CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR

INVESTIGATIONS IN 1922

CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

(I) Ceramic materials: by Howells Fréchette.

(II) Investigation of road materials along Hawk Creek-McLeod Meadows section of the Banff-Windermere highway, Rocky Mountains Park: by H. Gauthier.

(III) Prospecting for road materials between Massive and Johnson Canyon: by H. Gauthier.

(IV) Experiments for investigating the test for the crushing strength of rock: by H. Gauthier.

(V) Road materials in Nova Scotia: by R. H. Picher.

(Annual Summary Report of the Mines Branch, pp. 226–261)

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1924

No. 610.

CERAMICS AND ROAD MATERIALS DIVISION

Howells Fréchette
Acting Chief of Division

Owing to the lack of staff and the disorganized condition of the division following the transfer of Mr. Joseph Keele to the Geological Survey, very little, aside from routine testing of samples submitted by the public, was attempted in the ceramic laboratory, and almost no field work pertaining to ceramics was done during the year.

Investigations on road materials were conducted by Mr. H. Gauthier and Mr. R. H. Picher. The field work consisted of road material surveys in the Rocky Mountains Park, and in Nova Scotia.

A large number of samples of rock, gravel and other road materials collected in the field were subjected to tests[1] in the laboratory during the winter. A number of crushing tests on granite cylinders of various dimensions were made in connection with the study, by the American Society for Testing Materials, of methods of testing rock to determine *crushing strength.*

The following reports set forth the activities of the various officers in the field and laboratory.

I

CERAMIC MATERIALS

Howells Fréchette

Clays and shales.—During the year many samples of clay and shale were submitted for testing by field officers of the Department of Mines and Provincial Bureaus of Mines, and by individuals and corporations from various sections of the country. In practically all cases these samples were given a complete test for brick making, including the determination of the temperature of softening. In the case of such samples as appeared to warrant it, they were tested for suitability for pottery or for other special uses.

In many cases the samples were very unsatisfactory for testing purposes, being too small in amount or carelessly packed. Even for purposes of preliminary tests a sample should not weigh less than two pounds, and a ten pound sample would be preferable. Clay may be shipped either dry or moist, but care should be exercised to see that the containers are perfectly clean and sufficiently strong to withstand rough handling during transportation. When moist samples are shipped they should be in cloth bags or wrapped in cloth and placed in a sound container. All express or postal charges must be paid in advance by the shipper. Failure to do this is a frequent cause of delay and confusion. A definite statement as to the exact locality from which the sample was obtained should be furnished in all cases.

Magnesite.—A research was commenced on the problem of producing a dense, dead-burned product of high dielectric strength from the magnesite of Argenteuil county, Quebec. Owing to pressure of other work this could not be carried to completion, although considerable progress was made.

Pottery.—Very little was done in this line except to test a few clays on the wheel and to work out a satisfactory casting slip for one of the new commercial potteries using Canadian clay.

[1] An explanation of the laboratory tests for road-building stone and gravel was given in the Summary Report for 1921; pp. 272-275.

II

REPORT ON INVESTIGATION OF ROAD MATERIALS ALONG THE HAWK CREEK-McLEOD MEADOWS SECTION OF THE BANFF-WINDERMERE HIGHWAY, ROCKY MOUNTAINS PARK

H. Gauthier

The investigation of available road materials along the Banff-Windermere highway, in the Rocky Mountains Park, which was undertaken two years ago, was resumed and completed during last summer.

At the end of the 1921 field season there remained 25 miles of the road to be surveyed, that is from Hawk creek to McLeod Meadows camp.

During the summer of 1922 this was completed. Every occurrence of road material lying close to the roadway was examined. In carrying on this investigation 38 samples of gravel were collected for laboratory tests. These tests were made in the Road Materials laboratories of the Mines Branch during the winter. They include granulometric analysis, gravel pebble classification, determination of percentage of clay and silt, together with examination of the shape of the pebbles and of the amount of impurities present. The results of these tests are tabulated in this report. They also contain remarks on the suitability of the gravels examined for use in road construction.

A great deal of information regarding the location and character of the available road materials along the entire mileage of the Banff-Windermere highway is now at the disposal of the park officials. There still remains the problem of economically improving the binding and the bearing power of certain classes of material occurring along the road, in order to secure a satisfactory road surface. This problem will be worked upon in the laboratories.

SOURCES OF SUPPLY OF ROAD MATERIALS

The available material suitable for road surfacing along the Banff-Windermere highway, from Castle, at its northern end, to Hawk creek, and from the Kootenay valley to the Columbia valley at its southern end, includes, as stated in previous reports, three classes of road materials: bedrock, gravel and boulder clay.

The subsoil and the character of the gravel and boulder clay deposits along these two sections of the road vary a great deal from place to place, and in several instances for long distances, clay is the only material occurring.

In the Hawk creek-McLeod Meadows section of the road, which was surveyed last summer, the material is much less variable. Stoneless clay and boulder clay occur, but only for very short distances. The subsoil generally consists of gravel containing a varying amount of loam or clay. Gravel is exposed in the road cuts nearly all the way, and deposits where pits could be opened are found at short intervals and close to the road. Because of its common occurrence, gravel constitutes the main class of road material available in this section.

There are a few bedrock outcrops close to the road, but they are, as a rule, composed of soft shales unsuitable for road work. The only occurrence of bedrock suitable for the production of crushed stone is an important ledge of limestone, which forms a cliff over 25 feet in height, on the west side of the road, at approximately one-fourth of a mile north of Mile 8 creek. The exposure is continuous for several hundred yards and the opportunities for quarrying are good. The limestone is fresh and of fairly good quality. Its value as road metal can be compared with that occurring east of Johnson canyon on the Banff-Lake Louise road. The results of laboratory tests made upon a sample collected there are included in the appendix to this report.

Crushed stone could be produced by using boulders, bouldery gravel, or certain talus and morainic materials.

In the production of crushed stone from such material the crusher can be located at the pit, talus or slide, next the road, and the boulders or stone fragments picked up and put into the crusher with little or no preliminary breaking. Boulders form a cheap and often valuable source of roadstone. The disadvantages of using this form of material for road surfacing arise from its heterogeneous character, which may cause one section of a road to wear more rapidly than another or may give rise to uneven wear in the same section of road. In the area surveyed last summer it was found that in many deposits the stone aggregate was almost entirely composed of limestone, therefore a fairly homogeneous crushed stone product could be obtained from that source of material.

Gravel deposits in which boulders are common occur quite frequently beside the road. Boulders which were rejected when gravel was taken out are also to be found in many old pits, such as those at Hawk creek, Middle camp, south of Mile 8 creek, and in the Kootenay valley.

The more convenient talus or morainic deposits, where stone for the crusher can be obtained, are the following two.

Near the road chainage 330+00, between Mile 8 creek and the big gravel slide at chainage 250 + 00, a talus on west side of the road. There, a certain amount of angular blocks of fresh limestone can be had without any excavating.

Opposite the road chainage 666 + 00 and approximately 75 feet west of the road, a big slide made up of apparently morainic material composed of limestone fragments and clay. A more detailed description of this deposit is given elsewhere in this report.

GENERAL CHARACTER OF THE GRAVEL

Good road gravel should not disintegrate under traffic, and the pebbles should be of variable size so as to have the minimum quantity of voids. A certain amount of fine material is necessary to fill these voids. Gravel to be used for road surfacing should not contain pebbles over 1½ inch in size and should have at least 55 and not more than 75 per cent of its constituents retained on a ¼ inch screen. From 8 to 15 per cent of the material under ¼ inch in gravel should be clay, oxide of iron or similar binding material. The binding or cementing value of gravel is also improved by an appreciable amount of calcium carbonate. It is claimed that if a gravel occurs in a somewhat cemented condition in the bank it is likely to make a good road material, and that gravels containing many pebbles of rocks which have good roadmaking qualities are desirable. Specifications usually call for gravel containing not more than 15 per cent of soft, friable pebbles. Angular pebbles will compact under traffic more rapidly than rounded pebbles and produce a firm road surface in a shorter time. The fact that a gravel packs quickly does not necessarily indicate that it will make a good road, for clayey gravels do this, and those containing more than 20 per cent clay are liable to make a muddy road.

The gravels found in the Vermilion valley between Hawk creek and the Kootenay river differ somewhat in their general character from those occurring along the other sections of the road, which were surveyed in 1920 and 1921[1].

From Castle to the Summit the gravels to be found are generally coarse and carry a high percentage of sand with a small binder content. Those occurring between Marble canyon and Hawk creek vary from very sandy to loamy or clayey gravels. In the Sinclair pass the amount of fine material passing the 200 mesh sieve carried by the gravels is quite high and of a more silty nature.

In the area surveyed last summer the gravels of the various deposits lying along the Vermilion river resemble each other more in character and are as a rule of fairly good road-making quality. The gravels in the flats generally are loose and carry in the upper layer a certain amount of loam. Below a certain depth they lack binding material. In the ridges and in the exposures where the road cuts through shoulders of deposits the gravels, though not cemented, contain a sufficient amount of material in powder form to bind well in a road surface.

Gravel is especially plentiful near the Kootenay river and is of very good quality for road surfacing. In most deposits there, the gravel is fine and possesses good binding qualities. The proportion of sand is comparatively low, the percentage of voids in the total aggregate high, but the pebbles are coated with calcium carbonate, and because of the highly calcareous nature of the binder contained good results can be expected from their use. The gravels found in the bottom of the valley south of Kootenay Crossing, however, lack binding properties.

Thirty-five samples were collected from the more promising deposits between Hawk creek and McLeod Meadows camp. In the majority of these samples the proportion of sand to gravel is just about right. In twenty-six samples the percentage of sand is not over 40, and in four samples only is it less than 25. The amount of fine material passing the 200 mesh sieve contained in the sands ranges from 5 to 33 per cent, in eighteen samples this percentage being 10 or over. The amount of clay and silt in the sands, determined by washing through a 200 mesh sieve, was found to vary from 5 to 47 per cent, with fourteen samples having 20 per cent or over and eleven samples with 10 per cent or under.

Few of the gravel samples collected are clean enough to make good cement concrete, but washed gravel for that purpose can be easily found along the river.

[1] Mines Branch, Summary Report for 1919. Report of the Road Materials Division, by K. A. Clark, p. 146. Report on Investigation of Road Materials in Rocky Mountains Park in 1921, by H. Gauthier, Mines Branch.

