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Soil Mechanics and Foundation Engineering**  
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NATIONAL RESEARCH COUNCIL OF CANADA  
ASSOCIATE COMMITTEE ON SOIL AND SNOW MECHANICS

ANNUAL REPORT  
of the  
CANADIAN SECTION  
of the  
INTERNATIONAL SOCIETY OF SOIL MECHANICS  
AND FOUNDATION ENGINEERING  
FOR YEAR ENDING JUNE, 1959      ANALYZED  
INCLUDING MEMBERSHIP LIST OF THE CANADIAN SECTION

Prepared by  
C.B.Crawford

Technical Memorandum No. 62

OTTAWA  
August 1959

FOREWORD

This Annual Report is a summary of the activities of Canadian members of the International Society of Soil Mechanics and Foundation Engineering, for the period July 1958 to June 1959.

It is published for the purpose of keeping Canadians informed of those soil mechanics investigations which are being conducted in their own country. In this way, it will assist in overcoming the natural handicap offered by the widespread geographical distribution of soil mechanics work in Canada. It will supplement the Annual Canadian Soil Mechanics Conference, which has now been held for twelve years under the auspices of the Associate Committee on Soil and Snow Mechanics.

This report in principle does not include reports on routine work of the members of the Society. It is difficult, however, to distinguish in the annual reports of individual members on which this report is based between routine and non-routine work. It is probable, therefore, that some of the work noted was of a routine nature but was considered worth including because of possible general interest. Brevity in reporting the work has been attempted.

TABLE OF CONTENTS

	<u>Page</u>
1. Soil Properties and their Measurement	1
2. Techniques of Field Measurement and Sampling	7
3. Foundations of Structures:	
(a) General Subjects and Foundations other than Piled Foundations	12
(b) Piling and Piled Foundations	14
4. Roads, Runways and Rail-Tracks	17
5. Earth Pressure on Structures and Tunnels	24
6. Earth Dams, Slopes and Open Excavations	25
 APPENDIX A - Alphabetical list of Members of the Canadian Section of the International Society of Soil Mechanics and Foundation Engineering.	
 APPENDIX B - List of Members associated with Organizations	

## 1. SOIL PROPERTIES AND THEIR MEASUREMENT

### H.G.Acres & Company Limited:

(a) Continued study of shear strength and compressibility characteristics of saturated and unsaturated clays, including the effect of negative pore pressures on shear strength parameters, in connection with the design and construction of earth dams.

(b) Triaxial testing of core samples from permanently frozen inorganic clay and silt for the determination of strength and consolidation characteristics. Triaxial consolidation tests were carried out under  $K_0$  conditions. The results of the tests were used for the analysis of stability and settlement of dykes on permafrost foundations.

(c) Examination of the properties of anorthosite rock with respect to usability in a rock-fill dam.

### E.W.Brooker:

A series of critical void ratio tests was performed on clean sand from the McMurray tar sand deposits. It was interesting to note that the Casagrande critical void ratio obtained correlated with the void ratio of a small pile of the same material in a saturated condition, which became quick when submitted to vibrations. The latter void ratio was determined on the basis of moisture content in a saturated state.

### L.J.Chapman:

Continuing measurement of potential evapotranspiration at Norman Wells, N.W.T., in co-operation with the Division of Building Research, National Research Council, and at Kapuskasing in co-operation with the Dominion Experiment Station.

A study of the mineralogical composition of sands in Southern Ontario by (Mrs.) Caryl Dell. The first part of this has been completed.

### D.F.Coates:

Study of effect of time and stress on strain and failure of clays.

Study of relative density of low N glacial till.

M.M.Davis:

Study of fundamental properties of some Ontario clays with emphasis on thixotropy.

Division of Building Research, National Research Council:

On a sensitive marine clay triaxial compression tests were carried out with pore pressure measurements, in order to obtain typical shear strength parameters in terms of effective stresses. These tests showed that the rate of strain had a considerable influence on the failure stress and on the pore pressure at failure. The shear strength parameters were therefore affected by the rate of strain. A paper has been submitted to ASTM.

A series of consolidation tests has been done in order to assess the influence of variations in test procedure. In addition to the usual incremental loading technique, a number of tests were carried out using constant rate of strain application and constant rate of stress increase. The preconsolidation load was found to be considerably influenced by the method of testing. A paper on this was presented to ASTM.

Preliminary laboratory tests to assess strength regain with time after remoulding were made. Based on these test results a more extensive programme has been undertaken.

Laboratory tests to study volume change/water content relationships, volume change reversibility, linear and volumetric shrinkage and swelling pressures are continuing.

Work on varved clays has included a comparison of field vane and laboratory strength tests results, the analysis of a road fill failure over varved clay and some settlement observations.

Literature on the technique of measuring soil moisture suction and the application of these measurements to engineering problems was reviewed and published in ASTM Proceedings.

Correlation of the one-point liquid limit test with the standard test was made for several hundred samples and the results presented to ASTM.

Observations of the effect of land clearing on permafrost conditions were made at Fort Simpson in areas where the land clearing dates are known and some extend back to the Nineteenth Century. The investigations initiated late in August 1958 consisted of drilling thirty boreholes (average depth - 25 feet) at various locations throughout the island on which the town is located. Observations were made on the depth of permafrost, terrain features, soil types and ice contents.

Ecole Polytechnique:

Mapping of pleistocene deposits in the City of Montreal include some physical characteristics of the main deposits. (Thesis by S. Hode Keyser).

Shearing properties of compacted till.

Research continued on cohesion and compressibility conditions of clays as related to double layer data; subsequent research on stabilization of natural cohesive soils and artificial granular fills by adding fillers and natural deposits.

GEOCON/FENCO:

- (a) Study of lateral pressures set up in stacks of pulpwood to determine the effect of pressures induced thereby on adjacent foundations.
- (b) Studies of settlements resulting from the thawing of permafrost.

