CANADA

DEPARTMENT OF MINES

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

MINES BRANCH

JOHN McLEISH, DIRECTOR

INVESTIGATIONS

IN

CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

1923

OTTAWA
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Annual reports on Mines Branch investigations are now issued in four parts, as follows:—

Investigations of Mineral Resources and the Mining Industry.

Investigations in Ore Dressing and Metallurgy (Testing and Research Laboratories).

Investigations of Fuels and Fuel Testing (Testing and Research Laboratories).

Investigations in Ceramics and Road Materials (Testing and Research Laboratories).

Other reports on Special Investigations are issued as completed.

Canadian Ceramic Exhibit, British Empire Exhibition, 1924.

MINES BRANCH INVESTIGATIONS IN

CERAMICS AND ROAD MATERIALS, 1923

INTRODUCTORY

Howells Fréchette

Chief of Ceramics and Road Materials Division

Since the inauguration of ceramic work in the Department of Mines particular attention has been devoted to the investigation of the clay and shale resources of the Dominion, and advice on their utilization has been freely given when sought.

It is proposed, in future, to devote more attention to the technological problems of the clayworking industries, with a view to assisting the producers in bringing their wares up to the highest standards and in lowering the cost of production. With the facilities available in the Ceramic Laboratories many problems can be attacked which could not be worked out in industrial plants without seriously interfering with regular output.

In August 1923, Mr. L. P. Collin, ceramic engineer, was appointed to the Division. During 1924 he will devote the summer months to studying the cost of burning brick at a number of Canadian plants and endeavour to determine in what manner the greatest saving may be effected.

Work was continued on the investigation of road materials adjacent to the main highways of the country and a study was made of existing gravel roads in Ontario and Quebec for the purpose of establishing what properties of a gravel control its usefulness as a road material, particularly with regard to that very common fault of gravel roads known as corrugated cr "washboard" surface.

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I

INVESTIGATION OF CERAMIC INDUSTRY

Howells Fréchette

During 1923 the field work carried on was of a general nature. Many brick plants, from Quebec to the Pacific, were visited to ascertain in what way the activities of the Division should be directed so as best to aid and advance these clayworking industries.

In Ontario and Quebec industrial conditions, so far as the brick business is concerned, were found to be far better than elsewhere in Canada, though the production for the year was below that of 1922. It will probably be several years before the building trades have become sufficiently stabilized to bring the brick production up to pre-war levels, even in the eastern part of Canada. In western Canada very little construction is going on.

During the war period production fell to about one-third that of the previous high level year (1912). In 1919 it rose and continued to do so in 1920. Since then it has fluctuated.

VALUE OF CLAY PRODUCTS PRODUCED IN CANADA

1910	$ 7,629,956	1915	$ 3,914,488	1920	$ 10,664,929
1911	8,359,933	1916	4,120,805	1921	8,857,818
1912	10,575,869	1917	4,779,038	1922	11,438,456
1913	9,504,314	1918	4,583,489	1923	10,258,712
1914	6,871,957	1919	7,906,366		

Though the total value of clay products reached $11,438,456 in 1922 as compared with $10,575,869 in 1912, the quantity production was considerably lower than in 1912; the higher prices prevailing in recent years accounting for the apparent discrepancy.

One notable feature brought out by the statistics covering the period since the outbreak of the war has been the marked rise and fall in the production of farm tile. From 1916 to 1919 there was a very rapid rise in production from $359,387 to $616,510. This was followed by as rapid a decline during the ensuing three years, the production falling to $407,386 in 1922 and remaining about the same in 1923. The rapid rise in production corresponded with the rise in the price of farm produce and took place at a time when all other branches of the clay industry were at the lowest ebb. With the fall of farm produce prices the demand for drain tile fell rapidly.

II

EXHIBIT FOR THE BRITISH EMPIRE EXHIBITION

At the request of the Canadian Government Exhibition Commission an exhibit of Canadian ceramic products was assembled for the British Empire Exhibition. Thanks are due to many manufacturers for contributions to this exhibit, which embraces practically all the various types and colour range of brick produced in the country, structural and drain tile, sewer pipe and other salt-glazed ware, firebrick, stoneware, pottery, electrical porcelain, sanitary ware, enamelled iron, and glass of various kinds. This exhibit will illustrate very comprehensively the classes of ceramic products made in Canada.

In recent years there have been several new lines of ware manufactured. The following table shows the fairly wide range now covered by the ceramic industry in this country:

Common Brick	Clay Brick	Red Buff
	Sand-Lime Brick	Grey Coloured
Face Brick	Plastic Process (various textures)	Red Buff Flashed
	Dry Press	Red Buff Flashed Enamelled
Common Clay Ware	Hollow Building Tile	Wall and Partition Tile, Fireproofing, etc.
	Farm Drain Tile	
	Flower Pots	
Vitrified and Semi-Vitrified Clay Ware	Unglazed	Flue Lining Chimney Pots Sewer Brick Floor Tile Roofing Tile
	Salt-Glazed	Sewer Pipe Segmental Sewer Pipe Conduits Wall Coping, etc.
Pottery	Domestic	Stoneware Rockingham, Cainware, etc.
	Art	Unglazed Glazed
Whiteware	Electrical Porcelain	High Tension Low Tension Electric Stove Disks
	Table Ware C.C. Sanitary Ware Floor Tile (Ceramic Mosaic)	White Coloured Non-slip
Refractories	Fire Clay	Brick Locomotive Blocks Special Shapes
	Silica	Brick Special Shapes
	Magnesia	Dead Burned Magnesite Magnesite Brick
Refractory Raw Materials	Fire Clay Quartzite Magnesite Chromite Carborundum and other Refractory Products of the Electric Furnace	
Glass	Blown and Pressed	Bottles, etc. Illuminating Glassware, etc. Table Ware
	Rolled	Window Glass
Enamelled Ware	On Sheet Iron	Wide Range of Ware
	On Cast Iron	Sanitary Ware

III

LABORATORY INVESTIGATIONS

During the year 114 samples of clay and shale were tested to determine their suitability for ceramic purposes. These samples were submitted for testing by officers of the Department of Mines; the Quebec Bureau of Mines; the Department of Colonization and Development of the Canadian Pacific Railway Company; and by individuals.

The results of the tests on certain of these samples are given below, as they furnish data on clays in various districts which had not been previously covered.

British Columbia—

A sample of light buff, calcareous, silty clay was secured by Mr. Henri Gauthier, of the Mines Branch, at a point one mile below Vermilion Crossing on the Vermilion river near the Castle-Windermere road. When tempered with 37% water it is fairly tough and plastic but becomes flabby and sticky with an excess of water. It would make good drain tile and common brick. When fired to 1900° F. the body is fairly hard and strong and light salmon coloured. It softens and deforms at 2200° F.

Three samples of light grey, non-calcareous clay were collected by Mr. Harlan I. Smith of the Victoria Memorial Museum, on the coast of British Columbia.

Sample No. 1 from lot 43, South Bentinck arm, was rather soft and fairly plastic when tempered with 28% water. It would produce common brick by the soft mud process and might possibly be used for wire cut brick. It has a drying shrinkage of 6·3% and a fire shrinkage of 1% when burned to 1740° F. Burned to this temperature the brick is light red, fairly hard, and has an absorption of 18·5%. When burned to 2000° F. it becomes brownish red, steel hard, and has an absorption of 8%. It softens at cone 2 (2138° F.).

Sample No. 2 was taken from the east bank of the river which empties into Green bay, opposite or north of South Bentinck arm, 1½ miles from its mouth. It is fairly plastic when tempered with 22% water and dries with a shrinkage of 4%. It is suitable for making drain tile or stiff mud brick. When burned to 1886° F. it is light red, sound, and quite hard and shows no fire shrinkage. It has an absorption of 15%. It becomes steel hard and dark red when burned to 2000° F. It shows a fire shrinkage of 4·6% and an absorption of 6·7%.