The petrological composition of the gravels tested does not vary greatly, as an examination of Table II will show. This composition includes only a few types of rock which were divided into durable, intermediate and soft types according to their average resistance to wear and impact. The durable types include igneous and metamorphic rocks, the intermediate types include limestone and dolomite, and the soft types include shales and weathered stones of all kinds. In nearly all the samples that were collected limestone pebbles predominate in number. In eleven out of thirty-five samples 75 per cent or more of the pebbles are of that type of rock. In six samples only the percentage of limestone pebbles is less than 50 per cent. Most of the gravels occurring north of Vermilion Crossing carry a high percentage of soft shales and weathered rocks, indicating that they will not wear well. The greater number of gravels examined south of Vermilion Crossing were, however, comparatively low in soft material, and so were the deposits along the Kootenay river. Of the total number of samples taken fourteen contain more than 20 per cent of soft pebbles, but in only four is this content higher than 50 per cent. In the majority of the gravels the pebbles are well rounded, but whenever shales occur in their constituents these are flat and thin in shape.

For purposes of comparison one sample of the road surface was collected at chainage 740, a short distance south of Vermilion Crossing, where the road subgrade, made up of gravel, had packed to a hard and smooth surface. This is sample No. 15 in the tables. It may be noted that this gravel is comparatively fine, well graded, and contains the amount of binder which is usually recommended for road gravel. It is also largely composed of durable material.

Among the gravel samples tested there are several which compare favourably with this material and should give satisfactory service on road surfaces.

In the following pages the character of gravels in the different deposits is briefly described, together with such information regarding their actual service as could be obtained from the road subgrade wherever they entered into its construction.

This section, and the tables giving the results of tests, should be read, for comparison purposes, in conjunction with the results of analysis of sample No. 15.

LOCATION AND DESCRIPTION OF GRAVEL DEPOSITS

Road chainage 447 + 00[1]

Immediately south of Hawk creek, ridge 50 feet wide extending eastward at right angle with the road.

Exposure in road cut, from 5 to 7 feet high and approximately 30 feet long, of loose, coarse, loamy gravel largely composed of rounded fresh limestone pebbles. One-half of the gravel is over 1½ inch in size but there are few boulders present. The sand, which is in the proportion of 33 per cent, is of medium grading and contains a large percentage of material passing 100 mesh sieve.

A high working face is not available but small quantities of fairly suitable gravel can be had for road maintenance work.

[1] Chainage from north.

Sample No. 1 was taken. The results of tests are given in tables I and II.

485 + 00 to 505 + 00.

From chainage 485 to chainage 505, some material could be had, but at a level lower than that of the road. The latter here is located on top of a flat topped gravel bank. The material exposed on the road grade and in the ditches consists of gravelly loam. In depth, loose coarse gravel with only little binder is to be found. This gravel contains a large proportion of shales and soft pebbles.

A 10 to 15 foot working face is readily available at various points along the edge of the bank, particularly opposite chainages 492 and 499, at distances of from 10 to 25 feet west of the road side. However, the use of this material is not to be recommended because it lacks binder and contains a high proportion of shales. Sample No. 2 was collected in the neighbourhood of chainage 488 + 00.

547 + 00

Lens-shaped deposit of small extent. Fairly well graded, medium gravel with clay binder, is exposed in a 5 foot cut, on east side of road, at curve. This is good binding gravel but the amount available is small. See sample No. 3.

555 + 00

On either side of spring creek, exposures of uneven, loose bouldery to sandy gravel. The chances for excavating are poor. Sample No. 4 was taken and tested.

572 + 00

Just south of outcrops of shales, at curve, there is a good exposure of fine gravel with binder. Few boulders present. There is possibility for a 10 foot working face but the amount available is probably not over 1,000 cubic yards. North of the rock outcrops fine blue gravel is to be seen but it is devoid of binder.

One sample of the material occurring south of the rock outcrop was collected and has tested very good, as far as grading and amount of binder present are concerned, but, on account of the very high proportion of soft flat shales contained, this gravel will not resist wear. See the results of analysis of sample No. 5 in the tables.

583 + 00

At top of grade, where road reaches a flat north of Middle camp. Cut 7 feet high and approximately 100 feet long on east side of road. The exposure consists of 1 to 2 feet of loamy sand underlain by gravel varying from fine to bouldery and containing a moderate amount of clayey binder.

There is a fairly good opportunity here for a pit. The deposit is in the form of a small ridge, the maximum height of which is about 15 feet above the road level. Probably a thousand cubic yards could be excavated.

Sample No. 6, representative of the average bank run, was taken and proved to be properly graded, to contain a sufficient amount of binder, and to be largely composed of fresh limestone pebbles.

The results of tests are given in the tables.

850 + 00 to 836 + 00[1]

Ridge parallel to road, on east side, averaging 20 feet in height, with rather steep slope only 25 feet or so away from the road side.

Three test pits were made. In a 5 feet deep excavation made in the upper part of the slope, opposite chainage 838, the material encountered was 2 feet of gravelly loam, with boulders, underlain by loose, well graded, fine gravel, carrying a small percentage of clay and silt. See sample No. 9.

The two other test pits, from 4 to 5 feet deep, were made at different levels opposite chainage 845.

The upper one, near the top of the ridge, revealed the presence of one foot of coarse loamy gravel overlying medium gravel and coarse sand with little binder. See sample No. 7.

In the lower pit, at the foot of the slope, coarser gravel with a high proportion of loam was found. See sample No. 8.

The results of laboratory tests upon samples Nos. 7 and 9 show that the binder content is low, but that the gravel is well graded and suitable for surfacing on clayey subsoil.

Large quantities of gravel could be easily had by excavating along the edge of this ridge, as a wall from 12 to 15 feet high and several hundred feet long could be obtained. The timber is light and the amount of necessary stripping not over 2 feet thick.

820 + 00 to 810 + 00

Flat topped ridge, presenting an escarpment about 15 feet high and from 20 to 25 feet distant from the road, on east side.

One test hole, 5½ feet deep, made in the upper part of the slope at chainage 812, showed that the material in the upper 2 feet is bouldery gravel carrying much loam, while underneath rather coarse gravel with coarse sand, containing very little binder, is to be found. One sample of this material was taken. See the results of analysis of sample No. 12 in the tables.

A similar test pit, 7 feet deep, was made opposite chainage 815. There, the material encountered is as follows: 2 feet of loamy coarse gravel underlain by 2 feet of loose very coarse gravel followed in depth by well packed gravel such as represented by sample No. 11. This material is well graded, free of boulders, and carries a certain amount of clay.

In a third test pit made at chainage 816, coarse gravel, with a large proportion of boulders between 3 and 6 inches in size, was found in the upper 3 feet. Below this, medium size gravel with only a small percentage of sand occurs. This gravel, however, contains a good deal of binder in the form of clay lumps and calcium carbonate coating on the pebbles, and therefore should bind well. Sample No. 10.

A 10 to 15 foot wall could be developed along the edge of the ridge between the above mentioned chainages, close to the road, and with but a comparatively small amount of stripping to do. The chances are that fairly good gravel will be found.

[1] Chainage from south, Kootenay Crossing.

755 + 00

From chainage 770 southward, there are several exposures of gravel subsoil but nowhere do the deposits form any elevation which would favour the opening of a pit. Some material, however, could be obtained by scraping off the surface in flats on either side of the roadway.

As a rule the gravel along here is fine but lacks binding material. An average representative sample was collected from the 2 feet deep road cut at chainage 755. Sample No. 13.

747 + 00

Vermilion Crossing. On either side of the crossing there are borrow pits from which material was obtained for the construction of the bridge approaches. The material exposed in the shallow excavation, alongside the road, at the north end of the bridge, consists of loose, clean, fine sandy gravel.

South of the river the exposure is 6 to 7 feet high, but the gravel is loose in the bank, coarse to bouldery, and lacks binder. Sample 14 was taken and tested.

740 + 00 to 705 + 00.

From Vermilion Crossing southward to chainage 705, the natural subsoil is loamy fine gravel. Certain stretches of the newly graded road were found to be in good condition, while in places, where loam is in excess, mud holes and deep ruts had formed.

For purposes of comparison, one sample of the road surface was collected at chainage 740, where the road grade had packed to a hard and smooth surface. See the results of analysis of sample No. 15 in the tables. It may be noted that the material is comparatively fine, well graded, and contains the amount of binder which is usually recommended in the specifications for road gravel. Among the gravel samples collected there are several which compare favourably with this material. Therefore, the gravel which they represent ought to give as good results if used in road surfacing.

Except very low ridges located a short distance west of the road, between chainages 740 and 735, and in the neighbourhood of chainages 725 and 711, the flat character of the country offers no opportunity for a pit. The underlying gravel is exposed in the high bank of the river to the east of the road, but, as a rule, it is sandy and does not contain binder. A pit there would not be practicable as such location would mean a difficult haul up hill to the road.

A representative sample of the well graded fine gravel occurring at the surface along this section was taken at chainage 705 where the road cuts through the edge of the small knoll. The exposure shows clay, which if mixed in proper proportion with the overlying gravel would improve it. The amount of gravel available there, however, is small.

Sample No. 16.

666 + 00

Big slide approximately 75 feet west of road, composed of apparently morainic material consisting of fresh limestone angular fragments and clay.

In a 4 feet deep test pit dug in the steep and cleared slope, facing the road, the material encountered was 2 feet of coarse material underlain by finer aggregate with a high clay content but which appears not to be in excess.

The analysis of sample No. 17, which was taken at a depth of 4 feet, at a point about 20 feet above the flat, shows that this aggregate is well graded and suitable for road surfacing. Its use, as a trial, is advisable.

If the deposit runs uniform, very large quantities of material can be obtained without trouble, as a high working face and only a small amount of stripping are possible features.

In case only small quantities of material are wanted, a still better aggregate will be found in the occurrence described below.

The results of tests upon sample No. 17 are given in the tables.

660 + 00 to 653 + 00

Morainic material, similar to that described in the preceding number but of a still better grading, is exposed in extensive cuts made to reduce the grade of road and to build a fill.

The sections of exposure vary from a few feet to 15 feet in height, and large quantities of material could be easily excavated, with hardly any stripping to do.

Sample No. 18, which was collected opposite chainage 653, shows that in this mixture of limestone fragments and clay the stone aggregate is well graded, and that the clay content is about just sufficient to act as binder.

The actual condition of the road surface where this material occurs, after it had been built for a month, last summer, proved that the clay content is not too high.

An inspection, in the spring, would probably give better information as to the suitability of this material for surfacing.

See sample No. 18, in the tables.

651 + 00

Immediately south of the occurrence above described, gravel is exposed on the west side of the road in a cut 8 feet high and some 30 feet long. This gravel varies in texture from fine to medium and contains comparatively little sand. The sand is coarse and carries some binder. Some of this gravel was used last summer for maintenance. The amount available is small.

Sample No. 19.

648 + 00 and 630 + 00

Interstratified fine gravel and clay is exposed in cuts varying from 5 to 10 feet in height at chainages 648 and 630. In the first instance the gravel is coarser and contains more sand than at chainage 651. In the second deposit good fine gravel occurs but with large pockets of clay. The run of the bank could not be used, as an excess of clay present was shown by the muddy surface of a section of the road grade built with it.