A.H.Graves:

In connection with proposed construction of a permanent townsite, the Department of Public Works has recently undertaken a series of temperature readings in the permafrost soil at Frobisher Bay, N.W.T. The maximum depth from which readings were obtained was eighty-five feet below ground surface. Thermocouples with potentiometer were used to obtain the temperature readings.

G.T.Hughes:

Have completed a preliminary report of soil conditions and review of geology of the Kingston area. Report is titled "Geology and the Engineering Properties of Soils in the Kingston Area".

W. Kalbfleisch:

The bogland soils of Newfoundland are of relatively recent geological formation and do not have the same characteristics as bog or peat soils of Ireland. These soils have an organic content of almost 100 percent.

Special attention is being given to methods of drainage of these soils and to the design of equipment for this purpose.

Ditches  $1\frac{1}{2}$  feet wide and 2 feet deep cut with conventional V-plows will close in almost completely in 2 to 4 years due to soil flow. Moreover, spoil banks from V-plow ditches restrict surface drainage.

As an alternative, circular rotary blade ditchers are being designed for test purposes. The soil bearing capacity of about  $1\frac{1}{2}$  pounds per square inch is a critical factor in machinery design.

Water level records are being secured in relation to the depth and spacing of ditches. Crops can be reasonably successfully produced on these soils when the water table is 6 to 12 inches below the surface. Due to the high water table and soft soil conditions, agricultural tillage and harvesting equipment also present problems in the utilization of bogland soils.

J.A.Knight:

Sponsoring university research on the effect on base exchange of calcium chloride on illite clay found in the Ottawa Valley. Report expected in 1960.

Dr. W.H.Mathews

With Drs. J.R.MacKay and B.S.MacNeish - analysis of data on arctic soils at the Engigstciak archaeological site, Yukon Territory, and the preparation of a report entitled "Geology of the Engigstciak Archaeological Site" dealing with the overturning of the active layer in an Arctic environment.

Dr. G.G.Meyerhof:

Research has been started on an investigation of the skin friction between clays and construction materials. Undrained direct shear tests are being made with various clays and concrete, steel and wood having different surface conditions (Master's thesis by R.P.DeLory).

Laboratory studies of the relationship between the impact energy per blow and the compaction of dry and moist sand have been continued. (Research by V.E.Vaughan).

G.C.McRostie:

Due to the economic significance of relative density determination studies by Gibbs and Holtz (London Conf.) a local study of relative densities was initiated as group discussion and later experimental investigation was made in till soils.



Preconsolidation was also studied in group discussions with emphasis on methods of determination of preconsolidation load and of estimating settlements for loads less than the preconsolidation load.

The relationship of strength of clay soils to time was studied by means of triaxial tests at very slow loading rates.

#### P.F.R.A.

Studies are continuing on the shear strength, swelling and consolidation characteristics of highly plastic clays, clay shales and compacted clays.

#### Racey, MacCallum and Associates Limited

Information is being gathered on the geotechnical properties of the Leda clay in an effort to see if any statistical inter-relation between its properties exists.

A detailed study of the deformation properties of clay deposits near Fort William, Ontario, is being carried out in the triaxial compression apparatus utilizing a pore pressure measuring device which has been constructed in accordance with the basic design of Bishop and Henkel. It is hoped that the study may also be extended to include the clay deposits from the south-western regions of Ontario.

#### Dr. N.W.Radforth:

A means of distinguishing origin of physiographic difference between certain given areas of organic terrain by reference to microscopic indices in the peat of the terrain has been reported on at the annual meeting of the Royal Society of Canada - paper under the authorship of N.W.Radforth and L.S.Suguitan.

#### A. Rutka:

It is hoped to develop an engineering chapter for each soil survey report prepared by the Department of Agriculture. Samples of all soil types are now being taken for Peel County, Ontario.

#### St. Lawrence Seaway Authority:

An investigation of the settlement of granular fills was made. Time-settlement curves were derived from field observations of

fills of glacial till and broken shale, limestone and sandstone, placed under a variety of conditions. Supporting data were obtained from a review of literature.

By empirical methods it was attempted to assess the effect on settlements of variations in type of material and method of placement, height of fill, submergence, traffic, length of construction period, surcharges and time of initial observation.

The age of fill at which future settlement would be negligible was estimated for each material. Results of the programme were applied to a considerable variety of practical problems.

R.G.Tanner, "The Settlement of Granular Fills", Master's Thesis, University of Liverpool, March 1959.

R.C.Thurber:

Fort St. John shale and clays from the Dawson Creek area are being studied to determine the nature and extent of the rebound characteristics of these materials.

University of Alberta and/or Alberta Research Council:

A laboratory study of the variation in unit weight and strength of typical Alberta soils during cyclic closed system freezing and thawing.

A laboratory study of the variation of permeability of a base course with varying quantities of chemical additives.

A study of the permanence of the effect of admixtures in reducing the plasticity of base course fines.

Hydro-Electric Power Commission of Ontario:

Investigation of the shearing properties of clays - This work involves studying the methods of laboratory determination of the shear parameters in terms of effective stresses  $c'$  and  $\phi'$  and more specifically to effects on  $c'$  of the stress history of a sample.

Following Henkel (unpublished) and Rutledge (1947) the drained and undrained tests will give similar results, the shear strength varying only with moisture content at failure. The current study seeks to confirm this in terms of the undrained test with pore pressure measurement and the drained test, both

with increasing axial effective stress and with decreasing lateral effective stress in the hope that these drained tests may then be used to determine accurately the shear parameters in preconsolidated materials.

R. Yong:

Strength characteristics of frozen soil - further investigation of behaviour of frozen soil under varying conditions of loading.

Physico-chemical analysis of high swelling clays - co-operative study with Dr. Warkentin on the properties and behaviour of high swelling clays - sodium and calcium montmorillonite soils.

Laboratory study of behaviour of silt under loading - a study of the "elastic" constants of silts and their relation to behaviour under load. Model correlative tests under simulated field conditions.