Sample No. 3, taken from the west side of Neklitkonnei river, 735 feet north of the bridge at Bella Coola, is quite plastic, though somewhat sticky when tempered with 25% water. It has a drying shrinkage of 6% and cracks badly even with very careful drying. It would require the addition of a considerable percentage of sand to make it suitable for the manufacture of brick.

Mr. John D. Galloway, Resident Engineer, British Columbia Department of Mines, Hazelton, B.C., submitted the following samples. One from Burns lake, apparently a glacial clay. When dry it was light yellowish grey and required 23% of water to bring it to best working condition.

It possessed fair plasticity, but, being silty, was not very strong. It would make common brick and possibly field tile. When burned to 1886° F. briquettes were found to be strong, hard and sound and of a fine light red colour.

A sample taken from a bed ten to fifteen feet thick in Kispiox valley, was a dark grey, non-calcareous, silty clay. When tempered with 45% water it is rather flabby and sticky and would require to be mixed with about 25% of sand to make soft mud brick. It burns to a light red at 1900° F. A similar sample from the same locality was found to contain small patches of vivianite (hydrated phosphate of iron).

Alberta—

A calcareous, grey clay, from sec. 36, tp. 99, range 8, W. of 4th meridian was submitted by Mr. S. C. Ells of the Mines Branch. When tempered with 21% water its plasticity was only fair. It would probably be suitable only for the production of soft mud brick. It is hard and has a buff colour when burned to 1750° F., and becomes steel hard and reddish brown when burned to 1886° F. The appearance of the brick is marred by a bad scum due to soluble salts in the clay.

Dr. G. S. Hume of the Geological Survey submitted three samples collected along the Athabaska river from ten to forty-five miles below McMurray. These are all semi-refractory clays, softening at about 2700° F., and could be used for stove linings and like refractory purposes where very high temperatures are not involved. They have long vitrification ranges, becoming semi-vitrified at about 1800° F. They burn to a dense, hard, cream-coloured body at 1650° F. and would make good brick were it not for their poor colour and the difficulty with which they dry.

Several laboratory investigations were made at the request of producers on samples of their raw materials with the object of overcoming certain troubles that they were having in their plants. Glazes were formulated for an electrical porcelain firm and advice furnished in connexion with their methods of setting and burning the ware.

IV

TUNNEL KILNS

L. P. Collin

Investigations, carried on in the United States during the war, with a view to conserving fuel, brought out the fact that there is great waste in most of the methods of utilizing fuel in the ceramic industries. This, with the greatly increased price of fuel and labour, has given an impetus to the development and introduction of more efficient kilns for firing ceramic ware.

The most efficient type of burning equipment used at the present time is the railroad tunnel kiln. The fuel-saving in these kilns, over intermittent types, is between fifty and eighty-five per cent[1]; and labour costs are, in many cases, cut in half.

Tunnel kilns in general are simply long tunnels, through which the ware passes on cars. As the ware slowly progresses through the tunnel it is subjected to increasingly higher temperatures until, about half way through, it reaches the zone of maximum temperature. From this point to the exit the temperature gradually drops. The fire boxes are placed on either side of the kiln, their position fixing the location and length of the high temperature zone. The preheating and cooling zones are controlled by various systems of ducts, dampers and fans.

Advantages and Disadvantages—

Aside from the saving in fuel and labour there are other advantages claimed for the tunnel kiln. The ware is burned with much more uniformity because the temperature is readily controlled. Working conditions are better and plants are cleaner. The average burning and cooling time in tunnel kilns is about four days and in periodic kilns about twelve days.

There are three points about tunnel kilns which may be regarded as disadvantages. One is the high initial cost. Another is the necessity for continuous operation throughout the year. The third is the liability to shutdowns, caused by displacement of the ware. The last, however, may be largely controlled by carefulness on the part of the kiln operators.

[1] Journal Am. Ceramic Soc. Vol. III, pp. 460-475; 706-711; 752.

The following table gives the number of tunnel kilns that were in use in the United States in June 1923[1]:

Kind of Ware	Tunnel Kiln Companies						
	Didier March	Owens	Russell	Harrop	Dressler	Misc.	Total
Vitreous china		1		2			3
Semi-porcelain		3		4	2		9
Sanitary ware			6	3	4		13
Cooking and art					1		1
Stoneware				1	1		2
Refractories	2				3	1	6
Floor and wall tile		4		3	5		12
Terra cotta					1		1
Brick and tile		5		2	6	2	15
Drain tile					1		1
Roofing tile			1	1			2
Elect. porcelain	1			2	3	2	8
Carbon electrodes	1	1	1				3
Abrasives					1		1
Specialties	3						3
Total	7	14	8	18	28	5	80

Since this table was compiled at least ten new installations have been contracted for to April 1924, or, according to some reports, double that number. This, in conjunction with the fact that there were only three tunnel kilns in use in the United States in 1915, illustrates the rapidly increasing popularity of this form of kiln.

There are at present only two plants in Canada with tunnel kiln installations. Considering the high cost of fuel it would seem that from the fuel-saving standpoint alone, the tunnel kiln deserves careful consideration by ceramic manufacturers. The high initial cost and the problem of continuous operation throughout the year are hindering factors. Capital can be secured by most manufacturers who have sufficient output to profit by the tunnel kiln and the saving in operation may be counted upon to more than meet the interest charges. The item of all year operation was discussed by Professor Worcester, of the University of Saskatchewan, at the meeting of the National Brick Manufacturers Association, in Cincinnati, January 1924.[2] This problem does not seem to offer the great difficulties so generally imagined, although it involves the necessity of having tunnel driers, and, in some cases, provision for storing large quantities of raw material for use during the winter months.

The advantages of the tunnel kiln certainly seem to outweigh the disadvantages and its more general use in Canada may be expected.

[1] Ceramic Industry, July 1923, p. 84.
[2] The Clayworker, March, 1924, p. 230.

V

INVESTIGATIONS OF ROAD MATERIALS IN ONTARIO AND QUEBEC

Henri Gauthier

During the past field season the writer reviewed the present condition of the improved roads built in recent years in the provinces of Ontario and Quebec, with the object of comparing the relative merits of the various materials used in them and to determine the reliability of the several tests on these materials.

Reference has often been made to the need of research work on subjects in which highway engineers are not agreed, such as, for example, the cause of so-called "washboard" or corrugations in gravel road surfaces, and their relation to varying conditions of traffic. As the gravel road is today the prevailing type of road construction and is likely to be so for some time, it was thought that our first study of road condition and of the materials used in their construction should be made on gravel road surfaces.

From June to October the writer examined about 400 miles of gravel roads in Ontario and 600 miles in Quebec.

An examination was made of the present condition of these roads and of the manner in which they are wearing. Comparison was made of these conditions in their relation to the character of the material used, the nature of the soil, the topography of the country and the amount of maintenance they have been given in comparison with the traffic passing over them.

More than 200 samples of the material used in these roads were collected and, later, tested in the Road Materials Laboratory of the Mines Branch. These samples were collected from the road surfaces along the visited routes, wherever a different material had been used or where a sudden change in the road condition occurred, either caused by a variation in the nature of the material or in local conditions. In all cases they represent the average character of the material that has been used in the construction or maintenance of one section of the road, where its condition was carefully noted for comparison with the results of tests.