The amount available is small.

Sample No. 20.

621 + 00

Road cut 100 feet long and from 4 to 8 feet high, showing 2 feet of sandy loam underlain by coarse gravel without binder. An 8 foot wall can be excavated and large quantities of gravel are available. Unless used on clayey subsoil this material will not yield a bond.

Sample No. 21.

608 + 00

Coarse gravel, resembling in character that exposed at chainage 621, is to be found in road cuts, 4 to 6 feet deep, between chainages 608 and 606. See sample No. 22.

593 + 00 to 576 + 00

Important ridge, in brule, rising to over 35 feet above the road and close to it, on the west side.

Test holes have shown that this deposit is very complex in its composition. Fine sandy gravel underlying gravelly loam occurs in place, while elsewhere stony clay is to be found.

The chances are that material similar to samples No. 24 and No. 25, composed entirely of limestone fragments and clay, properly graded, may be found in this ridge.

One sample of the surface gravel occurring along the roadside in the vicinity of chainage 580 was taken. See sample No. 23. It is medium size gravel containing only a low per cent of sand and very little binder.

Sample No. 24 was collected from the road cut at chainage 576, and although containing a high percentage of stone aggregate over 2 inches in size this material is well graded and contains just enough clay to make it yield a good hard road surface.

570 + 00 to 568 + 00

Drift material like that occurring at chainage 576 is exposed in cuts on west side of the road.

The aggregate, here, contains more clay than that of the above mentioned, but quite large quantities of fairly suitable material are easily available.

Sample No. 25, which was collected and tested, represents about the average character of the deposit.

547 + 00 to 544 + 00

Exposure in road cut, of medium size gravel with a low per cent of sand and very little binder.

A 6 foot wall alongside the road could be excavated.

The use of this gravel, however, is not recommendable as it lacks fines and binding material.

See sample No. 26.

510 + 00 to 500 + 00

Loose gravel varying from fine to medium in texture, in which the proportion of sand is comparatively low, but with a fairly high content of clayey loam binder is exposed in a series of cuts on the road. This is near where the road reaches the flat of the valley.

The loamy gravel occurs at the surface of slopes and the thickness is variable but in no case great. It is underlain by sandy gravel without binder. However, there are good chances for fairly large quantities of gravel with binder. Sample No. 27 was collected in the neighbourhood of chainage 501.

450 + 00 to 403 + 00

Loamy, fine to coarse gravel subsoil is frequently encountered in the flat, from chainage 450 + 00 to Mile 8 creek, a distance of nearly one mile.

Some gravel was obtained from a shallow borrow pit at chainage 430. More gravel with loamy binder could be had by scraping off the top soil at various points along this stretch of the road. The timber, as a rule, is light, and the overburden to be stripped amounts to very little.

Sample No. 28 is representative of the average character of the gravel to be found here. The road surface showed that this material packs well.

Sample No. 28.

400 + 00

A few hundred feet south of Mile 8 creek, at first curve, there is a good exposure of drift material which presents good opportunity for opening a pit.

The exposure consists of a 15 foot cut. The material is composed of angular, flat, mostly limestone pebbles and contains clayey binder. In the upper 3 feet the aggregate is quite coarse, but the balance of the cut shows fine to medium textured material. This is fairly suitable road material and it could be easily excavated. The amount available is in the neighbourhood of a thousand cubic yards.

Sample No. 29 was collected and tested.

400 + 00 to 250 + 00

From the above described occurrence to the big slide at chainage 250, the subsoil generally encountered, in the flat, is either fine loamy gravel or sandy washed gravel. There is no ridge close to the road from which material could be had. However, there are several borrow pits where some of this surface gravel has been excavated to a shallow depth for grading purposes.

The gravel to be found in these pits is represented by sample No. 30, which was taken from a pit at chainage 305. It lacks binding material.

250 + 00

Big, steep slide over 75 feet in height, with extensive exposure of stratified gravel, sand, clay and silt.

The gravel, as a rule, is fine in texture and silty, but certain parts of the section exposed at a point where the river has cut the deposit show well cemented gravel. The amount of boulders present in the deposit is comparatively small.

The quantity of good gravel available is very large, the only drawback to this deposit being a too high and dangerous face. The road lies at the foot of the slide and the gravel could be loaded directly into the trucks by the use of chutes.

The actual condition of the road alongside this slide showed that this gravel packs to a hard and smooth surface. One sample was taken from the lower part of the wall at its northern end. It represents the average character of the greater part of the material exposed there.

See the results of analysis of sample No. 31.

Similar gravel is also to be found in a big cut, on west side of the road, between chainages 255 and 260. The conditions there may be found more convenient for excavating.

195 + 00 to 190 + 00

Fine gravel containing binder is exposed in hillside cuts on the west side of the road. This occurrence offers a good opportunity to obtain gravel of good quality. The pebbles in this gravel are well graded in size and are coated with clay and calcium carbonate which cement them together. The boulders present in the exposure are few. Large quantities of good gravel can be obtained directly from the road side with only a small amount of stripping. A 20 foot working face can easily be made.

The road surface along this hillside cut is well compacted, firm and smooth.

Sample No. 32 was collected and examined. See the tables.

154 + 00

Gravel pit, from which material was obtained for the surfacing of that section of the road immediately north of this occurrence where sand is the natural soil.

The pit is located on the edge of a knoll on the west side of the road. A 15 foot wall has been developed. The gravel is fine textured, fairly uniform, and contains very little sand. Pockets of fine sand, however, occur in the exposure. The gravel is fairly well cemented in the bank, the pebbles being coated with clay and calcium carbonate. However, probably because of its low sand content, this gravel has failed to compact on the road. The road surface, where it was used, is loose and ravels. If used on clayey subsoil, this gravel will give much better results.

The amount of gravel still available in this deposit is large.

Sample No. 33 was taken and tested.

130 + 00 to 90 + 00

Between chainages 130 and 120, from 2 to 3 feet of loamy fine gravel overlying loose, clean, fine gravel without binder, is exposed in several instances, in cuts varying from 3 to 4 feet high, along the road.

This surface gravel packs well on the road but the topography in the immediate neighbourhood, which is flat, offers no facility for excavating except by scraping off the surface.

Similar material is also exposed in cuts from 4 to 8 feet high at chainages 105, 95, and 90.

85 + 00 to 0 + 00

From chainage 85 or so, southward to Kootenay crossing, a distance of approximately one mile and a half, occurrences of very good road gravel with binder are plentiful. The gravel runs from fine to medium in texture, is packed hard in the bank, and well cemented with clay and calcium carbonate coating the pebbles.

Among the best occurrences are the following:—

Around the big bend in the neighbourhood of chainage 85. There, 8 feet of the gravel is exposed in an extensive cut. While widening the roadway at this dangerous curve, very good material will be obtained by excavating.

Between the chainages 75 and 70—

From 5 to 8 feet thick of fine gravel carrying enough binder is readily available from the road side.

From chainage 65 southward to small lake, chainage 50—

All the way very suitable fine gravel, containing binding material, is almost continuously exposed in cuts varying in height from a few feet to 10 feet. If a site for a huge pit is looked for, a knoll rising to over 50 feet in height, with steep slope and almost cleared of timber, just north of the lake, will be found. A large pit could be operated on the flank of this deposit in the vicinity of chainage 52, that is about one mile north of Kootenay river.

Other occurrences which offer good opportunities for the opening of pits are the extensive road cuts which face the two small lakes at chainage 45 and 30. The gravel in these deposits does not carry as much clay and loam as that occurring north of the lakes, but it is well cemented. The pebbles are coated with a limy substance which produces a good bond. In either place a large amount of gravel can be obtained without trouble.

One sample of this gravel was collected from the road cut along the first lake north of the Kootenay river. It is sample No. 34 in the tables.

The suitability for road surfacing of the gravel to be found along this section of the highway is well shown by the actual condition of the road surface, made of the same. This surface, as a rule, is well bound.

Samples were also taken for purposes of comparison, from the pits which were opened last year at chainage 10 + 00, a short distance north of the Kootenay, and at the end of the tangent south of the river. They are samples No. 35 and No. 36. In examining the results of analyses in the tables, it will be noted that they contain a small percentage of sand. These gravels belong to deposits which have once been washed. However, they carry a sufficient amount of binder to give good results in a road surface, their constituents being thickly coated with carbonate of calcium, which will act as a cement.

The gravel in both pits is of rather uniform and fine grading and fairly well packed in the banks. The upper foot carries loamy clay.

Not less than one thousand cubic yards of material have been excavated in the pit north of the Kootenay, but several times as much material is still available. The deposit forms a big knoll.

In the other pit located at the sharp turn of the road, to the south, in the Kootenay valley, more material can be obtained, but there the gravel occurs in a flat and a high wall could not be excavated.

0 + 00 to 243 + 00[1]

Between Kootenay crossing and Mud creek, in the Kootenay valley, gravelly soil is of frequent occurrence. However, on account of the flat character of the country, there are few opportunities for the opening of

[1] Chainage from north, 0+00 at Kootenay Crossing.

gravel pits. The more suitable sites are the extensive cut, on hillside, about half way between the river crossing and Mud creek, and a ridge located at about 150 feet west of the road and running parallel to it, a short distance north of the creek.

In the first instance there is a good exposure of fine clayey gravel. A high wall is readily available to start with in excavating, and large quantities of gravel can be obtained without trouble. The material exposed resembles that found to the north of the Kootenay near the lakes. It is packed hard in the bank and the pebbles cemented with clay and calcium carbonate.

In the second instance, the chances are that good clayey gravel will be found. Test holes made along the foot of the slope showed the presence of fine gravel with clayey binder. There is a clearing from the road to the foot of the ridge and the latter is but slightly covered with shrub and light timber.

250 + 00

From Brothers camp to McLeod Meadows, where our survey ended in 1921, there are several gravel pits from which material was obtained for the surfacing of the road last year.

These gravels, as a rule, resemble each other. They are generally fine in texture, fairly well graded, but except in the upper part of the deposits, do not carry enough binder. The road surface built during last summer appeared to be in excellent condition last fall, but, although this surface was rolled, it is doubtful whether under heavy traffic it will stand up without ravelling.

For purposes of comparison, one sample was collected from the pit, located immediately west of the road, north of Brothers' camp. It represents the average character of the gravel occurring in this part of the valley. In examining the results of analysis of sample No. 37, it will be noted that the per cent of clay and silt is rather low, but this may be counterbalanced by the presence of calcium carbonate on the pebbles.