2. TECHNIQUES OF FIELD MEASUREMENT AND SAMPLING

H.G. Acres and Company Limited

(a) Extraction of 2-inch diameter cores of permanently frozen inorganic clay and silt using fuel oil as a drilling lubricant.

(b) Seismic determination of bedrock profile and general classification of overburden up to 200 feet deep of 30 miles of river using a water-borne high-powered echo sounder in order to assist in the initial selection of dam sites. A similar determination from ice of eight river crossings totalling 6,000 feet with maximum overburden depth of 120 feet was made using portable refraction type seismic equipment in order to assist in the final selection of locations of hydraulic structures.

(c) Design, installation and operation of extensometer type apparatus in rock plug 60-foot diameter, 60 feet thick, serving as a watertight seal between the bottom of a reservoir and the end of an intake tunnel prior to its removal by blasting. This work allowed the rock movements in the plug to be detected during a portion of the period of rock excavation beneath the plug.

R. Audy:

A study of the influence of oversize particles in the determination of the field density of glacial till.

S.J.Bourget:

An experiment was conducted to study different methods of installing the electrical resistance units (gypsum) into soil for moisture measurements. The units were installed in three different ways:

- (a) in undisrupted soil cores;
- (b) in sieved soil packed to original field density;
- (c) in unpacked sieved soil.

Three soil types were used. The moisture content readings obtained by the gypsum units for the same electrical resistance varied with the type of installation. The differences were greater on the fine-textured than on the coarse-textured soils. The variation in soil moisture obtained, ranged from 1 to 6 percent within the available water range.

Care must be taken in installing blocks in the field to get good packing.

W.G.E. Brown:

Application of aerial photography to soil surveys and access evaluation, gravel searches and irrigation design.

D.F.Coates:

Plate load testing on sands and clays to measure in situ strength and subgrade reactions for building foundations.

Comparison of normal open Shelby tube sampling with piston sampling.

Division of Building Research, National Research Council

An annotated bibliography on the field vane shear test was prepared. Some in situ vane testing was done using different types of vane and the results compared with laboratory tests.

A neutron meter for the in situ measurement of soil moisture, employing scintillation counting technique has been constructed.

Much consideration was given to the preparation of artificial media for laboratory calibration of the apparatus and the calibration was begun.

A drilling programme was carried out at Norman Wells, N.W.T., to obtain experience and information on drilling deep holes in permafrost and to obtain more information on permafrost temperatures. Two holes were drilled to depths of slightly greater than 200 feet, using a diamond drill. Observations were made on wash water temperatures, rates and times of penetration and bit pressures. Measurements of ground temperatures in these deep holes began in the spring of 1959.

A study was made of the possibilities of geophysical methods in permafrost areas. Field investigations with a portable shallow refraction seismograph and an earth resistivity measuring device were conducted to evaluate their use in determining the depth to permafrost.

#### Ecole Polytechnique:

Study of laboratory and field measurements of properties of natural deposits of soil by the use of the "GEOCEL" pressiometric devices.

#### GEOCON/FENCO

The execution of an extensive drilling programme in the Azores Islands, drilling from towers in a bay exposed to ocean swells.

#### M. Lebel:

Sampling very soft or loose material that could not be undertaken with normal D.P.W. sampling equipment, i.e. Shelby tubes and stationary piston samples, has been carried out with success last winter at Portneuf, P.Q.

Disturbed samples of soft river bottom material have been recovered by driving a 2½-inch casing down to refusal into hard material with a view to plugging the casing shoe. Eight 5-ft. sections of 2½-inch casing have been used and the casings were sent to D.P.W. Testing Laboratories for identification and classification of the material.

Undisturbed samples of very soft and loose river bottom material have been recovered by pushing down to refusal a pipe equipped with a sampling shoe made up of Shelby tube. The end

of the sampling shoe is provided with a curved door operated by means of a rod connected to a handle fixed at the top of the string of pipe. The door is kept open when lowering down the pipe and sampling shoe and is closed when the predetermined elevation is reached. This sampler, called a "Mud Sampler", is expected to be standard D.P.W. equipment in future. Eight 5-ft. sections of 2-inch pipe have been used and the pipes were sent to D.P.W. Testing Laboratories for the evaluation of the mechanical and physical properties of the material recovered.

Dr. W.H.Mathews:

With Dr. J.R.MacKay - investigation of solifluction in the Mount Garibaldi area, B.C., and a study of the influence of snow creep on movement of the surface layer of the soil. Methods have been established to measure seasonal displacement of the soil and rate of movement of the winter snow pack. Field work is continuing.

G.C.Morgan:

The use of helicopters, although seemingly expensive, has proved to be very economical for carrying out preliminary geological surveys for hydro power developments, even in fairly accessible areas. Apart from being a great time-saver, the results are more complete than they would otherwise be. Also using helicopters we have been able to drill "impossible" holes several hundred feet up on a canyon wall.

Electrical resistivity geophysical surveys have been carried out on damsites to supplement drilling. However, the results of such surveys in the coarse overburden found deposited in many of British Columbia's valleys are questionable.

G.C.McRostie:

For detection of seams or fissures in rock deposits, portable drills using operators' weight as reaction have been found to give positive identification sometimes lacking with conventional drill methods.

P.F.R.A:

A series of holes was drilled on the South Saskatchewan River Dam project, in which continuous undisturbed sand samples were obtained. The samples were used to determine densities of the sand, and to study its stratification.

An investigation of the quality of samples obtained in a highly plastic clay, using various sampling methods, is under way.

R.W.Pryer:

Seismic and resistivity surveys along route of proposed railway and at sites for power developments in Labrador.

Racey, MacCallum and Associates Limited

A Dutch deep-sounding apparatus equipped for soil sampling by means of a special type piston sampler and incorporating a recently developed "Friction Mantle Cone", which facilitates the measurement of local friction at any depth and has proven to be a vast improvement over the original method of measuring the total friction on the rods, has been acquired. It is felt that this apparatus will allow a closer evaluation of the bearing capacity of both pile and spread foundations in granular and non-sensitive clay soils than is possible with the conventional methods.