The roads studied were:—In Ontario, the Montreal-Toronto highway, the Toronto-Windsor highway, the St. Thomas-Windsor highway, the London-Stratford highway, the Barrie-Orillia highway, the Ottawa-Kingston highway, the Ottawa-Pembroke highway; in Quebec they were: the Levis-Rimouski highway, the Rivière-du-Loup-Edmundston highway, the Levis-Jackman highway, the Sherbrooke-Valley Junction highway, the Sherbrooke-Beauceville highway, the Sherbrooke-Derby Line highway, the Sherbrooke-Coaticook highway, the Montreal-Sherbrooke highway, the Sherbrooke-Richmond highway, the Montreal-Sorel highway, the Montreal-Mont Laurier highway, the Three Rivers-Grand'Mère and miscellaneous county roads.

The financial difficulty of keeping up with the demand for good roads, resulting from the increased use of motor vehicles, is responsible for the increasing use of gravel as road surfacing material. According to the Chief Engineer of Iowa, and his figures are probably applicable to Ontario and Quebec, the use of Iowa roads is increasing 11 times as fast as is the revenue for keeping them in proper condition.

No one will contest the statement, today, that the older waterbound macadam built of crushed field stone or soft limestone, which happens to be the most available rock in Ontario and Quebec, will not stand automobile traffic. It has failed wherever the surface is not protected with bituminous top.

The Chief Commissioner of Canadian Highways reports that 62% of all road projects placed under agreement during the fiscal year 1921–22, for federal aid, were gravel construction, compared with 2·9% for waterbound macadam. For 1922–1923 they represent 40% to 2·7% for waterbound macadam and 15·3% for more permanent kinds of construction. The U.S. Bureau of Public Roads figures applying to 25,000 miles of federal aid roads in use in 1923 show that the gravel roads lead by far all other types in relative road mileage, being 39%.

The patrol system of maintenance is becoming more general on the main highways. Patching and dragging are done as defects appear, but the conditions observed during our survey prove that, even if properly maintained, gravel roads will not provide for a traffic of over 300 vehicles per day, unless great care is exercised in the selection of the gravel for both construction and maintenance. With a traffic of over 500 vehicles per day it is doubtful if, even with the best gravel and a very efficient patrol maintenance system, the road can be kept in good condition with fast motor traffic, unless some artificial binder is used.

The Maintenance Division records for 1922 of the State of Kentucky show that although the initial cost of gravel road is $19,000 per mile compared with $36,000 for concrete and bituminous concrete, the ultimate cost per mile including construction and maintenance for a period of 15 years, are, respectively, $25,000 and $41,000 per mile. These figures interpreted in terms of capacity to withstand traffic, (2,000 vehicles per day for concrete and 500 for gravel) expressed as cost per vehicle mile per year are $50 for gravel and $20 for concrete or bituminous concrete. Conclusions from the results of tests made on roads in good condition in the States of Washington, Oregon and California are that on gravel or macadam the gasoline consumption is from 10 to 35% greater than on bituminous or cement concrete roads, and on poorly maintained gravel roads the difference would be much greater.

RESULTS OF GRAVEL ROADS INSPECTION IN ONTARIO

Montreal-Toronto Highway

About 70 miles of gravel road surfaces, most of which have been in use for several years, were examined on this highway between Deseronto and Belleville, and between Trenton and Oshawa.

The country traversed by the highway is partly flat and partly rolling and is underlain by both sandy and clayey subsoils. The traffic is heavy, especially near the larger towns, Belleville, Trenton, Cobourg, Port Hope, Bowmanville, and Oshawa. The Ontario traffic census, taken in 1922 from August 30th to September 5th inclusive, gives the following figures for average daily traffic. East of Belleville, 641 vehicles, west of Belleville, 1,048 vehicles, immediately west of Brighton, 550 vehicles, west of Welcome, 821 vehicles, nearly all automobiles. These numbers were probably greater in 1923.

A considerable number of the road surfaces examined had been treated with calcium chloride and were found to be in much better condition than the untreated surfaces. As a whole the road was found to be in good repair, considering the traffic it has to withstand. From Deseronto to Marysville, where gravel similar in character to sample 837 collected from the Provincial Department of Highways' pit, has been used, good results are obtained from calcium chloride treatment. The road surface is well bound, a little coarse but only slightly corrugated. Between Marysville and Shannonville finer gravel is used for maintenance. The road, there, was found to be well dragged, with very few loose pebbles except on the sides, but in several places some corrugating was seen, even where calcium chloride had been applied. Sample 826 is representative of the gravel used.

West of Trenton coarse gravel, carrying oversized pebbles up to 6 inches, has produced a very rough surface. A thin coat of about 2 inches of fine gravel like sample 831, had been put on a similar coarse and uneven worn surface in the wheel tracks. Near Brighton, the use of coarse gravel has also resulted in a well bound but uneven surface. A few miles west of Brighton, sandy gravel, sample 833, is used for maintenance. Corrugating is seen there, too.

West of Colborne, to Grafton, corrugating is prevalent where the road has not been re-surfaced for some time. Sample No. 823 represents the gravel used for repair. It is well graded and gives good results.

From Grafton to Port Hope the road was found to be in better condition. The older surfaces are wearing somewhat uneven and rough but the newer surfaces, though apparently slow to pack, do not become corrugated. Sample 832 shows that the material used lacks binder but that it is well graded and contains the proper proportion of coarse sand.

Between Port Hope and Bowmanville corrugating is prevalent. Even where calcium chloride has been used it occurs to some extent. Samples Nos. 830 and 829, collected east of Clarke and east of Newcastle, respectively, are from corrugated surfaces. Gravel like sample 828 is giving good results. Road surfaces built of such gravel wear dusty and rather uneven but do not become rutted, ravelled or corrugated.

Near Oshawa, where the traffic is more than 1,000 vehicles per day, the surface is very dusty and ravelled. Representative sample 827 was collected east of Courtice.

Most of the samples taken along this road are largely composed of rounded fresh limestone pebbles, which have good wearing quality but are not tough. With a lighter traffic they would probably give good service. They do not contain, as a rule, oversized material and where they have not an excess of sand produce a dusty but fairly even wearing surface.

Toronto-Windsor Highway

On the Toronto-Windsor highway, *via* Brantford, London and Chatham, gravel road sections are found between Brantford and Woodstock, between Ingersoll and London, and from Lambeth to Maidstone, totalling approximately 120 miles in length. The traffic passing over most of them is heavy. The average daily traffic in 1922, east of Woodstock, was 704 vehicles per day, mostly motor cars, at Crumlin east of London, 935 vehicles per day, east of Wardsville, 732 vehicles per day. Between Chatham and Maidstone, however, it is much lighter.

Good gravel roads were seen, especially west of Paris and west of Ingersoll, samples 821 and 770. Coarse gravel, largely composed of fairly durable limestone which is available at Paris, has produced a well bound but rough wearing surface between Paris and Brantford. It will make a good foundation for future concrete pavement.

West of Lambeth to Delaware good maintenance is obtained by the use of material like samples Nos. 780 and 781. Between Christiana and Melbourne a 7-year-old gravel surface is being re-covered with gravel from Middlemiss, represented by sample No. 779. A 2-inch coat of that material is applied and, although not pronounced, corrugating has begun. The whole road from Melbourne to Wardsville was given a 2-inch re-covering in the fall of 1922. Corrugating is prevalent, especially between Ekfrid and Wardsville. Gravel similar in character to sample 778, collected from a pit by the road 5 miles east of Wardsville, has been used. Such material packs well but becomes corrugated under heavy traffic. Between Wardsville and Chatham the older surfaces, whether on sandy or clayey subsoil, are from moderately to decidedly corrugated, especially near the towns. Sample 773, collected 2 miles west of Kent Bridge, represents the average character of the gravel used for maintenance.