650 + 00

Approximately 2 miles south of McLeod Meadows camp, there is an important ridge of drift material, parallel and close to the road. The ridge is several hundred feet in length, over 25 feet in height, and presents an escarpment facing the road, a short distance south of a creek.

A small pit was opened there, at a late date last year, when the surfacing of that section of the road had been nearly completed. A small amount of the material excavated was tried as surfacing material and the best results were obtained. This drift material is composed of gravel compacted very hard in the bank and cemented with highly calcareous clay. As a road surfacing material, the run of the bank is too coarse, about 30 per cent of the gravel being coarser than 1½ inch. The material under this size, however, is well graded and contains a proper amount of binder. It packs well on the road and gives a smooth and hard surface.

The amount available is large and a high wall can be excavated with little stripping to be done.

Sample No. 38 was collected from the actual wall of the excavation just started. The results of the tests are given in the accompanying tables.

TABLE I

Results of Physical Tests on Gravel Samples from the Hawk Creek-McLeod Meadows section of the Banff-Windermere Highway, Rocky Mountains Park

Sample No.	Location of deposit (road chainage)	Granulometric analysis: Proportion of gravel to sand		Gravel: Per cent retained on screens							Sand: Per cent retained on sieves						Per cent passing 200 mesh	Remarks on suitability for use in gravel road construction
		Per cent grav.	Per cent sand	2½″	2″	1½″	1″	¾″	½″	¼″	8	14	28	48	100	200		
1.......	447-00	67	33	20	5	25	15	6	11	18	24	15	10	9	12	16	14	Too high proportion of gravel over 1½ inch in size.
2.......	488-00	50	50	17	5	12	19	15	12	20	25	22	19	15	8	3	8	This material should prove satisfactory in the base course of gravel roads. Lacks binder and is too coarse for top course.
3.......	547-00	55	45	8	10	17	20	11	18	16	20	11	10	10	9	20	20	This material should prove satisfactory.
4.......	555-00	60	40	8	3	11	20	16	17	25	20	13	11	10	8	25	13	
5.......	572-00	55	45	....	4	13	18	17	19	29	22	16	13	12	10	14	13	Well graded fine gravel and sand.
6.......	583-00	66	34	....	5	11	15	16	23	30	38	17	11	9	6	9	10	This material should prove satisfactory.
7.......	845-00	60	40	....	15	9	16	14	18	28	23	25	25	12	5	3	7	Per cent of fines is low.
8.......	845-00	60	40	....	29	13	12	14	14	18	21	13	10	8	6	9	33	High proportion of pebbles over 2 inches.
9.......	839-00	50	50	...	....	14	18	14	23	31	23	9	9	22	16	14	7	Well graded fine gravel. Should prove satisfactory on clayey subsoil.
10.......	816-00	80	20	18	21	22	28	5	3	3	17	20	18	10	9	20	6	This gravel is coarse and the proportion of sand is low. Lacks material between 1 inch and ¼ inch in size.
11.......	815-00	70	30	...	8	12	29	13	15	23	34	19	15	8	4	5	15	Should prove satisfactory.
12.......	812-00	57	43	20	6	13	18	8	11	24	35	27	18	6	2	4	8	Large proportion of gravel over 2 inches. Low per cent under 28 mesh.
13.......	755-00	58	42	....	27	12	22	10	14	15	15	16	27	28	6	2	6	Should prove satisfactory on clayey subsoil only.
14.......	747-00	65	35	14	11	12	20	10	13	20	29	21	19	15	7	3	6	" " " "
15.......	740-00	57	43	....	6	17	17	9	16	35	18	11	15	20	9	9	18	Sample from firm and smooth road surface for comparison purposes. Notice grading and amount of fine.
16.......	705-00	63	37	....	9	14	22	17	16	22	30	23	19	13	6	3	6	Well graded gravel but lacks binder.
17.......	666-00	45	55	....	14	15	22	10	15	24	16	13	13	10	8	18	22	Proportion of sand a little high, but on account of high clay content should bind well.
18.......	653-00	65	35	....	16	17	25	9	13	20	25	15	12	11	9	8	20	This material should prove very satisfactory.
19.......	651-00	63	37	....	17	4	18	16	18	27	31	16	14	13	8	5	13	Well graded.
20.......	630-00	55	45	....	17	10	12	13	18	30	28	15	13	13	9	9	13	"

21.......	621-00	64	36	27	4	11	23	12	9	14	16	20	36	19	4	2	3	Coarse gravel without binding material. Suitable for concrete.
22.......	608-00	70	30	5	11	13	23	13	15	20	24	24	22	15	5	4	6	Coarse gravel without binding material. Suitable for concrete.
23.......	580-00	75	25	9	7	12	29	11	16	16	23	9	9	23	18	7	11	The proportion of sand is low.
24.......	576-00	65	35	32	16	7	13	8	13	11	17	15	13	12	9	16	18	This material should prove satisfactory, after the excess of material over 2 inches has been rejected.
25.......	568-00	60	40	18	16	12	10	7	17	20	19	15	13	12	9	16	16	This material should prove satisfactory, after the excess of material over 2 inches has been rejected.
26.......	545-00	77	23	8	13	20	25	12	11	11	20	15	19	24	10	4	8	The proportion of sand is low.
27.......	501-00	75	25	15	7	20	20	12	13	13	22	11	8	15	18	10	16	Although containing a low per cent of sand may prove satisfactory on account of binder contained.
28.......	430-00	75	25	7	11	29	19	11	11	12	18	14	21	19	7	5	16	Although containing a low per cent of sand may prove satisfactory on account of binder contained.
29.......	400-00	60	40	16	4	12	20	12	15	21	30	18	12	8	5	7	20	About 20 per cent of the gravel portion to be rejected as being too coarse, but balance well graded.
30.......	305-00	67	33	....	12	6	28	15	17	22	17	13	20	34	10	3	3	Suitable for concrete.
31.......	250-00	75	25	....	8	24	29	15	13	11	13	9	9	13	20	26	10	Sand silty but on account of low proportion of sand to gravel will prove satisfactory.
32.......	190-00	62	38	....	7	8	25	12	16	32	24	12	10	10	8	28	8	Well graded. Should prove very satisfactory.
33.......	154-00	84	16	....	5	4	11	13	18	49	42	8	5	6	7	22	10	Well graded but too low proportion of sand. Reason why this material, though containing binder, failed to pack in roadbed.
34.......	30-00	55	45	12	12	5	14	8	16	33	33	24	16	8	3	8	8	This material has proved very satisfactory.
35.......	10-00	75	25	....	....	18	27	17	18	20	26	12	17	20	8	10	7	Fine gravel with too low per cent of sand. Has proved satisfactory on account of binder contained.
36.......	0-00	80	20	6	17	16	9	13	20	21	58	17	6	3	2	4	10	Fine gravel with too low per cent of sand. Has proved satisfactory on account of binder contained.
37.......	250-00[3]	65	35	4	8	8	15	10	15	40	36	20	20	10	3	2	9	Well graded, but lacks binder.
38.......	650-00	60	40	15	4	11	15	13	17	25	28	15	14	20	10	6	7	Except an excess of material over 2 inches is well graded. Service test has given very good results.

[1] Chainage from north.
[2] " south, Kootenay Crossing.
[3] " north, "

TABLE II

Results of Physical Tests on Gravel Samples from the Hawk Creek-McLeod Meadows section of the Banff-Windermere Highway, Rocky Mountains Park

Sample No.	Character of material: Composition of pebbles[1]						Remarks
	Durable	Intermediate	Soft	Shape of pebbles	Impurities	Per cent[2] clay and silt in sand	
	Per cent	Per cent	Per cent				
1	5	90	5	Rounded	$CaCO_3$ coated on the pebbles and organic matter	28	This material should bind well
2	5	40	55	Rounded and flat	....	10	Too high content of soft shales. Lack of binder
3	....	75	25	Angular, flat	Organic matter and clay	39	This material should bind well
4	20	20	60	Angular	“ “	34	High proportion of soft rock. Should bind well but will wear fast
5	15	15	70	Angular, flat	“ “	29	High proportion of soft rock. Should bind well but will wear fast
6	....	95	5	Flat	Clay	18	Composed of fresh limestone pebbles with sufficient amount of binder
7	10	50	40	Rounded and flat	Little $CaCO_3$	10	Low binder content
8	15	30	55	“ “	Some $CaCO_3$ organic matter and loam	37	High proportion of soft rock. Loamy gravel, should bind well
9	20	50	30	Subangular	Little organic matter	14	
10	45	50	5	Rounded	$CaCO_3$ and clay coating in large amount	47	High per cent of clay in sand, but it will be noted that the gravel carries only 20 per cent of sand
11	45	45	10	Rounded to subangular	$CaCO_3$ in small amount on the larger pebbles	18	Should bind well
12	40	60	....	Rounded	....	10	Low binder content
13	20	80	....	Rounded to subangular	....	10	“ “
14	5	95	....	“ “	....	10	“ “
15	40	50	10	Rounded	Organic matter and loam	23	Sample from firm and smooth road surface
16	25	50	25	“	Very little $CaCO_3$	10	Low binder content
17	....	100	....	Angular	Clay	45	High clay content in the form of lumps
18	....	100	....	“	“	28	Proportion of binder to total aggregate about proper
19	15	65	20	Subangular to rounded	Clay and organic matter	13	
20	....	95	5	Rounded and flat	“ “	33	Should bind well
21	20	50	30	Rounded	....	5	Lacks binder

22	25	75	....	Rounded to subangular	....	5	Lacks binder
23	10	60	30	" " ..	Loam	12	
24	....	100	....	Angular	Clay	25	Should bind well
25	....	100	....	Subangular	"	40	High clay content, may produce a muddy surface when wet
26	20	65	15	Rounded	$CaCO_3$ in small quantity on pebbles	10	Low binder content
27	55	25	20	Rounded to subangular	Loam and organic matter	20	Should bind well. Loam binder
28	25	65	10	" " ..	" "	15	" " "
29	....	75	25	Angular and flat	Clay	25	" " "
30	20	50	30	Flat	....	5	Lacks binding material
31	....	95	5	Rounded	....	20	Binder of rather silty than clayey nature
32	40	50	10	"	$CaCO_3$ organic matter and clay.	35	Should bind well
33	35	55	10	Rounded to subangular	$CaCO_3$ and clay coated on pebbles	24	Proper amount of binder but sand content too low
34	25	70	5	" " ..	$CaCO_3$ coated on pebbles and highly calcareous clay	16	Should bind very well. The amount of clay present is not high, but calcium carbonate coating present to act as binder
35	40	50	10	" "	$CaCO_3$ coated on pebbles and highly calcareous clay	15	Should bind very well. The amount of clay present is not high, but calcium carbonate coating present to act as binder
36	10	50	40	Rounded	$CaCO_3$ coated on pebbles and highly calcareous clay	15	Should bind very well. The amount of clay present is not high, but calcium carbonate coating present to act as binder
37	15	60	25	"	Thin film of $CaCO_3$ on pebbles..	7	Doubtful if will bind without rolling
38	20	75	5	"	" " " ..	15	Service test has proved that this material binds well

[1] The pebbles are classed as durable, intermediate or soft, according as they are composed of rock which would show a per cent of wear of less than 3, between 3 and 6, or over 6, respectively. The durable class, here, includes pebbles composed of fresh rocks of igneous origin, the intermediate includes fresh limestone, and the soft includes weathered pebbles of both types and shales.