Dr. N.W.Radforth:

The theory of measurement in relation to drainage and bearing strength of muskeg was a subject reported on at the Fourth Muskeg Conference 1958 (T.M. No.54, NRC Ottawa, August 1958). This work has been extended but no further report is available at this time.

In addition, a method whereby tensile strength of muskeg mat can be measured is being explored with the application of an anchor type instrument to which a force is applied while the anchor is inserted in muskeg mat of designated type.

St. Lawrence Seaway Authority:

The seepage of water through a sandstone with horizontal bedding was investigated using pressure and flow measuring devices. The results related to action of the water on a structure embedded deep in the bedrock.

R.C.Thurber:

A new type of piston sampler has been developed and is being tested.

3. FOUNDATIONS OF STRUCTURES:

(a) General Subjects and Foundations other than Piled Foundations

H.G.Acres & Company Limited

Examination of the effect of admixtures on cement grout with respect to the effect on mobility, retention, shrinkage, bleeding and strength.

D.F.Coates

Design of mat foundations using rational soil reactions.

Study of temperature distribution below foundations with respect to decreasing frost cover on foundations and predicting desiccation effects under hot structures.

Supervision and analysis of rock anchor tests for cantilever hangars.

Appraising rock cores to permit higher bearing pressure than in Tabular Values.

Checking effects of foundation movement on rigid frame highway bridges.

Examining effects of frost action through normal construction frost protection.

Advising on dam foundations on rock containing structural imperfections.

Division of Building Research, National Research Council:

Correlation of actual settlement with predicted settlement of buildings was continued. As a check on the laboratory values, one full-scale experiment is being conducted in which the compression of a deep deposit of marine clay under a 23-foot high earth fill is being measured. A special instrument was developed for remote measurement of the compression of incremental layers of the subsoil. This instrument is described in a paper submitted to GEOTECHNIQUE. A second full-scale investigation of this type is planned, in which pore pressures will be measured in the subsoil, along with the settlement measurements.

Information on the effect on trees on ground movements in clay soils which has been collected in Ottawa during the last



four years was assessed and submitted to GEOTECHNIQUE for publication. Studies of the seasonal movements of existing building foundations and the measurement of ground movements at various depths and distances from trees is continuing.

In co-operation with the City of Winnipeg, a field study of backfilling practices was made as a further step toward an understanding of the reasons for the high incidence of watermain failures in Winnipeg. An extensive field investigation of ground movements around newly installed watermains is being carried out.

J.Z. Dobrowolski:

Provision of sand belt 12 inches thick and equal in depth to the depth of foundation walls successfully prevented damage to the Saskatoon Armoury Building by excessive swelling of heavy clayey soil typical for this location.

Ecole Polytechnique:

Field study of creep of loaded soils in order to compute bearing capacity with respect to differential and long-term settlement.

GEOCON/FENCO:

- (a) Engineering studies for the underpinning of a large structure which included the execution of plate bearing tests with pressures up to 20 tons per square foot.
- (b) The foundation investigation of a structure which experienced settlements greater than 3 feet soon after erection.
- (c) The corrosive effects of ground water, contaminated by the effluents of a paper mill, on steel and concrete foundations.

Dr. G.G. Meyerhof:

An investigation has been made for an extensive industrial plant to be built on fill placed in a sea-water bay enclosed by an earth dam carrying a highway.

P.F.R.A.

A frost research programme was continued, primarily to determine the effects of frost action on spillway structures.

Apparatus was installed to measure the depth of frost penetration, the amount of heave due to frost action, and the fluctuation in ground water levels. This apparatus was installed at 11 sites in Western Canada, and was read at two-week intervals throughout the period when frost action might occur. Laboratory tests were conducted to measure capillarity and grain size of potential frost heaving soils.

Observations were continued on the heave associated with spillway structures founded on clay shale and other clay soils.

R.C.Thurber:

A unique type of preloading is being used to eliminate any possible settlement of the Alexandra Bridge in the Fraser Canyon.

3. FOUNDATIONS OF STRUCTURES:

(b) Piling and Piled Foundations

D.F.Coates:

Studying methods of more accurately appraising pile safety factors to reduce costs on large piling jobs.

Advising on pile loading testing in permafrost.

J.Z.Dobrowolski:

(a) Compacting of sandy soil by vibrofloatation in lieu of piling method was investigated but not yet used. Results of compacting by this method in Canada would be appreciated.

(b) Static testing in lieu of penetration tests also would be appreciated if this method will prove satisfactory.

L.A.Fraikin:

In order to determine the average skin friction value in a soft clay for design of a floating pile foundation, a 12-inch Ø tube pile was jacked down under a nearby building, in lengths of approximately 2 ft. 6 in. to a depth of 49 feet below surface. This operation took 13 days to complete.

The jacking and failure pressures were noted for each embedded length and a skin friction value of steel against clay was derived. This value was found to be of the order of

760 lb. per square foot. Knowing that the friction value of rugged concrete against clay would be somewhat higher, the ultimate bearing capacity of a 22"Ø-concrete shaft was derived.

A load test was carried out on one of the piles to a value of twice the design load (120 tons). The results were very satisfactory.

#### GEOCON/FENCO

(a) The application of electro-osmosis to increase permanently the capacity of steel friction piles in clay.

(b) The measurement of pore pressures induced in silt by pile driving, by means of piezometers.

(c) The study of the effect of artesian pressure on the capacity of Steel-H friction piles driven in silt by means of pile driving and loading tests and piezometer observations.

(d) The use of creosoted square timber piles in prebored holes for a large structure in a permafrost area.

#### Peter Kozicki:

An evaluation of the effect of skin friction and end bearing on the carrying capacity of cast-in-place concrete piles in typical Edmonton clays revealed that the skin friction developed was 50 percent greater than that indicated by laboratory test results made on the material. Results of field tests on end bearing of the piles agreed with values determined from laboratory tests.