From Chatham to Maidstone the road is comparatively new. On the greater part of it the new clayey subgrade had had only one or two, apparently thin, applications of gravel, put on in 1921 and 1922. This gravel has packed hard into the clay. Ruts and holes have formed in places but, in general, the road presents smooth wheel tracks. These become dusty in dry weather, but where the road had been dragged after rain, it was found in good condition. A new layer from 4 to 6 inches thick was laid down last summer east of Maidstone and between Comber and Ruscom. Samples 810, 815, 816 and 817, collected in these localities, show that the material used is fairly uniform. The percentage of sand in these samples is high but the sand is coarse.

The gravel used in new construction west of Ringold, sample 818, packs well on a clay subgrade but produces a rough surface with ruts which are hard to drag without displacing the coarser pebbles.

It will be noted that most of the samples collected along this highway show that the gravels are fairly durable. They compare favourably with the limestone gravels collected on the Montreal-Toronto highway as regards percentage of wear and are tougher, except those containing a large proportion of weathered pebbles.

St. Thomas-Windsor Highway

More than a hundred miles of gravel roads were examined along this highway between St. Thomas and Maidstone.

The traffic is very heavy, especially over the western part, from Blenheim to Windsor, as it absorbs much of the through traffic of the London-Windsor road via Chatham, owing to sections of that road being under construction, east of Maidstone. The Ontario traffic census of 1922, gives 686 vehicles per day, mostly motor cars, at Maidstone, 735 vehicles per day south of Cottam, and 948 vehicles per day at Cedar Springs.

Between Blenheim and St. Thomas the average daily traffic recorded in 1922 ranged from 236 to 430 vehicles.

Very good gravel surfaces were seen along this highway. Corrugated surfaces were observed, but they are not prevalent, and, as a whole, the road was found to be in good condition.

In the neighbourhood of St. Thomas, the roads are good. Corrugated surfaces, however, were seen east of that town, at New Sarum. Sample 775, collected there, shows that the gravel used in that locality contains much fine sand. The road south of St. Thomas, to the summer resort at Port Stanley, which carries heavy traffic, presented a hard, well bound surface, wearing somewhat rough and dusty but not corrugated. Oil and calcium chloride have been used as dust preventive on some sections of this road and these sections were found to be in much better condition than the rest. Samples 784 and 783, collected north and south of Unionville, respectively, show that the gravel used is well graded and largely composed of limestone.

West of St. Thomas, from Talbotville to Clearville, the road was in good condition. Fine gravel of good wearing quality, applied in thin coats (4″), is used for maintenance. Samples Nos. 776, 786, 777 and 785, collected west of Wallacetown, show the character of the gravels being used. These gravels contain a large amount of sand but the sand is fairly coarse and the pebbles largely composed of limestone with good wearing and binding qualities. Very little corrugated surface was noticed on these sections.

Sample 792 taken west of Clearville is from a corrugated wearing surface. It contains an excess of sand.

Very good results are obtained near Morpeth from the use of gravel like sample 800, collected from the pit where the gravel was obtained. This gravel is well graded and cements well, owing to the presence of a lime carbonate coating on the pebbles. Applied in thin layers in 1920, 1921, and 1922, it has produced well cemented smooth wearing surfaces.

Corrugated surfaces were observed west of Guild. The surfaces were apparently built of material similar to sample 802, taken near the town, where a new coat 3″ thick had lately been put on. This gravel packs fast but corrugations soon form. It is fairly well graded but contains too much sand.

Near Blenheim, sandy but apparently much coarser gravel than that near Guild was used. The road has had four coats of gravel: one in 1920, one in 1921, and two in 1922; the last one (3″ thick), after the surface had been graded. The road surface is well packed, but wears rough, with loose coarse pebbles in the middle of the road. Representative samples were collected from pits near Blenheim, where gravel for road work was obtained. Sample 808, largely composed of weathered material and containing much sand, is representative of the bank run of a pit on the Ridgetown road, just northeast of Blenheim, where the road apparently built of similar gravel, is wearing rough, rutted, and very dusty.

Hard, well bound surfaces were seen on the road just north of Blenheim, leading to Chatham. These showed no loose pebbles except at the edges but were wearing into a rough surface with oversized pebbles protruding. Sample 807, taken where a new covering had lately been put on, shows the character of the gravel used for maintenance. It was noticed that this sandy gravel is either forced out of the wheel tracks by traffic or becomes corrugated shortly after its application.

From Blenheim westward to Cedar Springs, the road, gravelled in 1920 and re-coated in 1921, needed re-covering. The surface was firm but worn rough, with holes.

Near Cedar Springs fairly good sections were seen. In places, however, holes and depressions have formed, apparently from lack of drainage. Sample 799 is representative of the material used.

Lake gravel samples 791 and 812, collected between Cedar Springs and Dealtown, and sample 805, collected west of Dealtown, are from corrugated sections. These sections were built in 1920 and re-coated in 1921. The samples show an excess of sand.

Between Port Alma and Romney the road has had three coats of gravel, applied in 1920, 1921 and 1922. The surfaces are fairly good. In places, however, they are slightly rutted or corrugated. Sample 809 was collected from one of the pits used and sample 814 from the road surface at a point where a new layer, 3″ thick, had been applied this year. These gravels also contain a high percentage of fine sand but they are largely composed of soft pebbles of good cementing value. This may account for a smaller amount of corrugated surface than near Dealtown, where the gravels were composed of durable pebbles.

From Romney to Wheatley light coats of gravel were put on in 1920 and 1921. The road was graded and re-gravelled in 1922. Pit gravel represented by sample 813 was used in 1920 and 1921, and lake gravel, represented by sample 806 collected from the road surface east of Wheatley, was used in 1922. These gravels have produced smooth surfaces which tend to rut or pit but do not become corrugated. It will be noted that they do not contain over 55% sand, that they are largely composed of pebbles of good cementing properties and that they contain a large percentage of soft material.

Good surfaces were seen between Wheatley and Leamington. They were very slightly corrugated. These were built in 1920, re-coated in 1921 with lake gravel, and in 1922, after the road had been graded, with Olinda pit gravel. A thin coat was applied in each case.

East and west of Leamington very good gravel surfaces were seen, especially where calcium chloride had been used. These were cemented smooth with hardly any corrugations in spite of the fact that they are built of sandy gravels. Samples 796 and 797 are representative of the gravel used. Between Ruthven and Olinda, a section which had a light application of calcium chloride in 1922 and which was later on re-graded and re-gravelled showed in 1923 a better bond than the untreated sections.

The use of gravel like sample 803, collected east of Essex, where the traffic is heavy, has resulted in the formation of a rough, uneven, and corrugated road surface. Such gravel packs but does not bind and corrugations form under fast traffic. Similar gravels, samples 793, 794, 798, were collected from roads with a much lighter traffic, probably not over 300 vehicles per day, on which the surfaces were in much better condition.

London-St. Mary's-Stratford Highway

The traffic just north of London is very heavy; according to the Ontario traffic census for 1922, 940 vehicles per day, largely motor cars. Near St. Marys, it is between 300 and 400 vehicles per day, and south of Stratford, over 600 per day. North of London, limestone gravel, similar to sample 838 and of good wearing quality, was used. This gravel binds well but under heavy traffic wears very dusty. Along this road, which is well dragged, dust and loose pebbles were observed all the way from London to Elginfield but very little corrugated surface. Considering the amount of traffic, it was in very fair condition.

From Elginfield to Stratford, coarse limestone gravels with a low sand content have been generally used. The material has bound in the wheel tracks but has worn very dusty. Outside the tracks, this gravel, owing to its poor grading, is either loose or packed into a very rough and uneven surface. Much stone, coarser than the maximum size contained in the samples collected, is of common occurrence in these roads. In many localities ridges of this coarse material were seen in the centre of the road, where they had been brought by the dragging operations.