[2] This determination was made by washing through a 200 mesh sieve.

III

PROSPECTING FOR ROAD MATERIALS BETWEEN MASSIVE AND JOHNSON CANYON

During the first part of the field season a successful prospecting was carried on between Massive and Johnson creek along the Banff-Lake Louise road, where no suitable material for road work had previously been found.

The general character of that area, called Hillsdale, is very rolling. The road for 1½ mile cuts through a series of small foothills made up of decomposed shales. On either side of this hilly area, near Johnson creek and near Massive, gravel occurs, but it lacks binding material.

A thorough examination of every hillock within hauling distance of the road and the digging of many test holes finally resulted in the finding of gravel at two places close to the road and in sufficient amount to constitute a supply of material for the surfacing of that stretch of the road.

At a distance of 1·4 mile east of Johnson creek, gravel was found on the crest of a ridge immediately north of a shallow gully on the north side of the road. The maximum thickness of this cap-like covering of gravel may exceed 20 feet. The ridge presents steep slopes and is only partly covered with light bush. It is continuous for 500 feet in a direction parallel to the road and its elevation above the gully is about 100 feet.

Two test pits, four feet deep, were made. The gravel found in them is fine in texture and carries only a small proportion of stone over two inches in size. The proportion of material passing the ¼ inch screen is rather high but contains a good deal of binding material. The pebbles are coated with calcium carbonate, angular in shape, and largely composed of fairly durable shaly limestone. Soft or weathered pebbles are few. The material is packed very hard and ought to bind well on a road surface. The overburden consists of one foot of loose, gravelly loam.

The amount of gravel available can be estimated at several thousand cubic yards. The material could be loaded by means of a chute directly into trucks standing at the foot of the slope by the road side.

One sample was taken and analysed in the field. The proportions in the sand were determined roughly by volumetric means. They are as follows:—

Gravel, 33 per cent; sand, 57 per cent.

Sand retained on 8 mesh	30 per cent
" " 20 "	25 "
" " 48 "	15 "
" passing 48 "	30 "
	100 "

The second occurrence of gravel that was located lies at 1·7 mile east of Johnson creek, or one-half mile west of the large cribwork construction.

In following a gully, which is crossed by the road at the above mentioned mileage from Johnson creek, clayey gravel was found in small knolls at a distance of 100 yards north of the road. The amount available, however, was found to be small and the location unsuitable for a pit.

Similar material was finally located in a flat-topped ridge about 35 feet high, just east of this gully and immediately north of the road.

The chances are that fairly large quantities of gravel can be obtained there. It is difficult, however, to estimate the amount available without determining the average thickness of the gravel overlying the shale formation. But even if there should be a thickness of only a few feet, the opening of a pit will probably be worth while. A high wall can be developed next to the road, with very little necessary stripping. There is one foot of loamy overburden and a few trees.

The material taken out of a test-pit 4 feet deep, made in the upper part of the slope facing the road, consisted of clayey gravel, packed hard and containing few boulders. The pebbles are largely composed of limestone and coated with calcium carbonate. On account of a reasonable amount of binding material contained therein this material should prove satisfactory in road surfacing. The analysis of one sample taken is as follows:—

Gravel, 36 per cent; sand, 64 per cent.

Sand retained on 8 mesh	35 per cent
" " 20 "	20 "
" " 48 "	20 "
" passing 48 "	25 "
	100 "

Deposit of Bedrock east of Johnson creek

About three-fourths of a mile east of Johnson creek, there is on the north side of the road an important outcrop of limestone, from which large quantities of material of good quality could be obtained for the production of crushed stone.

The deposit forms a high cliff several hundred feet long, parallel to the road and only one hundred feet or so distant from it. The total height of the scarp is approximately 75 feet, and about two-thirds of it is talus covered.

The beds exposed in the upper part could be easily quarried on a large scale.

The limestone is light grey, of medium texture, and occurs in thin beds which are frequently jointed and much fractured. The stone is somewhat weathered but laboratory tests performed upon one sample which was collected have proved that it compares favourably in durability with the Mount Rundle limestone, which is giving satisfactory results as road material in Banff. The physical properties of both limestones are given below:—

Sample	Per cent of wear	French co-efficient of wear	Tough-ness	Hard-ness	Specific gravity	Absorption in lbs. per cu. ft.
Limestone, east of Johnson creek	2·4	16·7	7	14·9	2·72	0·46
Limestone from Mount Rundle, Banff	3·3	12·3	6	14·9	2·72	0·50

IV

EXPERIMENTS FOR INVESTIGATING THE TEST FOR THE CRUSHING STRENGTH OF ROCK

Samples of granite for pavements were received in 1920 in connection with the compression test of rock which Dr. K. A. Clark, former chief engineer of the Road Materials Division of the Mines Branch, had in charge as Chairman of the Sub-Committee of Road Materials of the American Society for Testing Materials.

The sample consisted of two types of granite blocks respectively from Georgia and from Maine, the sample from the Pine Mountain quarry at Lithonia, Ga., being a light grey granite of fine texture, and that from the state of Maine being of a darker colour and of coarser but more even texture.

The object of the test was to determine the best type of test piece considered both from the standpoint of uniformity of results and of practicability in preparation. The experiments were carried on in cooperation with Mr. H. H. Scofield, Professor of Materials, College of Civil Engineering, Cornell University, Ithaca, N.Y.

The types of test piece considered were:—

Cylinder	1″	in diameter	and	1″	high
"	1″	"	"	1½″	"
"	1″	"	"	2″	"
"	2″	"	"	2″	"
"	2″	"	"	3″	"
"	2″	"	"	4″	"

Rough cube 2″ x 2″ x 2″.

The test pieces were prepared in accordance with the methods described in Bulletin No. 347 U.S. Department of Agriculture, 1916, by Frank H. Jackson "Methods for the determination of the physical properties of road building rock."

The cylinders were obtained from the block with a diamond core drill, cut to length with a diamond dust saw, and ground true on a grinding lap with the use of finely powdered carborundum as an abrasive agent.

The cubes were cut from the blocks with a chisel and ground to size in the same manner as the cylinders.

The test pieces were broken in an Olsen, 20,000 lbs. "3 Screw Type" Universal Testing Machine electrically operated. The speed used in applying the load was ·022″ per minute.

Every test piece was checked as to the dimension and the condition of the bearing surfaces before testing.

It was found that in the case of the 1″ cylinders it had been difficult in the preparation of the test piece to obtain accurately parallel faces.

The two types of granite used in making this test proved to be of similar quality. If stone blocks containing less cleavage planes and of a more uniform texture had been used, probably more comparable results would have been obtained in this test. More illuminating data would also have been secured if one of the samples used had been decidedly weaker than the other. The results of tests were sent to Mr. Scofield. They are not given here because they are part of a series of tests not yet concluded.

V

ROAD MATERIALS IN NOVA SCOTIA

R. H. Picher

Investigation on road materials in Nova Scotia, commenced at the end of the summer of 1920, was continued during the field season of 1922. The field work consisted of making an exhaustive study of the condition of the surfaced main roads, and inspecting and sampling materials available for road construction, especially along the lines of proposed improvements.

In order that the results of the investigation might be of most direct assistance to the Department of Highways of Nova Scotia, inspection work was carried on in those parts of the province where information on road materials was more urgently needed. After a consultation with Mr. W. A. Hendry, chief engineer of the Nova Scotia Highway Board, it was decided to begin first with the areas in the vicinity of the main highways. It is the policy of the present Department of Highways to improve all the main highways and maintain them in good condition at all times, and in this connection it was noticed that considerable progress had been accomplished in the last two years.

The following main roads were examined in detail, and all possible sources of surfacing material thoroughly investigated: The Truro-Sydney road; the South Shore road, from Halifax west to Shag Harbour; the Middleton-Bridgewater road; the Kentville-Chester road; the Windsor-Halifax road; the Windsor-Truro road, from Windsor to West Gore; the Annapolis Valley road, from Cambridge to Brickton; the Amherst-Parrsboro road. Some time was spent studying the character of extensive trap rock deposits outcropping for a distance of over one hundred miles along the bay of Fundy, and a few days were spent along the Amherst-Oxford road, to locate surfacing material. Sixty-five samples were collected and sent to the laboratory for testing.

ROAD CONDITIONS

The purpose in studying the condition of the surfaced roads was to ascertain the possibility of the materials employed in their construction to form a hard, resilient and impervious surface that can withstand the wear and impact of the traffic, and keep the water from penetrating into the subbase. By comparing results observed on roads with those obtained in laboratory tests, the suitability of materials for road purposes can be determined with reasonable accuracy. In making observations on the condition of a surfaced road its age and the methods used in its construction have to be taken into account. In cases where the material is spread over the road in one single course and left to be rolled by the traffic, no satisfactory conclusion can be drawn as to the wearing quality of the stone. A soft material will soon compact into a smooth surface under traffic, but will wear out very rapidly. A hard stone will remain loose a long time, so that two deep ruts will form in the wheel tracks before the stone is sufficiently compacted. Water will be retained in the depressions, thus softening the surface and accelerating its destruction. The amount of traffic is another important factor to be considered. A stone may have given good service for years on a light trafficked road and utterly fail under increasing traffic. Some of the gravel stretches along the Halifax-Truro highway illustrate this. Another cause of failure in road pavements is insufficient drainage of the subsoil. A good gravel or broken stone surface will eventually yield under the weight of traffic, if the subsoil is not kept properly drained. Some clay soils in particular lose much of their supporting power when in a wet state.

Sydney-Truro highway.—The road between Sydney and Blackett Lake, gravelled in 1921 with material from pit No. 1, (see tables II, III), was in very good condition in the summer of 1922. The North Sydney road, surfaced with the same material and subject to a larger amount of traffic, showed slight signs of wear. A short stretch northeast of St. Peter surfaced with gravel No. 7 was in excellent condition. Much gravel from pit No. 11 has been used at different times to cover stretches of the main road between Heatherton and Antigonish. The road was in very good condition only on stretches not more than one year old. The Telford-Sutherland River road, surfaced with conglomerate gravel No. 16, and the Sutherland River-New Glasgow road, with gravel No. 14, were both in very good condition after one year. Gravel No. 16 is much too soft and No. 14 somewhat fine. The road at Alma has been kept in fair condition by gravelling at different times with material from deposit No. 17 and others. The gravel is not durable and the road requires frequent attention.