#### Dr. G.G.Meyerhof:

The influence of compaction of granular soils on the bearing capacity of driven piles and Franki displacement caissons has been studied by full-scale field tests, laboratory research and theoretical analysis. A paper summarizing this work has been prepared for publication.

#### G.C.McRostie:

The possibility of failure of a pile-supported bridge abutment due to creep of medium clay foundation stressed by the approach fill was investigated.

P.F.R.A.:

A vertical and a lateral load test has been carried out on timber piles driven into saturated sand.

Raymond Concrete Pile Company, Ltd.

The ultimate capacities of the piles as checked by load tests proved to be considerably higher than predicted by empirical formulae.

Two borings were made on a diagonal across the site. Standard Penetration Tests were made every  $2\frac{1}{2}$  ft. to 42 ft. Both borings indicated good continuity of soil conditions. To a depth of 12 feet were found strata of fine sand and silt with a trace of organic matter. The Standard Penetration Tests indicated soils having N-values from 2 to 8 blows per foot. Below 12 feet and extending through the depth of the boring was found a very clean medium dense sand with a trace of fine gravel. The N-values of this stratum varied between 12 and 17 blows per foot. The water table was at ground surface.

Five Raymond Standard piles were driven to depths ranging from 27 ft. to 37 ft. These piles have an 8 inch diameter point and are uniformly tapered which increased their diameter 1 inch for every  $2\frac{1}{2}$  feet of pile length.

Generally, in all cases, the piles after running the first 10 ft. built up resistance uniformly. Resistance at 27 ft. averaged 4 blows per inch and at 37 ft. about 9 blows per inch, using a No. 1 Vulcan steam hammer. Retapping of piles showed a build-up of resistance of 50 to several hundred percent after a day or more; however, this build-up was temporary and broke down to slightly over the original resistance after 4 to 6 inches of penetration.

Results obtained showed piles of approximately 37 feet in length to have an ultimate capacity of 280 tons, while the shorter piles or piles of approximately 27 feet failed around 180 tons.

It is felt that one should not generalize in classifying all taper piles as belonging to one category for estimating pile capacity by empirical formulae. The degree of taper is believed to be a most important item.

A. Rutka:

It was discovered by pile load tests at the Big Pic River on TCH 17 that sufficient load bearing capacities could not be

developed after the piles were driven. Laboratory tests indicated that pile capacities could be increased by electro-osmosis. This project will include additional pile load tests and undisturbed sampling prior to electro-osmosis treatment, undisturbed sampling during electro-osmosis and pile load tests and undisturbed sampling after electro-osmosis treatment. It is intended to find out the increase in shear strength and increase in pile capacity by the electro-osmosis treatment.

University of Alberta and/or Alberta Research Council

Pile loading tests on drilled, cast-in-place concrete piles.

4. ROADS, RUNWAYS AND RAIL-TRACKS

R. Audy:

(a) Installation of 70,000 feet of vertical sand drains as a means of foundation consolidation and accelerating settlement of an embankment over soft clay. Study of the complete records: settlement plates, displacement stakes and piezometers.

(b) Study of frost penetration.

P.M. Bilodeau:

Special investigations carried out during the year included 24 pedological studies, 3 studies of compaction and control, 19 studies of frost heaving and 3 studies of bank stability.

F.C. Brownridge:

The Canadian Good Roads Association has established a Special Committee on Pavement Design and Evaluation with the following two principal objectives:

- (a) To develop economical methods of design for rigid and flexible pavements for Canadian conditions of environment and traffic;
- (b) To develop one or more methods for evaluating the strength and serviceability of existing rigid and flexible pavements.

An overall plan for the Committee's investigation was developed with the following three constituent phases:

- (1) The determination of seasonal variation in load carrying capacities of existing highways.
- (2) An inventory of a paved highway system to determine its adequacy and to develop data from which new pavements may be designed.
- (3) A detailed investigation of certain pavement designs to explain the performance of these designs so that present experience can be complemented to new conditions.

In Ontario, Phase I of the programme is well in hand. Five complete coverages of selected sections of highway in S.W. Ontario have been completed. For these, Benkleman Beam deflections have been taken for both the outer and inner wheel path under a standard 9,000 lb. wheel load. Pavements in the adequate, border line and inadequate range have been included under varying traffic, soil conditions, and pavement design.

Plans are well advanced for the second Phase of the programme and an inventory of all existing pavements in a selected area of the Province will begin July 15. Seasonal variation readings will be continued for the full year for the selected sections as well as the prosecution of the inventory.

An analysis of the data is being made and the information tabulated and analysed for interim reports to be made in the near future.

L.J. Chapman:

Supervision of maintenance and alterations on the race tracks at Fort Erie, Woodbine and Old Woodbine. The amount of soil blown and washed off these tracks is considerable. Some extra material was added on all four in 1958.

M.M. Davis:

Study breakdown of shaly gravels - properties as base course material before and after cycles of freeze-thaw, wet and dry, wear test, etc.

Division of Building Research, National Research Council:

In continuing work on the fundamental process of frost action in soils, a new freezing apparatus was developed in which

heat flow into and out of a specimen can be measured together with moisture flow, amount of heave and moisture tension. Efforts are being made to design a simple test for frost action potential based on a complete understanding of the mechanism. Fundamental investigations on the freezing point depression and rate of crystallization as a function of the concentration of lignosol solutions has thrown some light on the mechanism by which this material reduces frost action. Publication of this work is mainly through the U.S. Highway Research Board.

A major highway engineering problem in Canada is the design and construction of roads over muskeg terrain. To study this problem, a co-operative programme with the Department of Highways of Ontario was organized to assess the performance of roads over muskeg in Northern Ontario. During the summer of 1958 a small field party travelled 6,500 miles to make a general assessment of the area. The results of this work will be presented to CGRA. A second field trip is being undertaken in 1959 to study a few typical locations in more detail.