London-Sarnia Highway

One sample, No. 772, largely composed of limestone, with 30% of soft material and containing an excess of sand, was collected near Poplar Hill on the London-Sarnia highway. Similar material, apparently, has been used for many miles west of London and the road is in about the same condition all the way to Adelaide. The traffic is very heavy and the road surface dusty and corrugated. Much loose fine material is seen at the sides of the road and coarse stones form knobs on the wearing surface.

Toronto-Barrie-Orillia Highway

This road is built of gravel from Fennell to Orillia, a distance of approximately 40 miles. The traffic over the gravelled portion of the highway is not as heavy as over the more permanent kinds of road surface between Toronto and Fennell. The 1922 census figure for average traffic at Holland Landing, a few miles south of the gravel sections, is 723 vehicles, mostly motor cars. Over the gravel sections the figures are as follows: 591 vehicles north of Stroud, and 439 vehicles just south of Barrie. Between Barrie and Orillia the traffic last summer was probably from 400 to 500 vehicles per day.

Good gravel roads were seen on this highway, especially between Barrie and Orillia.

From Fennell to Stroud the road is not quite so good. The sections which had not been re-covered lately showed a hard bound, but rather rough and dusty surface, with pronounced ruts. However, these surfaces were not ravelled nor corrugated. They are built of gravel, largely composed of limestone. Sample 766, taken north of Barclay, where a new layer had just been put on, shows the character of the material being used for maintenance. This fine gravel binds well, but wheel tracks soon form, and it becomes dusty, and tends to rut.

Well bound and smooth wearing surfaces were seen south of Allandale. They were built in 1922, of gravel from Allandale where sample 768 was collected.

Just north of Barrie, sections built, in 1920 and 1921, with gravel from the Dunsmore pit, sample 767, were found to be in very good condition. The surface on these well maintained sections is cemented and wearing smooth.

Farther north, most of the road, built in 1921 and 1922, is wearing dusty but evenly. Certain sections, however, where coarser gravel had been used in the wearing surface, were found to be rougher. Such a section was observed south of East Oro. It was built in 1921, of gravel from the Shaw pit, where sample 769 was taken.

Samples 763 and 764 show the average character of the material used for maintenance.

Sections built in 1921 and 1922, south of Orillia, were found to be in good condition. The surfaces are dusty and much loose fine gravel is seen at the sides, but they have not worn rough or become corrugated. Samples 761 and 762 were collected from the roadbed. These gravels are well graded.

Ottawa-Pembroke Highway

The traffic over this road, which is under construction, is not very heavy. It may reach 400 vehicles per day in the vicinity of Arnprior, Renfrew and Pembroke, but is light elsewhere.

The gravelling is completed over approximately 80 miles, the greater part of which was done a year or two ago. Older surfaces, which have been in use for a few years, are found between Arnprior and the junction of the road with the Ottawa-Kingston highway near Stittsville. These surfaces, built on clay subsoil, are, as a rule, bound but rough and rutted.

The gravel used is generally coarse, largely made up of apparently soft limestone, with comparatively little sand. Such soft limestone gravels, where properly graded, like sample 392 collected in a pit west of Braeside, on the road from Arnprior to Goshen, produce a well cemented surface but one that wears quickly into ruts. Near Arnprior and Renfrew, gravels largely composed of igneous rocks and of better wearing quality are being used. (Samples 840, 841, 842, 843, and 844.) Where these gravels do not contain an excess of sand nor too many pebbles over 2″ in size, a firm and fairly even surface is obtained. The gravels used east of Pembroke, in the newly constructed roads, are of soft material mostly and contain large percentages of fine sand. They pack very slowly and where they were packed in the wheel tracks, were dusty and showed much wear. (Samples 845 and 846.) It is doubtful if these gravels would give good service under heavy traffic.

Ottawa-Kingston Highway

This road is under construction. Two samples were taken north of Joyceville and between Morton and Elgin, to show the character of the gravel being used. Samples 835 and 824, taken east of Ashton, are from road surfaces that have been in use for some time. The automobile traffic is rather light where the first two samples were taken. East of Ashton it may reach 400 vehicles per day.

Ottawa-Point Fortune Highway

A good gravel road was built in 1922 between Hawkesbury and Point Fortune. Very good results were obtained from the use of crushed gravel (sample 839) as surfacing material. The traffic over this road is light, however, being slightly over 200 vehicles per day at L'Orignal and Point Fortune.

GRAVEL ROADS INSPECTION IN QUEBEC

Levis-Rimouski Highway

The total distance between these two towns is 188 miles by road, of which 120 miles is completed. This is practically all gravel road. The average traffic is 361 vehicles per day, 45% of which are horse drawn.

The road was visited at the beginning of August. Seventeen samples were collected which do not vary much in the composition of the pebbles. Most of them are composed of sandstone and shale. In eight of the samples the percentage of soft rock, weathered or friable, or thin brittle slabs, ranges from 50% to 100%. Only one sample contains good, hard and sound, durable rock. The road surfaces obtained by the use of these soft aggregates are fairly smooth, shortly after the gravels have been laid. The material crumbles under traffic and packs into fairly smooth wheel tracks but soon wears and the road becomes very dusty, rutted and uneven. Most of this road is in fairly good condition, owing to the comparatively low motor car traffic. With a heavy traffic it would require constant re-covering and dragging.

The grading in size of the gravels varies. The average proportion of sand to pebble is 62% sand to 38% pebble. Seven samples showed a sand content of 60% and over, to 87%. As a rule, the road surfaces from which these samples were obtained were wearing in corrugations. Samples containing pebbles over $1\frac{1}{2}$ inches in size were from rough, unevenly wearing surfaces. The amount of binder in all of these samples was found to be small, but, on account of the angular shape and soft character of the pebbles, a fairly good bond existed in most of the sections of this road. The general character of the material passing the 200-mesh sieve is reddish brown rock powder.

Rivière du Loup-Edmundston Highway

This road was visited in the second week of August, when an opportunity was afforded to see it both before and immediately after a heavy rain. The average traffic is heavier than on the Levis-Rimouski highway, being 545 vehicles a day, but is of the same type, with 302 motor vehicles or 55%. The entire length of the road, 67 miles, is surfaced with gravel and was from one to four years old when visited, as it was completed in 1922. As a whole the road surface was found to be in good condition both before and after rain, with the exception of a few miles south of Rivière du Loup, but in short sections corrugations were noticed. An examination of the tables will show that out of the thirteen samples collected, only four have a sand content over 60%, and that the average sand proportion is about 55%. There is no great variation in the grading of the sands. The results of analysis show that most of these gravels are largely composed of soft aggregate, mostly shale, which packs and produces a well bound even surface but apparently wears fast with a tendency to become rutted.

The better bond of these gravels over the gravels between Levis and Rimouski is not due to their higher binder content so much as to the soft character of their aggregate. It may be noted that three out of the four samples containing over 60% sand were from surfaces that were wearing in corrugations.

Levis-Jackman Highway

This highway is a striking example of gravel road which, although well built and properly maintained, is unable to withstand the traffic using it. The road is 94 miles long, 10 miles of which, south of Levis, is treated with bitumen. The average traffic from September 1st to 7th, was 745 vehicles per day, 66% being fast motor car traffic. This road which is from 5 to 6 years old, particularly between Levis and Beauceville is wearing in corrugations, with much dust and loose pebbles. The character of the twelve samples collected does not vary greatly in grading. The average sand content is over 62%. Six samples carried from 62 to 86% sand, and five of these were from corrugated surfaces. It may also be noted that these sands carried a large percentage of material passing the 14-mesh sieve. Few of these gravels contain large pebbles, most of them carrying none or only a small percentage over 1 inch in size.