There are several sections surfaced recently, which have not been long enough in service to show any results as to the wearing quality of the material, and sections which have not yet been surfaced.

Truro-Halifax highway.—Due to the ever increasing amount of traffic much difficulty has been experienced in keeping this road in good condition. The Halifax-Stewiacke section was in course of repair during the summer. None of the materials found along this section are durable enough, taking into consideration present traffic conditions. Imported material will have to be used between Truro and Stewiacke, as has been done on the Shubenacadie-Enfield section, which was surfaced with gravel from deposit No. 20, with very good results. From Brookfield south, the roadbed, largely composed of clay, is very soft when in a wet state, and in order to maintain a good surface, thorough drainage is necessary.

The Enfield-Halifax section was in very good condition, except stretches between Waverley and Bedford, just completed at the end of the summer. On these most of the stone was loose. The road has been surfaced nearly all the way from Enfield to Halifax with crushed quartzite boulders. In places some fine material, largely fine sand and silt from the drift deposits, has been mixed with the crushed stone, so as to act as a binder and make a smoother finished surface. Stretches treated in this way wear much more rapidly than where crushed quartzite alone has been used. From Bedford to Halifax, the road has been surfaced with crushed quartzite and bitumen, and is one of the finest examples of bituminous macadam pavement.

Halifax-Shag Harbour highway.—This road carries a fairly large amount of automobile traffic as far as St. Margaret and light traffic farther west. The Halifax-St. Margaret section, surfaced with crushed granite boulders mixed with sand, was completed in 1920. It was in good condition in 1922 but showed decided signs of wear. The St. Margaret-Chester section, covered in 1921 with gravel and sand largely composed of granite particles, was in rather poor condition and uneven after one year's service, due to the material being too fine. From Chester to Shag Harbour stretches have been surfaced at different times. The road is in good condition where the surfacing is not more than one or two years old, but poor elsewhere and rough in places. The material used is generally too fine to be durable.

Middleton-Bridgewater highway.—This road is in fair condition, having been recently surfaced nearly its whole length. The surface is rather soft and will wear very rapidly. Some stretches near Bridgewater, which have not been repaired for several years, are in bad condition. Most of the material used is fine gravel carrying a high proportion of sand. The only gravel which is coarse enough to be considered durable occurs at the Annapolis-Lunenburg county line.

Kentville-Chester highway.—The Kentville-South Alton section, which has been surfaced at different times, is in fair condition, except for one mile near Kentville, where the road has a steep grade and is somewhat rough. The South Alton-Forest Home section, and a few short stretches near New Ross and Chester Basin, covered with gravel and sand during the last two years, are in good condition, although the surface is soft. The remainder of the road is in very poor condition, with very bad stretches through poorly drained areas near New Ross Road and Aldersville. The gravel used almost exclusively for covering this road is much too fine for the purpose. Granite boulders are found in large quantity nearly all along this road, and if crushed would produce much better surfacing material.

Windsor-Halifax highway.—From Windsor to east of Newport Corner the road over three years ago was surfaced with gravel from five local deposits, and some sections since repaired with material from the same source. It is now in fair condition in places, poor in others. The gravel west of Ste. Croix is fairly durable, although mixed with much sand, and the gravel found east of Ste. Croix is very soft. The section from east of Newport Corner to Bedford, commenced in 1920 and finished in 1922, is in excellent condition, except the older stretches, which are very uneven. The material used on this road was crushed boulders mixed with fine sand and silt from drift deposits. Gravel is very scarce along this section, while boulder drift deposits are numerous.

Windsor-Truro highway.—The road was examined from Windsor to West Gore only. It has been gravelled during the last two years, except a few short stretches east of Clarksville, and is on the whole in good condition, though very rough on some of the steep grades between Scotch Village and Brooklyn. Gravels from more than ten deposits have been used to surface the road. Most of them are either too soft or too fine to make a durable pavement. More satisfactory material with regard to both size and composition is found at Mosherville station. Here also the deposit carries much sand in places.

Cambridge-Brickton highway.—This road has been gravelled for years and usually maintained in fair condition, except several miles of sand between Berwick and Auburn, which were gravelled for the first time in 1921. This part is now in very good condition, but somewhat soft, the gravel used being too fine. Among the gravels which have been used for road construction, only the following are sufficiently hard and coarse; the gravel at Berwick, West Brooklyn and two miles south of Brickton.

Amherst-Parrsboro highway.—The inspection of this road was made in the early summer, when the Amherst-Southampton section was under construction. From Southampton to Fullerton lake, the road surfaced with local gravel is in good condition, but soft and dusty. Southwest of Westbrook the road passes through a swamp, and is rough and rutted. From Fullerton lake to Parrsboro, the road, surfaced with local gravel and passing through gravelly soil nearly all the way, is in very good condition. The only durable material along the Amherst-Parrsboro highway is found in the Cobequid hills, between Fullerton lake and Lakelands. In order to get a durable surface on the Amherst-Fullerton Lake section, other material than that found along the road will necessarily have to be used.

ROAD MATERIALS

The most common types of suitable road materials encountered are bedrock and gravel.

Since a large proportion of the particles of which the gravels are composed are of the same character as the underlying bedrock, the durability of these materials is closely related. The gravel is in general durable in the hard rock areas, but less so than the bedrock, on account of the presence of a certain proportion of pebbles of other origin. For the same reason, the gravel is soft in the soft rock areas, although less so than the bedrock. Gravel is more plentiful in the hard rock areas, while in the soft rock areas pebble free sand is of more frequent occurrence.

Bedrock

Very hard and tough syenite and syenite porphyry are exposed at several points between Ben Eoin and Big Pond, along the Sydney-St. Peter section of the Truro-Sydney highway. (Table I, Nos. 3, 4). These rocks can be quarried in unlimited quantity.

Extensive trap rock outcrops are found on both slopes of the North Mountains which forms a flat-topped, steep ridge along the north side of the Annapolis valley. (Table I, Nos. 2, 10). This rock is available in any amount in loose blocks forming talus at the foot of cliffs, some within three miles of the main valley road. The same rock is exposed at several places along the Parrsboro-Economy section of the Amherst-Truro highway. This is a very good rock when fresh, but the partly weathered material is much less durable. If used in waterbound macadam construction, weathered rock will rapidly disintegrate into a clay which causes the road surface to be very slippery when wet.

A white, very coarse granite, which underlies a considerable portion of the western half of the mainland, is exposed at numerous places and can be easily obtained in large amounts. It is, however, too coarse and too soft to make a durable road material. The several quarries, southwest of

Middleton, where a sample was taken (Table I, No. 12), show a rather fine crystalline granite, much harder than the ordinary coarse variety commonly found farther south, and quite suitable for roads subjected to ordinary traffic.

The quartzite, or so-called whin rock, and the slate which are found associated together, underlie nearly all the southern and western part of the mainland. Although actual exposures of the rocks are not numerous, the overlying drift carries a tremendous amount of boulders, more particularly of quartzite. The quartzite boulders are nearly all fresh and hard and are a very good material. (Table I, Nos. 6, 13, 14). The schistose quartzite should not be used, as it has not the durability of the massive stone. The slate varies widely in appearance from very soft and shaly to massive and very tough. As seen from most of the exposures and drift boulders, the most common phase is a blue-black, fairly hard stone, with the characteristic slaty structure. It is unsuitable for road surfacing on account of splitting too readily.

The large igneous intrusions found south of the Antigonish-New Glasgow road and north of the Truro-Parrsboro road could furnish a very good road stone, but actual fresh rock exposures in proximity to the main highways are scarce.

Among smaller occurrences of good road material, there is diorite and felsite, exposed at several places along the St. Peter-Hay Cove section of the Sydney-Truro highway, 3 exposures showing fresh and very hard rock; a rock probably altered sandstone, exposed along the same highway just west of Mulgrave (Table I, No. 5); trap, exposed south of Nictaux, along the Middleton-Bridgewater highway; iron ores, of the Torbrook iron mines, the waste of which has been used for road work, (Table I, No. 11); and diabase, exposed along the South Shore at Cherry Hill and Black Point. (See 1921 Report.)

The limestone from the quarry of the British Empire Steel Corporation, near Point Edward, northwest of Sydney, is much superior in quality to other limestones found elsewhere in the province, and is quite suitable for road purposes (Table I, No. 1).

Most of the conglomerates, sandstones (Table I, No. 8), shaly sandstones, and shales are very poor materials, especially those which are geologically classified as belonging to the Carboniferous and Permian formations. Sandstones from older formations are generally harder, of closer texture, and some of them may be used in roads having light traffic, when no better material is available. Such is the case with the sandstone exposed for a distance of several hundred feet, three-fourths of a mile south of McNab Cove, along the St. Peter-Hay Cove section of the Sydney-Truro highway.

The test for determining the cementing power of a rock has not proven so far quite satisfactory, and for that reason too much importance should not be attached to the figures given in the column bearing the heading "Cementing Value." They will serve to indicate only in a general way whether the rock has a high or low cementing power. The test is of value only in cases where a stone is to be used in water-bound macadam surfacing. When bituminous or other artificial binders are used on road surfaces, the cementing power of the rock is of no account.

TABLE I

Results of Tests on Bedrock and other Materials

No.	Location	Type of material	Physical properties: Per cent of wear	French co-efficient of wear	Tough-ness	Hard-ness	Cement-ing value	Specific gravity	Water absorbed lbs. per cu. ft.	Remarks
1	B. E. Steel Corp's. quarry, near Pt. Edward.	Limestone	3·3	12·1	12	16·7	120	2·71	0·20	Dense stone.
2	B. E. Stéel Corp., Sydney	Blast furnace slag	8·6	4·7			250	2·49	5·40	Not uniform in texture.
3	Southwest of Ben Eoin	Syenite	2·1	19·0	25	18·9	48	2·78	0·11	
4	Northeast of Big Pond	Syenite porphyry	2·2	18·2	27	18·6	50	2·89	0·09	Dense stone
5	West of Mulgrave	Altered sandstone	1·5	26·7	18	18·8	32	2·65	0·44	
6	Grosvenor	Quartzite	2·1	19·0			17			Field boulders
7	James River	Felsite and syenite	1·3	30·8			46			Pebbles from river gravel
8	North of Joggins	Sandstone	6·1	6·6	5	4·5	89	2·54	6·02	Millstone. Very loose texture
9	North Mountain, northwest of Canning	Trap	4·1	9·8	10	17·4	110	2·96	1·26	Partly weathered loose rock
10	North Mountain, south of Upper Clarence	Trap	2·7	14·8	19	17·9	107	3·00	0·71	
11	Torbrook West	Iron ore	3·3	12·1	20	16·2	32	4·00	1·27	Iron mine dump
12	Southwest of Middleton	Granite	2·9	13·8	12	18·7	39	2·70	0·28	
13	East of Liverpool	Quartzite	2·0	20·0			37			Beach boulders
14	West of Tusket	Quartzite	2·0	20·0	18	18·0	18	2·70	0·47	Field boulders

Gravel

Gravels are fairly common throughout the province, except perhaps in the areas underlain by Carboniferous rocks. They are particularly scarce to the east and south of Sydney, between St. Peters and Hawkesbury, and in the low lands lying between Northumberland strait and the Cobequid hills. Most of the gravels are very fine, and many of them irregularly sorted and interstratified with layers of sand and silt. The coarsest material is, as a rule, found in the upper part of the deposits, and sand mostly in the lower part. Many gravels while composed of very hard particles are too fine to be considered suitable for road purposes. Beach or river gravels are usually coarser and contain a higher percentage of hard pebbles than the corresponding bank gravels, but when applied to a road surface remain loose a long time on account of lack of binder.