The study of permafrost in relation to the construction and performance of facilities at Inuvik, N.W.T., included soil temperature observations under various structures and terrain conditions. A detailed record of the history and method of road construction in the area up to 1958 was completed. Special depth-of-thaw observations under variations of moss cover were continued and an area for future qualitative observations on the insulating value of peat as a construction fill material was prepared. Soil temperature observations under the airstrip continued to be recorded on a weekly basis in co-operation with the Department of Transport.

#### Ecole Polytechnique:

Bearing criteria of roads from compressibility and strength data of base course and subsoil.

#### GEOCON/FENCO:

(a) The determination of sinkage profiles of several fills and causeways founded on soft ground by means of electric resistivity surveys.

(b) Study of highway foundations on peat.

W.G.Gerry

Investigations were carried out to determine the nature and causes of the land slides and soil movements associated with railway and highway construction in the Peace River area of British Columbia and Alberta. Based on our engineering reports remedial work to counteract these effects is now proceeding along the P.G.E. railway right-of-way and the Alaska Highway.

B.I.Maduke:

Continued analysis and research on the physical properties of peat and very soft silt-clays relative to highway construction over these materials. Test section results now in process of being analysed and report finalized.

Dr. G.G.Meyerhof:

Research has been completed on the influence of calcium-chloride on the workability of granular fill. The effect on index properties, Proctor density, California Bearing Ratio and workability of gravels, sand and silt has been studied at freezing temperatures. (Master's thesis by C.O.Brawner).

An extensive investigation has been made for the runways and structures of a large aerodrome on sand with a high water table. The physical and mechanical properties of the sand have been studied by laboratory and field tests including California and plate bearing tests under repeated loading.

A.A. McLean:

A comparative study of densities obtained in asphaltic concrete runway paving by steel wheel and rubber tire rolling. First results indicate heavy, self-propelled rubber rollers produce densities about three percent greater than those produced by two and three-axle tandems.

Using mixes (asphaltic concrete) from different airport paving projects, a comparative study is in progress of various methods of determining maximum specific gravity, zero air voids. Comparisons are being made between vacuum saturation, solvent and calculated methods.

Preliminary to laying a test section, some laboratory work, Marshall Method, has been done using a powdered latex additive in asphaltic concrete mixes.



N.W.McLeod:

Development of a general method for correcting maximum density and optimum moisture content of compacted soils for oversize particles. (Published in ASTM Procedures for Testing Soils, April 1958, p.143).

"Good Soil Construction and Maintenance Practices".  
(Presented at the First Ontario Good Roads Association  
T.J.Mahoney Road School, Toronto, Ontario, May 11 and 12, 1959.)

J.J.Paré:

Field and laboratory investigations on frost action were continued. This year, many severe frost heaves have been investigated and results, including characteristics of pavement, base courses and subgrade soils, were recorded together with the location of the water table, the depth of frost penetration, the actual drainage, seepage, etc. These results of field observations and laboratory analysis have been added to previous ones and a tentative classification of the degree of frost susceptibility of soils has been established. At most of the frost heave locations, drainage was inadequate and improvement of drainage conditions has contributed to reduce considerably the frost action.

The effect of blasting and traffic vibration on buildings and wells adjacent to the road was studied as well as the seepage of the roadway water on private property.

A few cases of slope stability have been also investigated using usual boring equipment.

Dr. N.W.Radforth:

Access, now regarded as the most urgent study in muskeg research, has received further attention. A paper entitled "Mobility in the Muskeg Frontiers" by N.W.Radforth and J. Evel has been submitted for publication in the July issue of the Journal of the Engineering Institute of Canada.

A. Rutka:

A project is under way jointly with the National Research Council to evaluate road performance over muskeg in Ontario and it is intended to find some correlation between muskeg type as classified by the Radforth classification system and road performance. This project is still under way.

G.Y. Sebastyan:

As part of the Department of Transport Runway Evaluation Programme, the load carrying capacity of unreinforced concrete pavements was determined by load testing the free corner of concrete slabs. Any support from adjacent slabs was removed by cutting it free to the full depth of the pavement by diamond saw. The deflection of the slab, the modulus of subgrade reaction and the modulus of rupture was measured at the same time. It was indicated by these tests that the load carrying capacity of concrete pavement is higher than that given by the Westergaard equation.

A theoretical analysis was made for the determination of the effect of a Flexible Overlay on the load carrying capacity of Rigid Pavements for different wheel loads, tire pressures and wheel configurations.

R.C.Thurber:

In connection with settlement of grade, selection of ballast, and frost heave problems, trial sections of the Pacific Great Eastern Railway are being treated experimentally to determine the most economical way of eliminating or reducing frost heaving south of Fort St. John.

D.L.Townsend:

The following two projects are being sponsored by the Joint Highway Research Project of the Department of Highways for Ontario:

- (a) Compaction Studies: Field testing to determine the various factors which will affect the production efficiency of highway compactors was continued during 1958. Some 80 tests were completed on the A-4 soil encountered on one contract at Newcastle, Ontario. Results have been analyzed and are being prepared for publication.
- (b) Sand Stabilization: Test sections of bituminous emulsion stabilization on sand-cushion highway sub-bases and numerous field observations of various construction projects were conducted during the summer. From the results of the laboratory analysis of fifteen samples it appears that sands whose Proctor density is

less than 70% relative density will be unstable under traffic. These sands will need stabilization treatment in addition to the normal control of moisture with various salt additives.

Testing on a larger scale is being conducted during the present summer, and it is expected that a preliminary report will be available before the end of the year.

#### University of Alberta and/or Alberta Research Council

A field study of the use of soil-cement as base course material on three separate highway projects involving sand and crushed sandstone.

A field study of the performance of 4½ miles of Portland cement concrete test road involving seven different designs.

#### Hydro-Electric Power Commission of Ontario:

A study of the use of lime-fly ash compositions for road base stabilization was continued. A field trial base was constructed comprising an area approximately of 20,000 sq.ft. in which various mixtures of lime and fly ash were added to base course material and in-place soil. Compressive strength tests carried out on cube specimens obtained from the completed base after approximately 3 months varied upwards to 2000 psi. Additional laboratory tests were carried out on various soil types including till, clay, fine sand and gravel.