As the road, since its completion, has received several re-coverings, the samples collected represent the gravels used for maintenance. Three samples collected in 1919, shortly after its construction, at about the same point where samples 928 and 929 were taken, showed that the material used for building the road, in that section, was composed of over 80% sand which carried a large percentage of 28 and 48-mesh material. It is very likely that the actual base of today's wearing surface is one of hard packed sand through which the action of subsoil moisture or clay could hardly account for the present corrugated condition of the road. Along the southern half of the road, from Beauceville to Maine, apparently, less sandy material was used in the first construction, as can be seen where the road is worn down. There, as a rule, the road surface shows less corrugation or washboarding. The examination of the samples shows that the pebbles do not vary much except in degree of durability.

The amount of binder in all these gravels is low. They are generally composed of rocks that have poor cementing value, and as the amount of weathered pebbles liable to crush under traffic is generally high, this factor may also be contributory to the formation of the corrugations.

Sherbrooke-Valley Junction Highway

This road includes 90 miles of gravelled surface. While part of it has been gravelled for many years, the balance was completed only a few years ago. The average traffic from September 1st to 7th, 1923, is given as 405 vehicles per day, with 274 motor cars or 68%.

The road was examined at the end of August, before and after rain. As a whole it was found to be in good condition. The reason corrugating is not so prevalent on this road as it is on the Levis-Jackman or the Sherbrooke-Derby Line roads, may be attributed to a lighter traffic, the use of gravel of better binding power, and to the topography of the country through which it passes. Corrugations usually form on flat, level roads and seldom occur on grades. Gentle but long grades are of common occurrence along this route. The greater part of it was found to be well dragged.

It should be noted that corrugated surfaces are seen only on sections of road where the traffic is heavier than the average given for this road. The traffic figures given are from a census taken north of East Angus and at Tring Junction. Between East Angus and Sherbrooke and through the asbestos mining district from Black Lake to East Broughton, the traffic is probably over 600 vehicles per day and in these sections corrugated or washboarded surfaces were seen. Samples 973, 974 and 990 are representative of such sections. They show over 60% sand, with a comparatively low binder content.

Gravels like those used north of East Angus, near Marbleton, Weedon, Garthby, and north of Coleraine, and others shown in the tables, largely composed of soft rocks with a high percentage of wear and containing a comparatively high binder content, bind well and produce a smooth surface, which, however, requires frequent dragging and re-covering. The surface soon becomes rutted or wears uneven and rough, with the larger pebbles in relief, especially if the gravels contain high percentages of 1½″ and 2″ pebbles. Along the sections referred to the surfaces did not appear to be so dusty as where the ravelled and corrugated roads were observed. In wet weather they are more muddy, but the powdered material in these gravels not being clayey, the softened surface is not so liable to cut or be picked up by traffic as would a sticky clayey surface.

Sherbrooke-Beauceville Highway

Part of this road was under construction during the summer and for that reason through traffic was light. The gravelling of the entire length, 90 miles, was nearing completion in September. The Quebec census gave as the average daily traffic, 423 vehicles per day. It is much below that figure for most of the route, that is, from Cookshire eastward. The Quebec figures show that at the eastern end near St. Victor, the average daily traffic is slightly over 250 vehicles and is largely horsedrawn. From Cookshire westward to Sherbrooke, the traffic is very heavy, being over 800 vehicles, or, twice the average figure attributed to this road, owing to the branching at Cookshire of the Valley Junction highway from East Angus to Sherbrooke. Here also, ravelling and corrugated surfaces prevailed. The average character of the gravel used in that section is represented by sample No. 927 in the tables. This gravel was composed of fairly tough pebbles but contained a large percentage of sand with little binder. Most of the samples collected along the various sections of this road show that gravel largely composed of soft material and carrying from 60 to 70% sand gives fairly good service under light traffic conditions. With these gravels, where traffic is slightly over 200 vehicles per day, a fairly smooth surface is obtained, which does not ravel and remains even. The horsepath, however, where the traffic keeps to the centre of the road as is usually the case with light traffic, is liable to become loosened. With heavier traffic these surfaces would wear rutted and uneven, with coarse pebbles sticking out of a sandy and dusty surface.

Samples Nos. 925 and 892 are good examples of fine gravel, largely composed of soft material and containing a comparatively high amount of binder, which produces good riding surfaces under light traffic conditions.

Sherbrooke-Derby Line Highway

The road surface condition of this highway is probably the best example encountered during this survey, of the inability of plain gravel to withstand an average daily traffic of from 800 to 1,000 vehicles per day, largely fast motor cars.

The number of cars crossing the line as registered at the customs office at Rock Island, is greater than at any other entrance from the United States. The number for 1923 until September 28th is 36,229 cars, which means a heavy and fast touring-car traffic.

This is not a newly gravelled road, but has had several years of service and has been re-covered several times. The subgrade of this thoroughfare is a well settled and compacted one but even proper maintenance can not keep its wearing surface in good condition in dry weather. Out of about 30 miles of gravelled surfaces probably 20 miles showed pronouncedly corrugated surfaces.

Gravels such as those represented by samples Nos. 959, 960 and 961 in the tables, containing from 44 to 57% sand and very largely composed of soft rock, would probably produce a road surface that could be kept in good repair under light traffic conditions. These gravels bind well, but under heavy traffic wear fast and as they contain a certain amount of material over 1½ inches in size, give a rough uneven surface which soon ravels. Sample No. 960 represents a well graded road surfacing gravel after the pebbles over 2 inches are taken out. Were the pebbles durable, it would be a good road gravel, as it contains sufficient binder.

Samples collected from the corrugated sections of this road do not differ much. They vary to some extent in the composition of the pebbles which, as a rule, are not of soft types, but are composed of stone that has poor cementing value. To show that the excessive amount of fine sand in these gravels is not the result of abrasion by traffic, one sample, No. 964, was collected from a stock pile of screened material being used for recovering. The grading of this sample and that of samples from corrugated sections of this and other roads are very much alike since they all contained over 60% of comparatively fine sand. The results of the analyses may be seen in the tables.

Sherbrooke-Coaticook Highway

No corrugated surface was seen on this road, except on a few miles just south of Lennoxville, where the traffic carried is probably over 470 vehicles per day, which is the average recorded by the Quebec census at Compton, about halfway between the two towns. The table of samples shows that the samples collected in these sections carried respectively 67 and 69% sand and that sample No. 956, in spite of a fairly high binder content, was from a corrugated surface. The results also show that the gravels are composed of fairly durable material, with poor cementing properties.

From north of Compton to near Coaticook the road was found to be in good condition. It presented a high crowned, well compacted surface, wearing with fairly smooth to somewhat uneven wheel tracks.

Fine gravel, like sample No. 955, carrying 80% sand but with a high proportion of fine material passing the 200-mesh sieve, produced a fine smooth surface. If this material had to sustain a heavy traffic, however, it would probably become corrugated or cut. Where the gravel contained pebbles over 1½ inches in size these were seen sticking out of the wheel tracks. The road condition just north of Coaticook is a good example of the fact that gravel (sample No. 952) containing a high proportion of sand but largely composed of soft material will wear uneven, with ruts, even if well bound. Altogether six samples were taken between the two towns, a distance of 20 miles. They do not vary in lithological character, except in the varied amounts of weathered material or shales which they contain.

Montreal-Sherbrooke Highway

This highway includes about 60 miles of gravel road. The greater part of the gravelled surfaces were found in poor condition during August and early in September, but they appeared to be better at the beginning of October. The traffic on this road is a heavy and fast one. The Quebec figures show an average traffic of 832 vehicles per day, the maximum, registered near Sherbrooke, being 1,367, with a minimum of 639. For Waterloo the figures are, respectively, 805 and 455 vehicles per day.

