite expert in the use of this equipment in the close confines of the 4 foot by 4 foot holes. Using this method of excavation, holes were dug to a depth of 16 feet.

The third method of excavation, the open pit method, is discussed in more detail because the problems were considerably different from the smaller holes. It was decided to use the open pit excavation for the boiler room piers because the pier spacing for this portion of the building was too close for individual hole excavation. Pier spacing was 7 feet 6 inches in the east-west direction and 6 feet 7 inches in the north-south direction. The total excavation covered an area of approximately 68 feet by 45 feet and was 16 feet in depth. This meant approximately 1,800 cubic yards of material were removed. The area was first stripped of its moss cover by the dragline down to permafrost. The jack hammers were then used to break out the frozen material and the pieces thus chipped out were gathered together and removed by the dragline. Severe thawing was experienced on the vertical surfaces exposed by the excavation, particularly on the north face which was exposed directly to the sun. The bottom of the excavation was channelled so that water flowed to one corner and was removed by continuous pumping. Solid shale was encountered at approximately 16 feet below the surface. The total excavation, forming of the piers, beams, and floor slab took exactly one month, from August 13 to September 14. As soon as the excavation was completed, 3 foot by 3 foot pier footings were placed and poured. The piers were formed in place in two 8 foot sections, the upper 8 foot section being placed approximately a week after the lower. The boiler house slab and beams were poured monolithically with the piers. Incorporated into the boiler house slab was a water tank enclosure. This structure was similar to a basement with the difference that the floor slab was supported on piers which went down to the hard shale. To date, no leaks have shown in this water tank enclosure. Figures 1 and 2 show details of the boiler house foundation and Figure 3 shows the completed hostel.

To compare the excavation of the individual holes with the open pit excavation method, the following advantages and disadvantages are listed:

The advantages of the individual holes were:

(i) Less thawing - because less surface was exposed to the sun;
(ii) Less excavation;
(iii) Less backfill is required if the permafrost can be prevented from thawing in the areas between the holes.

The disadvantages of the individual hole method over the open pit excavation were:

(i) Slow digging because of the cramped conditions of the small hole. Obviously the excavation of the hole was a one-man job;
(ii) At depths exceeding 5 feet, material had to be placed in 5-gallon pails and drawn out of the holes by hand;
(iii) Other than the jack hammers, it was impossible to use equipment for the excavation.

In conclusion, there are three points to emphasize as a result of experience at Fort McPherson in placing foundations in permafrost:

(i) Test pit or boring information must be obtained by a person qualified to assess the soil conditions as they are found;
(ii) Sufficient construction equipment of the right type to undertake the work must be available if a project schedule is to be maintained;
(iii) Material deliveries, which affect the construction schedule, must be expedited. In this regard, the critical path method of planning and scheduling appears to offer good possibilities.

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Discussion

The question was asked by the Construction Division, Department of Public Works if water froze in the excavation during the night. The author replied that the water did not freeze and added that many of the holes were excavated during the previous year.

H. G. Dutz enquired whether the pier foundations for the hostel were satisfactory once the firm shale was reached. Furthermore, did the garage on piles have a structural floor or was it a slab on grade? The author stated that some trouble was experienced with the reinforced concrete beams but there is no record of movement of the piers which bear on the shale. The garage consisted of a laminated wood floor on wood beams on piles.

A. Thorley wondered why churn drills and caissons were not used. The author's answer was that at the time of construction it was not known how deep the holes would have to be excavated. From the test pits, it appeared that the top of the shale was at a depth of 6 feet but it was actually encountered at a depth of 16 feet. Thorley then requested information on the pile foundations. The author remarked that piles could have been installed either by steaming or drilling. He added that it was not possible to drill for the piers because they were tapered, being 12 inches square at the tops and 18 inches square at the bottoms.

G. Jacobsen wished to know if construction was undertaken during winter, to which the author replied that it was undertaken

during the summer and early Spring. In September, difficulties were caused by rapidly melting ground ice which caused flooding in the excavations. Conditions were much better in April because the ice remained frozen.

R. D. Lawrence asked what material was encountered at the 9 foot depth. The author replied that it was the same as above. More than half of the ground material was ice.

N. D. Radforth commented that the use of moss and peat as insulating materials in construction is questionable. It deteriorates rapidly and has different properties from those in the undisturbed state. This applied whether it is used in buildings or roads.