Sydney to Truro.—Gravel from a large deposit, one and one-half mile northeast of Blackett Lake, has been extensively used for roads. It is not durable, but, considering the present traffic, it may be suitable for the main road. The beach gravel, available at several points along the shore between East Bay and Ben Eoin, is very hard and coarse, but does not possess sufficient fine material to act as a binder. Away from the shore very fine and hard gravel is found at several places, and can probably be used to advantage on top of beach gravel. A pit recently opened near Cleveland shows fairly hard gravel, although rather fine. This is the only good material found for many miles east and west. The several deposits to the east of Monastery hold probably more sand than gravel. The gravel occurring at Lower South River is too soft for road surfacing. A very large amount has been used for that purpose, since it is the best material found for several miles. Very hard gravel is seen in several pits and road cuts at James River, Marshy Hope, Avondale Station, and Barney River. They are all rather fine, except the river gravel at James River, which is very coarse and bouldery, and carries very little sand. The latter can be used with advantage for the bottom course in either a macadam or gravel road. The main road between New Glasgow and Sutherland River was, in 1921, surfaced with gravel hauled by rail from Avondale Station. In 1922 the road surface was in very good condition, although some of the gravel was still loose. The red gravel east of Telford, which is a loose conglomerate, and the gravels and conglomerates near Alma are too soft for road surfacing purposes. The river gravel found at West River is harder and coarser than any bank gravel occurring within several miles of this place, but is totally devoid of binder. Very durable gravel has been recently excavated at the foot of a knoll west of Lower Mount Thom. Several small road cuts in other deposits show a similar gravel, but with a higher proportion of sand.

Halifax to Shag Harbour.—The gravel is rather scarce between Halifax and Shag Harbour, and when not too fine, is of good quality. The gravels found west of the railway crossing at Mahone and two miles northeast of Bridgewater have given good service on roads for several years. The extensive deposits south of Jordan Falls and south of Sable River Station carry very good gravel, but a large proportion is too fine. Two and one-half miles east of Port Hébert, there is a very coarse and bouldery gravel composed exclusively of hard quartzite, and looks to be very good material.

Middleton to Bridgewater.—The gravel deposit two miles north of Albany Cross, like nearly all the deposits occurring in the granite areas, is very sandy. Although carrying a very high proportion of hard particles, the gravel is too fine to be considered durable. The only deposit of coarse gravel along this road is found between Hastings Junction and Cherryfield, very close to the Annapolis-Lunenburg county line.

Parrsboro to Amherst.—There are several deposits of good gravel near Lakelands. As seen in many road cuts, the deposits carry in places much sand interstratified with the gravel. The gravel at Halfway River station is of fair quality, although irregularly graded. The hauling distance from this deposit to the main road is three-quarters of a mile. A conglomerate, exposed in an excavation south of Aulac, N.B., just past the provincial boundary, has been used to some extent for road surfacing in Nova Scotia. It is composed largely of rounded quartz pebbles in a matrix of loose sandstone. As no suitable road material can be found for many miles south of the border this conglomerate will be extensively used on roads.

A very large railroad pit at Debert station shows a very hard and regularly graded gravel, but having very little fine material to serve as binder. A large amount has been used for road surfacing. Sections of the main road between Shubenacadie and Elmsdale have been surfaced with this gravel and were in excellent condition after two years of service. The sections which have been more recently surfaced show much loose gravel.

A large pit at Berwick shows fairly coarse, hard gravel in the upper nine feet of the deposit, and straight sand farther down.

There is a very large amount of beach gravel available at Digby. It is chiefly composed of trap rock pebbles, of high binding power. A fairly big deposit of bank gravel lying two and one quarter miles south of Digby shows very good material.

Other Materials

Boulder drift deposits, much more common than gravel deposits, are of less importance than the latter as a source of road material on account of their very small percentage of stone of proper size. Their chief interest lies in the fact that they form part of the subsoil on many sections of the main highways, where their composition greatly influences the bearing power and drainage of the road subgrade. When the drift holds a large proportion of hard boulders it may become an important source of material for road surfacing. As a matter of fact, it is the only available material at many points along the south shore. In places the boulders are so numerous that they literally cover the ground. In the case of quartzite boulders alone, there is enough of this stone on the surface available for crushing to pave the South Shore road several times. In localities where it becomes necessary to open pits in the drift deposits, in order to obtain a sufficiently large amount of boulders, no fine material from the pit should be mixed with the crushed boulders to serve as binder in the paving of the road. For that purpose crusher screenings are to be preferred, so as to obtain a homogeneous surface that will be durable and wear evenly.

Slag from the blast furnaces of the British Empire Steel Corporation, at Sydney, has been locally used in road surfacing. The material is soft and irregular in texture, but possesses a very high binding power. The Sydney-Glace Bay road has been partly paved with slag and the surface was very smooth after one year's service, although not very hard. It will probably wear out rapidly, but since the material is available in great quantity and at very low price, frequent re-surfacing can be made at a reasonable cost. It could probably be used to advantage as a binder in a road surface built with hard broken stone or gravel.

TABLE II

Results of Tests on Gravel Samples

No.	Location	Character of gravel: Composition of pebbles, Per cent of: Durable	Intermediate	Soft	Size, Per cent of: Boulders	Gravel	Sand	Remarks
1	N.E. of Blackett lake, 1½ m....	50	10	40	5	60	35	Fels, trap, ss; upper 5′ partly weathered.
2	N.E. of East Bay, 1 mile......	......	......	......	0	3	97	
3	East Bay, along road to Gillie Lake.	45	30	25	2	60	38	Gr, sy, trap, fels, ss; irregularly graded; sand layers; upper 5′ loamy.
4	N.E. of Ben Eoin, 2 m; along East Bay shore.	100	0	0	1	40	59	Trap, por, sy; all hard; beach gravel.
5	N.E. of Big Pond, 2½ m........	80	15	5	15	65	20	Por, trap; loose gravel; sand layers.
6	N.E. of St. Peter, 2½ m........	......	......	......	0	0	100	Intensely weathered sch.
7	N.E. of St. Peter, 2 m........	0	80	20	1	54	45	Glassy ss; very hard.
8	E. of Cleveland, 2 m...........	0	20	80	1	47	52	Shaly ss; boulder clay; upper 3′ loamy.
9	Near Cleveland...............	40	40	20	10	40	50	Dur: fels, qzte, trap; inter and soft: mostly ss.
10	E. of Tracadie, ¾ m............	70	10	20	1	57	43	Trap, fels, ss; clayey gravel.
11	Lower South River............	25	20	55	20	55	25	Dur: trap, gr; inter: trap, ss; soft: ss, sh; streaks of sand; slightly weathered.
12	N.E. of James River, 1½ m., along railway.	90	10	0	1	44	55	Qzte, fels, sy; streaks of clayey gravel.
13	Near Marshy Hope............	45	40	15	1	51	48	Trap, qzte, fels.
14	S. E. of Avondale sta., ¾ m.; 2 m. N. of main road.	27	30	43	5	55	45	Trap, sy, sh; sand layers.
15	Glenshee.....................	18	30	52	20	45	35	75 per cent is sch.
16	E. of Telford, ½ m.............	0	20	80	10	60	30	Fels, ss, gr, sh; partly weathered conglomerate.
17	S. of Alma....................	20	37	43	10	60	30	Fels, qzte, lst, ss: upper 9′ partly weathered.
18	W. of Lower Mt. Thom........	70	15	15	5	70	25	Sy, trap, ss.
19	N.E. of Mt. Thom, 1½ m.......	0	0	100	0	60	40	Dike of trap; material broken up by weathering agents.
20	Debert sta....................	80	20	0	15	63	22	Gr, sy, por, trap, other ign; regularly graded gravel.
21	Halfway River sta.; ¾ m. E. of main road.	33	45	22	3	72	25	Fels, qzte, gr, ss; sand layers.
22	Opposite Fullerton lake........	0	5	95	1	57	42	Mostly ss; sand layers.
23	S.W. of Southampton road forks, 1¾ m.	25	30	45	0	55	45	Ss, gr, fels, qzte; sample represents partly weathered gravel.
24	Same as 23..................	......	......	......	0	1	99	Large sand layer in very fine gravel.