#### W.E. Winnitoy:

A study of the performance of our existing pavements based on Benkelman Beam deflection tests was continued. Such tests were correlated with pavement and subgrade characteristics. Pavement deflection studies were applied to pavements prior to resurfacing and after resurfacing to determine the increase in strength of pavement per unit thickness of pavement applied. A study was made of the possibility of applying the Benkelman Beam test to finished base courses in order to determine any inadequacies in the surfacing thickness.

A rapid pavement thickness design method based on our subgrade soil Group Index values was developed for use in preliminary design considerations only. The method is approximate in nature and must be substantiated by our standard design method in the final stages of design.

Compacted densities of bituminous courses were studied on all construction paving projects. It was found that pavements compacted to densities below minimum designed densities, due to inadequate compaction method and paving in cold weather, ravelled during the winter.

A complete study of literature available on construction of highways in muskeg was made, and a manual outlining recommended methods was prepared for use by construction engineers assigned to construction of northern roads.

A study of the relation of tire pressures and wheel loads to tire size was made. The purpose of the study was to determine whether maximum axle loads should be based on tire width or size of tire. Among other findings, it was found that for tires of constant diameter, the tire ground contact area varied directly with the tire width. This substantiated our method of specifying maximum wheel loads based on tire width.

A study to determine changes in compacted shoulder subgrade densities from year to year was initiated. This study is applied mainly to dust-laid roads using asphaltic oil, and was confined to Highway No.7, Rosetown to Fiske.

## 5. EARTH PRESSURE ON STRUCTURES AND TUNNELS

### H.G.Acres & Company Limited

Study of the stabilization of a 110-foot high vertical granite gneiss rock face with forty 80-ton post-tensioned expansible horizontal anchorages, 120 feet long.

### D.F.Coates:

"Energy Released in Rockbursts" 3rd Symposium of Rock Mechanics, 1959, Colorado School of Mines.

Advising on retention of compressed air by soil over deep and shallow tunnels.

Analyzing effects of time on bridge abutment stability and on tunnel construction in clay.

Planning orogenic stress study in 38-inch diameter vertical holes in rock.

Examining rock stability problems underground in several mines.

J.Z. Dobrowolski:

Electro-osmosis stabilization of silty fill behind bridge abutments, tried in some locations during previous years, resulted in only limited success. Replacement of silty fill with gravel gave generally good results.

GEOCON/FENCO:

(a) Application of the freezing process to stabilize a water-bearing silt stratum prior to tunnelling.

(b) The investigation of the failure of a steel sheet pile cofferdam in soft clay, in which an excellent agreement was obtained with the theory of base failures.

P.F.R.A:

Studies and measurements are continuing on the deflection of flexible metal culverts installed beneath an earth dam and a highway fill.

St. Lawrence Seaway Authority:

An investigation was made of the deflection of an openwork abutment under active and passive earth pressures.

6. EARTH DAMS, SLOPES AND OPEN EXCAVATIONS

H.G. Acres & Company Limited:

(a) Design of a rock-fill dam, 110 feet high, with a thin sloping core constructed of rolled earth fill. Proposed impervious fill consists of plastic clay with a liquid limit up to 60 percent, and a plasticity index up to 35 percent.

(b) Examination of the use of the wet-fill method for the construction of the vertical impervious core of an earth dam, 85 feet high, using glacial till with a natural moisture content of 9 percent, liquid limit of 25 percent and a plasticity index of 10 percent. Triaxial testing of the till was carried out in order to determine the variation of shear strength parameters with moisture content below and above the proctor optimums for the various states of compaction.

(c) Design and supervision of chemical and cement grouting programme for stopping underseepage through sand and gravel strata to a depth of approximately 200 feet.

(d) Design and installation of a fully effective relief well system at the downstream toe of an earth-fill dam, for reducing artesian pressures in the dam foundation.

(e) Photogeological study of the power reaches of part of the Quebec North Shore in order to determine the geomorphic history and classification of surface deposits. Examination of the form, extent and profile of the terraces indicates post-glacial upwarp and it is suggested that marine or estuarine deposits can be expected in areas where the surface of the projected upwarp of the former Champlain Sea level is above or intersects the present topography.

H. Angel:

Installation of a grout curtain to provide a cut-off beneath the Mission Dam from elevation -150 (below a clay stratum) to elevation -510 (bottom of valley) involving the grouting of alluvials, moraine and slide materials and using clay/cement base grouts.

Installation of sheet pile curtain roughly in the middle of the clay core of the old diversion dam which now forms the toe of Mission Dam. This job required the extraction of piles from 14 buried crosswalls and the formation of a trench by drilling tangent holes into which piles were placed and subsequently driven.

E.W. Brooker:

Research is being carried out on a major landslide which occurred at Dunvegan, Alberta. This slide involves some four to five million cubic yards of earth. The object of the investigation is to determine the possible slide mechanism and corresponding corrective measures. The material consists of bentonitic silts and clays. Triaxial tests with pore pressure measurements will be performed in connection with this landslide.

Other troublesome slide areas in the Peace River area are being investigated in connection with this programme.

D.F. Coates:

Economic study of sloped versus sheeted excavations in two deep cuts in clay.

Examining and advising, before and after pool filling, on underseepage potentials and relief well installation and inspection programme under earth dams.

J.V.Danys:

Inspection of earth dykes, especially piezometric pressures in foundation in the International Section of the St. Lawrence River. Over one hundred piezometers and relief wells were observed in Cornwall, Ontario, and Massena, N.Y., area in connection with the St. Lawrence Power and Seaway Project.

Published an article "St. Lawrence River Diversion by a Rock-Fill Cofferdam" in The Engineering Journal, September 1958.

Division of Building Research, National Research Council:

To evaluate field performance, the failures of a bridge approach fill over soft marine clay and of a rock fill road grade over varved clay were studied. Field vane tests and laboratory tests on undisturbed samples were made and the computed factor of safety compared with the actual factor of safety.