This is a comparatively new road, most sections having been completed from one to two years ago.

Six of the seven samples collected showed quite large percentages of material over 1½ inches in size. The greater part of the road is built of gravel containing a large amount of sand and coarse pebbles, which are raked off the surface every time it is dragged. The writer cannot see the advantage of using this excess of coarse pebbles or boulders which has to be removed afterwards. The use of such material results in the formation of an uneven and rough wearing surface, with the coarser pebbles loosened in the roadbed, especially in the case of a hard aggregate such as that represented by sample No. 949 which does not crumble under traffic. It will be noted that here also corrugating corresponds to high sand content and poor cementing value in the aggregate, and is not dependent on the durability of the pebbles.

Sherbrooke-Richmond Highway

This road is part of the Sherbrooke-Levis highway. The part inspected includes 34 miles of continuous gravelled surface from Sherbrooke northward. Except for perhaps 4 miles north of Sherbrooke, the road to Richmond, a distance of 24 miles, was found to show comparatively newly gravelled surfaces in course of packing. As a rule the surfaces were still loose except in the wheel tracks, where the gravel had packed but evidently was not cementing and was showing pronounced signs of corrugating. The average daily traffic over this road is given as 458 vehicles per day at Comptonville. The gravels used, as shown by the analyses of four samples collected from these non-cementing and corrugated surfaces, do not vary much in character except in the amount of weathered material. They all carry a high proportion of fine sand with little binder and the pebbles are composed of rocks of poor cementing value.

Sample No. 972 taken just north of Sherbrooke appears to be a fairly good road gravel. It is well proportioned and composed of durable material. It contains 50% coarse sand, with 7% passing a 200-mesh sieve. The surface obtained is well bound and, were it not for a small percentage of oversized pebbles, it would be a fairly even and good gravel road. The traffic east of Richmond is much lighter than that southward to Sherbrooke. Material containing 72% sand but with 20% binder has produced, there, a smooth surface which is easily kept in good condition.

Vercheres-Sorel Highway

This section of the Levis-St. Lambert highway, now under construction, includes 20 miles of newly gravelled road. It was visited in September. The gravel used is generally composed of fairly durable material but lacks binder and contains much sand in most cases. The traffic on this road, south of Sorel, was slightly over 200 vehicles per day during the first week of September. As a whole, except near Contrecoeur, where apparently a light application of calcium chloride was used as a trial, the road is packing in wheel tracks but shows that the gravel lacks binding properties. Corrugations were noticed in one place below Contrecoeur and sample No. 943 collected there shows a content of 60% of fine sand, with very little binder. South of Sorel, where less sandy or coarser gravel of a more durable character was laid down, apparently last summer, the surface is packing but ravelling and shows many loose pebbles.

Montreal-Mont Laurier Highway

The part of this projected highway which was inspected early in October, comprised the gravelled section, completed last year, between Ste. Therese and Ste. Agathe, a distance of about 40 miles. The traffic between Ste. Therese and St. Jerome is between 400 and 500 vehicles per day. North of St. Jerome to Ste. Agathe, it is lighter.

The road surface north of St. Therese, represented by sample No. 853, entirely composed of limestone gravel, is a good example of how such gravel wears. It binds well but requires constant dragging to avoid the formation of ruts, and wears like a road built of broken limestone.

The other five samples collected are composed of pebbles from Precambrian rocks. They are generally durable and include only small percentages of soft material. They do not carry an excessive percentage of sand, as a rule, and the sand is coarser than that in the gravels of the Eastern Townships. When upwards of ten per cent of binder is contained, as in the case of sample No. 935, the gravel binds comparatively fast and can be maintained with a traffic of about 500 vehicles per day.

Miscellaneous Roads

What has been said about the gravels sampled on the Mont Laurier road can be applied to the gravels used on the Two Mountains District roads, which nearly all carry a high percentage of igneous rocks. The roads in the parishes of St. Hermas and St. Benoit, which carry a medium traffic showed no sign of corrugating. The gravels from which they were built do not appear to contain an excess of sand, and the sand contained is coarse. The road at La Trappe, Oka, although carrying no heavier traffic and notwithstanding the fact that the gravel used contains more binder, is ravelling much more rapidly. The gravel used there contains 71% sand; see sample No. 850.

The gravel used south of Almaville on the Three Rivers-Grand'Mère road, represented by sample No. 854, although practically entirely composed of tough pebbles of igneous rock and containing a comparatively high percentage of binder and only 30% sand, is a good example indicating that even such gravel is unable to withstand a traffic of over 500 vehicles per day in dry weather, as it ravels rapidly.

Gravel largely composed of soft, weathered dolomite and limestone, with 10% binder, such as sample No. 951, makes a smooth road to drive on, as can be seen at St. Zotique, in Soulanges district, where the traffic is very light, but such material would prove unsuitable for even medium traffic owing to its tendency to produce dust and form ruts.

CONCLUSIONS

It is generally accepted that gravel, to be suitable for road surfacing purposes, should meet the following requirements. The fragments should be so hard and tough as not to disintegrate readily under traffic. They should be so proportioned as to size that the void will be small. They should contain or be mixed with sufficient binding or cementing material to hold them in place.

The hardness or resistance to abrasion and toughness of gravel pebbles vary greatly as is shown by the results of the tests made in this investigation. The cementing value of the rock composing the pebbles may play a part of some importance. Some soft and fast wearing gravel pebbles under the abrasive action of traffic produce a rock powder which will act as a binder. Some siliceous rock pebbles, for instance, may withstand wear better than certain limestone pebbles; but, if these gravels contain the same ratio of sand and binder of similar character, the former will not bind as well as will the latter.

The ability of gravel to compact and wear down into a firm and even surface depends on several factors, including the relative proportion of coarse and fine, the gradation of size in the aggregate so as to produce the maximum density, the absence of unduly large stones, the physical properties of the pebbles and sand particles, and the presence of a satisfactory binder in sufficient quantity.

The Committee on Maintenance of Roads of the Highway Board and Highway Research of the National Research Council of the United States, reports as follows:—

"Corrugations form in all gravel roads when the traffic becomes excessive, probably 500 or 600 vehicles per day. Their formation is in no way dependent upon construction or maintenance methods. Corrugations are most apt to occur on flat grades. They are caused by displacement of the material due to the spin of the drive wheel, and by impact of the wheels, both front and rear, after a bounce."

"On flat grades during rains the depressions collect the water which is splashed out by passing vehicles, carrying out of the corrugations quantities of binder and fine material."

It is true that with a traffic of 500 vehicles or more, nearly all gravel roads are kept in good condition with difficulty, but it was found last summer that all gravels do not wear in the same manner and that corrugations form more readily with certain definite classes of gravel.

The Bureau of Public Roads of the United States found that with certain gravels the formation of waves is more apt to occur, but with other gravels, especially those that bind well, they do not form at all.[1]

[1] Paper on "Tests Roads Experiments" read by J. A. Duchastel, at Good Roads Convention held in Hamilton, 1923.

Our observations of last summer confirm the first part of this statement and it was noted that gravels that contain a high percentage of fine sand, even when they did not lack binding material and without regard to the durability of the pebbles, produced corrugated surfaces under heavy and especially fast traffic.

These corrugations, which are such an annoying fault in gravel roads and which engineers are trying to prevent by various methods of maintenance, are everywhere of the same type. The average length from crest to crest is about thirty inches and the height is from one to one and a half inches. They form on roads built on sandy subsoil as well as on those built on clayey subsoil. They are found on roads where the traffic is spread over the entire width of the roadway and where it is kept to a single track in the centre.