In reply to M. Bruno's request for information on the performance of roads, the author stated that they performed poorly at the beginning. Eventually clay was added to the shale which was an improvement although the roads were greasy when wet. Near the end of the job, the roads were surfaced with gravel which improved them considerably.

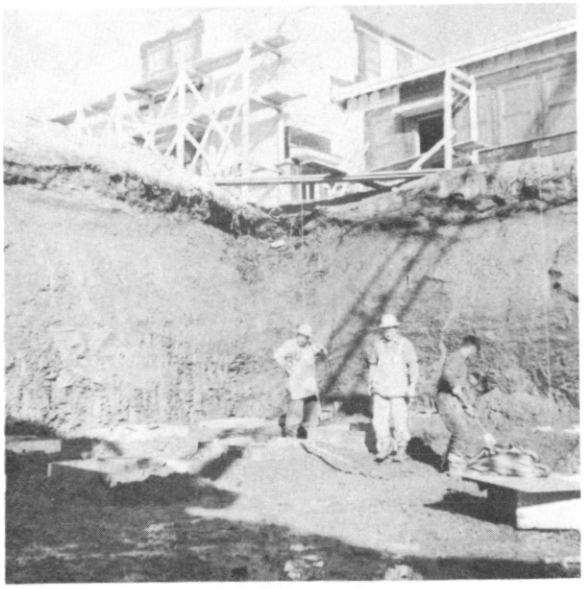

Fig. 1 View towards the northwest corner of the excavation for the boiler room piers. Note the depth of excavation - approximately 16 ft. below grade. August 29, 1957.

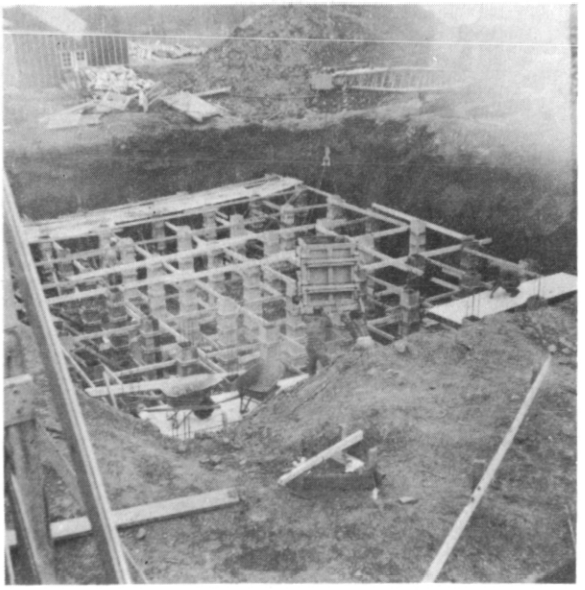

Fig. 2 Pouring first lift of boiler room piers. Note crane holding concrete hopper. August 30, 1957.

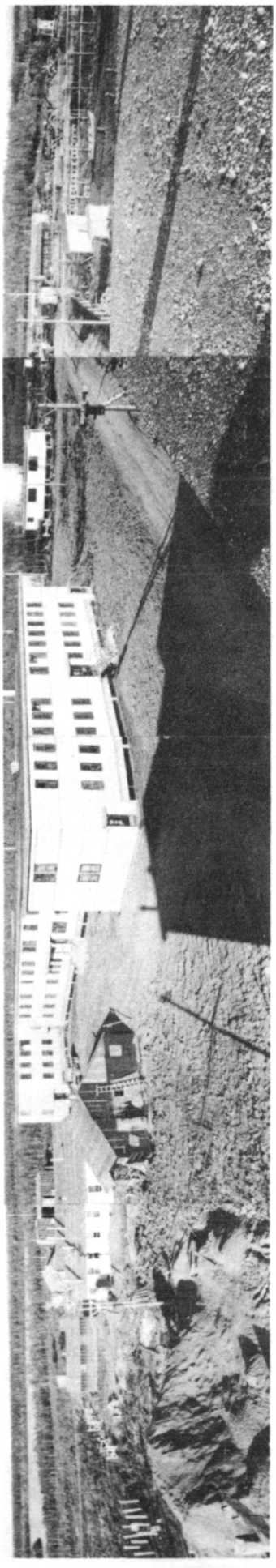

Fig. 3 View southeast showing front elevation of completed hostel. Note teacherage in background (center-right). June 1958.