25	S. W. of Southampton road forks ½ m....................	5	5	90	1	28	72	Ign, ss; weathered.
26	Near bridge, along Southampton road.	15	5	80	3	47	50	Mostly ss, some fels and gr; regularly graded.
27	S.E. of Amherst, 3 ½ m..... ...	3	0	97	0	30	70	Mostly ss; weathered.
28	S.E. of Aulac, N.B., ¾ m.......	90	10	0	5	70	25	Qz, fels; partly disintegrated conglomerate.
29	S. of West Gore, 1 m...........	33	12	55	5	82	13	Sl, ss, trap, qzte, gr; irregularly graded.
30	Mosherville....................	55	25	20	2	66	32	Trap, fels, ss, sh.
31	Brooklyn.......................	25	35	40	0	70	30	Sl, ss, lst, qzte, gr, fels; deposit mostly sand.
32	N.W. of Albany Cross, 2¼ m....	90	10	0	0	45	55	Gr, qzte, trap, fels; deposit mostly sand.
33	Berwick........................	52	30	18	1	47	53	Fels, trap, gr, ss; sand layers.
34	S. of Digby, 2 m...............	90	10	0	3	62	35	Gr, qzte, trap; upper 4' loamy.
35	Near Pleasant Lake............	52	43	5	–	60	40	Mostly qzte, well packed; bouldery; looks like boulder sand; irregularly graded.
36	Near Pleasant Lake............	60	35	5	5	67	28	Mostly qzte; irregularly sorted; sand and silt layers.
37	N.E. of Barrington, 3 m........	90	10	0	10	65	25	Sy, gr, qzte; size varies from place to place; sand layers.
38	S.W. of Birchtown, 3½ m.......	100	0	0	5	17	78	Gr, qzte; very fine boulder sand.
39	N.W. of Shelburne, ¾ m........	100	0	0	10	33	57	Gr, qzte; very fine boulder sand
40	Shelburne......................	80	15	5	30	45	25	Qzte, gr, trap; size varies from place to place.
41	N.E. of Shelburne, 2¼ m.......	80	20	0	–	30	70	Qzte, gr; very fine boulder sand carrying large boulders.
42	S.W. of Jordan Falls, 3 m......	67	28	5	3	59	38	Qzte, gr, sch, sh; sand layers.
43	S. of Jordan Falls, 1¼ m........	64	21	15	5	50	45	Qzte, gr; sand layers.
44	Near Sable River sta..........	85	15	0	1	64	35	Qzte; sample represents coarse gravel; deposit largely sand.
45	E. of Port Hebert, 2¼ m........	100	0	0	25	50	25	Qzte.
46	S. of Mill Village, 2¼ m.........	100	0	0	–	20	80	Qzte; fine boulder sand; per cent of boulders varies from place to place.
47	N.E. of Simpson Cor., ⅗ m.....	65	8	27	1	37	62	Gr, qzte, sl, sh.
48	Bridgewater....................	30	37	33	1	34	65	Sl, qzte; well compacted; mostly sand.
49	N.E. of Bridgewater, 2 m......	35	45	20	5	75	20	Sl, qzte, trap, ss; strongly cemented gravel; per cent of gravel includes many lumps of sand.
50	Near Mahone junction..........	75	20	5	2	55	43	Qzte, ss, sl; irregularly sorted; sand layers.

TABLE III

Results of Tests on Gravel Samples

No.	Granulometric Analysis														Remarks
	Gravel							Sand						Per cent passing 200	
	Per cent retained on screens							Per cent retained on sieves							
	2½″	2″	1½″	1″	¾″	½″	¼″	8	14	28	48	100	200		
1	5	4	15	21	11	18	26	27	21	22	13	8	3	6	Well graded.
2	......	......	......	......	......	4	96	7	17	28	29	14	3	2	Sand sample.
3	3	4	15	23	13	19	23	20	19	28	20	6	3	4	Very good.
4	......	......	3	8	14	25	50	18	26	48	8	......	......	......	Beach gravel; lacks binder; suitable for lower course in surfacing.
5	9	13	7	21	15	16	19	38	10	11	7	6	9	10	Very good if boulders removed.
6	......	......	......	......	......	......	......	11	23	24	20	12	6	4	Weathered schist; unsuitable for roads.
7	......	5	14	17	13	18	33	27	18	14	9	7	14	11	Well graded, good gravel.
8	5	......	16	25	14	16	24	16	14	15	14	11	16	14	Boulder clay; very poor material.
9	......	......	9	16	10	23	42	27	27	23	9	3	4	7	Very good.
10	......	21	12	19	12	17	19	13	19	37	19	4	4	4	Should prove a good material.
11	19	14	9	13	9	12	24	43	20	12	5	2	3	15	Too soft and bouldery.
12	......	5	3	14	16	21	41	21	20	23	17	8	6	5	Very good.
13	......	9	8	18	12	17	36	36	26	19	7	3	7	2	Sample represents coarser material than average. Good gravel.
14	......	26	9	14	10	16	25	32	26	25	12	3	1	1	Very good on roads with clay subsoil.
15	......	9	16	19	12	17	27	26	26	25	12	4	3	4	Soft and bouldery.
16	......	21	12	19	10	17	21	26	20	19	15	9	5	6	Red conglomerate; very dusty and soft.
17	5	......	7	16	8	22	42	46	27	16	6	2	1	2	Too soft, due to weathering.
18	......	4	2	12	13	26	43	64	19	8	4	2	1	2	Very good.
19	......	......	11	25	15	18	31	30	21	16	11	8	8	6	Too weathered.
20	9	8	22	18	10	14	19	28	18	22	20	9	2	1	Very good on roads with clay subsoil.
21	9	10	15	15	13	16	22	34	21	19	13	6	4	3	Sample represents coarser than average. Good gravel.
22	7	4	7	16	14	19	33	40	30	15	5	3	3	4	Very soft.
23	......	......	......	21	22	25	32	26	13	16	22	15	5	3	Should give good results on roads.
24	......	......	......	......	......	......	100	......	......	1	60	36	2	1	Sand sample.
25	......	......	20	7	6	19	48	23	26	18	17	10	3	3	Too soft and fine.
26	......	......	6	26	15	20	33	20	19	27	25	4	2	3	Well graded but too soft gravel.
27	......	......	16	26	13	18	27	7	4	4	14	28	21	22	Very poor.
28	......	......	3	22	17	26	32	45	20	12	9	7	3	4	Conglomerate; suitable for road surfacing.
29	2	7	13	39	21	12	6	15	10	14	23	14	15	9	Irregularly graded; suitable for roads with very light traffic.

30	10	13	10	23	10	15	19	25	15	23	25	6	2	4	Very good.
31	......	11	11	21	17	19	21	32	19	10	18	7	9	5	Deposit nearly exhausted.
32	......	......	8	8	8	19	57	34	28	24	0	2	1	2	Sample represents coarser than average. Much of the gravel is too fine.
33	......	7	13	17	13	17	33	33	25	25	12	2	1	2	Very good, but has little binder.
34	17	......	14	18	13	16	22	22	19	22	18	10	5	4	Very good.
35	4	3	27	21	13	14	18	27	15	14	10	5	10	19	Boulder sand; irregularly graded but fairly good.
36	4	13	14	19	13	17	20	30	16	14	14	10	6	10	Same as No. 35.
37	......	12	28	27	14	14	15	29	15	17	25	8	3	3	Good gravel.
38	......	13	19	26	8	14	20	11	9	10	12	14	22	22	Boulder sand; per cent of pebbles too low.
39	......	......	28	18	11	16	27	6	6	9	12	16	25	26	Same as No. 38.
40	10	10	17	17	10	13	23	26	25	24	13	5	5	2	Very bouldery; has very little binder.
41	......	17	6	23	14	14	26	11	9	12	15	16	18	19	Fine boulder sand; per cent of pebbles too low.
42	14	19	6	22	11	14	14	18	22	26	15	7	6	6	Very good.
43	16	4	8	19	12	17	24	22	21	26	21	5	3	2	Sample represents coarser than average. Much of the gravel is too fine.
44	6	12	10	27	10	13	22	17	13	20	29	10	4	7	Same as No. 43.
45	8	12	20	23	11	9	17	33	24	17	7	4	4	11	Very bouldery; very good if boulders removed.
46	25	......	13	9	9	14	30	9	8	9	11	16	21	26	Boulder sand; per cent of pebbles much too low.
47	......	......	6	19	13	20	42	20	19	20	21	11	6	3	Very good.
48	......	......	21	15	11	18	35	18	17	20	16	10	11	8	Too fine for roads except perhaps on top of a coarse gravel surfacing.
49	27	11	14	15	9	11	13	30	20	17	14	9	5	5	Fairly good.
50	8	......	22	20	10	16	24	30	31	24	8	2	2	3	Very good.

TABLE IV

Results of Tests on Gravel Samples

No.	Fineness factor	Sand Mortar: 1 cement, 3 sand					Remarks
		Per cent of water used	Tensile strength, Per cent of standard		Compressive strength, Per cent of standard		
			7 days	28 days	7 days	28 days	
1	3·19	15	82	105	72	95	Sand a little dusty and somewhat soft.
2	2·59	14	89	103	79	82	Rather fine.
4	2·54	11	115	108	101	100	Coarse hard sand from beach gravel; good.
5	3·19	16	41	75	24	59	Cracks in briquettes and cylinders, probably due to clay from weathered trap.
7	2·74	15	99	114	95	104	Very irregularly graded sand.
11	3·43	14	106	130	99	103	Much fine passing 200 mesh; fair.
14	3·66	12	166	147	149	152	Very good.
15	3·37	13	171	145	136	140	Very good, but a little dusty.
16	3·06	16	97	106	68	75	Very poor, due to metallic oxides as impurities.
17	4·00	13	229	197	174	177	Coarse sand; very good.
20	3·27	13	76	87	97	121	Coarse sharp sand; poor on account of rust.
24	1·59	17	65	84	43	54	Clean sand; too fine to be suitable.
26	3·11	13	100	112	88	105	Fair.
30	3·10	12	119	122	118	119	Coarse quartz sand; very good.
32	3·74	11	94	78	112	103	Sand from disintegrated granite; very poor.
34	2·98	12	111	79	123	135	Sample from near surface includes a little loam; good.
36	2·94	13	95	110	104	117	Very irregularly graded and too fine.
37	3·14	13	58	59	65	83	Sand from disintegrated granite; very poor.
38	1·21	18	54	57	49	68	Too much fine sand and silt, mostly quartz.
40	3·33	13	119	117	115	135	Good.
42	2·93	13	62	54	63	89	Clean, but too fine sand.
43	3·19	13	139	140	135	146	Very good.
44	2·65	12	87	83	116	137	Clean quartz sand, somewhat fine.
45	3·30	12	103	104	112	122	Fair.
47	2·89	12	93	94	94	93	Some soft shale and slate grains; very poor.
50	3·64	15	0	56	0	44	Cement had not set after 7 days, probably due to too much rust in the sand.

Explanation of Tables II and III

The proportions given for the pebble composition can be taken as representing the average composition of each deposit, but the same cannot be said about the classification as to size. Great care was taken in collecting samples that would represent the pit average as to the size of the particles, but when a thick sand layer intervened it was not included in the sample. In most cases the samples comprised the gravelly parts of the bank and thin layers of sand and silt occurring between gravel layers. In some cases the proportion of sand to gravel is so variable in different parts of the deposit that care must be exercised in applying the figures of percentage given for the average.

Abbreviations used in remarks

dur	durable
fels	felsite
gr	granite
ign	igneous
inter	intermediate
lst	limestone
por	porphyry
qz	quartz
qzte	quartzite
sch	schist
sh	shale
sl	slate
ss	sandstone
sy	syenite

Explanation of Table IV

The standard test referred to in Table IV is made on test pieces composed of 1 part cement, 3 parts Ottawa standard sand. Samples testing at least 100 per cent of the standard are considered suitable material for concrete works. All samples were taken from gravel and sand deposits, except No. 24, which is from a straight sand deposit, and No. 38, which is from a drift deposit, largely composed of fine sand and silt. As seen in the table, the fineness factor of the latter two samples is much below that of the gravels, which accounts for their low tensile and compressive strengths.