A study was begun of dykes to be constructed in an area of sporadic permafrost on the Nelson River in Northern Manitoba. Special instruments were designed and fabricated and five installations were completed, two in the future reservoir area and three in an undisturbed area of the site. Observations of soil temperatures to depths of 20 feet were begun on 1 November 1958 on a weekly basis. Work was started on the design and fabrication of special settlement gauges and additional ground temperature instruments for installation in the dykes to be constructed on perennially frozen ground in the spring of 1959.

Field investigations into the timing and magnitude of deformations occurring in natural soils under various sub-Arctic conditions were initiated at Schefferville, P.Q. Earlier field experience and review of the literature pointed to the possibility of significant deformations by creep under relatively low stresses in the frozen soil. A number of sites were selected which showed little surficial indication of movement and polyethylene tubes of small diameter were inserted to various depths. Deformation of these tubes is to be accurately recorded at intervals by means of electrical apparatus.

J.Z.Dobrowolski:

(a) Stability of slopes in cuts made in overconsolidated Peace River shales was sought by simultaneous application of the following:

- draining away the surface runoff;

- drilling 30 to 70 ft. deep drain holes in shale, 12 inches in diameter, filling them with gravel and connecting them to drain collectors;
- limiting the removal of existing overburden to prevent unloading of overconsolidated strata.

(b) Drainage of slopes in silty soil was tried by drilling horizontal and up-sloping holes up to 30 ft. long and auger packing the holes with sand. Results not yet known.

Ecole Polytechnique:

(a) Research continued on the study of landslides in eastern Canada;

(b) Computing charts for the stability of cohesive slopes;

(c) Study of stability of slopes in stiff fissured Laurentian clays.

Federal Department of Public Works, Banff, Alta:

Two-inch diameter horizontal perforated drains were installed in unstable highway backslopes in an attempt to lower the seepage conditions. The installations proved to be quite effective and economical.

GEOCON/FENCO:

The design of a causeway across a bay which has a 28-ft. tide in which emphasis was on changes in construction materials and methods of placing in order to effect a closure.

G.A.Gorman:

Work during the past year involved remedial work to rock fill dyke damaged by piping through foundation bedrock.

Pore pressure studies continued on sloping clay core rock-fill dam.

G.C.Morgan:

Some time and study has been spent on seepage from existing reservoirs through sandy gravels and varved clays and the associated unstable slopes and piping problems.



D.A.MacLean:

Studies are being continued of seepages from storage reservoirs through natural materials resulting in losses of needed water, erosion at spring outlets, and some damage by these seepage waters.

G.C.McRostie

A natural slope in stiff-ultrasensitive clay, existing at stability ratio near unity was unaffected by vibrations due to driving sheet piles at toe of slope. Observations of long term creep now being organized.

P.F.R.A:

Measurement of lateral movement in slopes and embankments with the slope indicator developed by Shannon and Wilson is continuing.

St. Lawrence Seaway Authority:

F.L.Peckover and T.G.Tustin "Soil and Foundation Problems of the St. Lawrence Seaway", Engineering Journal, September 1958.

A report was made on a study of the numerous recurrent slope movements at the Welland Canal, St. Catharines, Ontario, with particular relation to local soil drainage conditions. The project included a study of the regional geology, analyses of records of past slope movements, establishment of typical engineering soil properties, and correlation of findings. The slope movements were shown to occur particularly at seasons of rapid ground water rise and to be related to the direction of surface drainage.

The excavation of a portion of a navigation channel in an area of soft clay under artesian pressure adjacent to an important existing dyke was carried out under close supervision. The artesian pressure was drawn down by pumping in the underlying water-bearing sandstone and constant check was kept on water pressures by piezometers and surface observations.

The flooding of portions of newly constructed navigation channels lined with dykes was supervised. Effects of the resulting gradual rise of ground water in the vicinity were followed with piezometers and weirs. Control of the seepage flows which occurred mainly through limestone and sandstone bedrock was maintained by installation of relief trenches and filter blankets.

A. Thorley:

Unusual under-seepage conditions were encountered during excavation through 222 ft. of glacio fluvial and deltaic deposits. Vacuum-assisted deep wells were used to assist in drainage of the groundwater and excavation was achieved by monitoring and dredging.

R.C. Thurber:

Three full-scale horizontal drain programmes have been carried out at locations where pore pressures were found to be the principal source of instability. Observations have been made for one year and the programme found to be effective. These are thought to be the first full-scale horizontal drain programmes to be carried out in western Canada. The type of machine found to be effective for this work is a special machine developed by the Failing Drilling Company.

University of Alberta and/or the Alberta Research Council:

The detailed instrumentation and analysis of an infinite slope slide involving 5 million cubic yards of soil.

APPENDIX "A"

MEMBERS OF THE CANADIAN SECTION OF THE INTERNATIONAL  
SOCIETY OF SOIL MECHANICS AND FOUNDATION ENGINEERING

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- All -

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## APPENDIX B

### List of Members Associated with Organizations

In some cases, reports have been submitted in the name of organizations. Following is a list of members associated with those organizations. Individual addresses are in Appendix "A".

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Cook, R.H.  
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Grice, R.H.  
Hunt, C.A.  
Kenney, T.C.  
MacDonald, Dr. D.H.  
Sauve, H.  
Watson, G.H.  
Wright, C.J.

#### Department of Agriculture, Prairie Farm Rehabilitation Administration

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Goodwin, T.	Peterson, R.
Iverson, N.L.	Ringheim, A.S.
Jaspar, J.L.	Rivard, P.J.
Lamb, K.N.	Scoular, J.R.
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Crawford, C.B.	Penner, E.
Eden, W.J.	Pihlainen, J.A.
Frost, S.G.	Schriever, W.R.
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Ecole Polytechnique

Granger, J.  
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Federal Department of Public Works, Highways Division, Banff

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University of Alberta and Alberta Research Council

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