These corrugations were also investigated in the State of Vermont, where tests were made to determine the effect of moisture and clay content on their formation. The summary of the results of these tests is not conclusive. The percentages of moisture and of clay in the various surfaces where corrugations were prevalent and where they were not prevalent are contradictory. The writer is more inclined to believe that the density of the gravel, the grading of the aggregate and its cementing power are the most effective factors.

The Committee on Structural Design of the Highway Research Council reports on the matter of subgrade that "a layer of sand, cinder, broken stone, or other porous material will prevent capillary moisture from rising to the overlying road surfaces, and that when macadam or broken stone bases are used over a heavy clay subgrade it often happens that the clay is forced up through the voids of the stone and renders the broken stone layer much less resistant to loads. A light blanket of sand or similar material interposed between the subgrade and the broken stone is effective in preventing the clay from working up through the overlying stone layer."

As the wearing surface of a gravel road has immediately under it from 6 to 18 inches, or more, of gravel, the moisture and clay have little chance to work their way up from the subsoil to the surface. As a matter of fact none of the large number of samples collected from corrugated gravel surfaces contained an excessive amount of clay and there was no evidence of subsoil moisture having risen to the surface.

The writer's conclusion, after having examined over 900 samples of gravel from all over the country, is that no two deposits are likely to have the same characteristics so far as grading is concerned. The lithological character of the gravels of one locality, however, does not vary much, except in the degree of durability due to variation in weathering or to the various proportions in which rocks of different wearing qualities are present in the aggregate.

Many people believe that gravels which have been produced from igneous rocks by glacial action and which show a large percentage of hard, tough fragments, are better for road building purposes, than certain beach gravels derived from rocks such as limestone, which fractures and wears easily. Stratified rocks are not always inferior to the average igneous rocks for highway work as, under certain light traffic conditions, a comparatively soft gravel may produce, because of its binding properties, a road surface easier of maintenance than one of hard gravel.

The wearing quality of the gravel is sometimes given too much consideration compared with the grading and the binding qualities of the material. Gravels that are too coarse or too sandy are more often responsible for defects in roads than gravels made up of soft constituents. Sand is too generally regarded as a binder in gravel roads and, as a result, gravels carrying between 60 and 70% sand but with little binder are commonly used on them. They finally pack under the loads of traffic, but generally yield corrugated surfaces with fast traffic.

It used to be generally accepted that 15% was the desirable amount of binder in road gravel. Under present traffic conditions road builders think it doubtful if so much binder is advisable. Most gravel, under heavy traffic, will pack in a short time, and an excess of binder, especially of clayey composition, will result in a muddy surface and will pit or cut in wet weather or when the frost is coming out. It is true that one must not be over anxious to have a gravel road bind quickly. It is believed that from 10 to 15% of some binder is necessary, not so much for a quick bond as to curtail the corrugating wear that is evidently more prevalent when the gravel constituents lack cementing properties.

The use of calcium chloride is recommended, not only as a dust preventive but also as a binding agent. It will not prevent the formation of corrugations; but, with properly graded gravels, it will contribute to better bonding.

Sections of gravel roads thus treated, that were observed last summer, showed surfaces free from loose pebbles and were much smoother than adjacent ones built of similar material but untreated. Such roads were seen, for instance, along lake Ontario; west of Leamington; and west of Paris.

This material, aside from cost, has an advantage over light bituminous oil, in that it does not form a crust which interferes with dragging operations in maintenance.

SPECIFICATIONS FOR ROAD GRAVELS

Specifications for road surfacing gravel are not uniform throughout Canada. They usually include a general clause like the following from the Ontario Department of Public Highways and the British Columbia Public Works Department specifications.

"Gravel shall consist of naturally formed fragments of tough durable rock, well graded in size from the smallest to the largest, free from flat, elongated particles, and shall not contain more than 15 per cent by weight of soft friable material. It shall not contain an excess of clay nor an excess of loose adhering dust, vegetable loam or other deleterious matter. It shall be subject to the approval of the Engineer".

"The gravel shall consist of stone mixed with sand and clay or other binding material not less than 50% nor more than 75% by weight of the gravel shall consist of stone particles sufficiently large to be retained on a one quarter (¼) inch mesh screen. The gravel shall be moderately coarse containing a fair mixture of stone, varying from 2″ downwards and of sufficient sand or other fine binding material. The gravel shall not contain an excess of clay (usually less than 10%) and shall be free from defective material or other foreign matter. The stones shall be hard, tough and durable. No decomposed or other material liable to be disintegrated by water shall be allowed."

The Roads Department of Quebec specify that

"in the lower course of gravel, no stone over four inches in its largest dimension shall be allowed, that no stone over $2\frac{1}{2}$ inches in its largest dimension shall be allowed to enter the upper course of gravel, that no stone over 2 inches in size shall be allowed in the upper three inches of the last course, and that at the surface the gravel shall not be over one inch in size."

Gravels fulfilling the requirements of such general clauses are in some cases, before being accepted, submitted to certain tests and classed under definite grades or classes.

In Ontario, for instance, gravels are graded according to the coefficient of wear[1] and the proportions of the various sizes of particles present, as determined by laboratory tests.

Grade A gravel is one containing a large percentage of pebbles of igneous rocks; not more than 5% of material retained on a 4-inch screen, and not more than 45% of material passing a $\frac{1}{4}$-inch screen. It must not contain more than 3% of clay or loam, nor have a coefficient of wear less than 14.

Grade B is a gravel containing a smaller percentage of igneous rock pebbles. It must not contain more than 5% of material retained on a screen having 4-inch circular openings nor more than 60% of material passing a screen having $\frac{1}{4}$-inch square openings. It must not contain more than 9% of clay or loam nor have a coefficient of wear less than 11.

Grade C is a gravel composed chiefly of pebbles of sedimentary rock. It must not contain more than 5% of material retained on a screen having 4-inch circular openings and not more than 80% of material which passes a screen having $\frac{1}{4}$-inch square openings. It must not contain more than 12% of clay or loam nor have a coefficient of wear of less than 7.

In Quebec gravels before being accepted are tested and classed under 3 grades, according to the relative proportion of the various sizes of materials over 1 inch and of the sand produced in a crushing test of the material passing the $\frac{1}{2}$-inch screen and retained on the $\frac{1}{4}$-inch screen.

The classification is based on the grading of the coarse aggregate and on the crushing strength of the gravel.

Limits for the wearing qualities of gravel should not be set until a very comprehensive study has been made of the gravels of the district and of the wearing qualities of the bedrock from which these gravels were derived.

Igneous gravels are usually more resistant to wear than limestone gravels, though frequently the reverse is true, therefore specifying against the limestone gravel may result in the use of inferior material.

Some gravels containing flat elongated particles produce a better bond and better wearing surfaces than tough well rounded gravels, under certain traffic conditions.

Gravel pebbles which are tough and will not crush under the loads of traffic do not always give a firm surface, if the pebbles are mixed with too much fine sand. Specifications should include reasonable requirements for a proper gradation of the stone particles and call for a proper amount, say between 35 and 50 per cent, of well graded coarse sand, with from 10 to 15% of binder, according to the cementing value of the gravel. These are the gravels that will produce and maintain the smoothest surface under fast traffic.

[1] As determined by the Standard Deval Abrasion method.

METHODS OF TESTING ROAD GRAVELS

In the testing of gravels to determine their suitability for the construction of gravel roads an attempt is made to obtain a knowledge of their ability to resist wear and to bind in a road surface.

In the examination of gravels by the Road Materials Division of the Mines Branch, determinations are made of the relative proportion of the various sizes of the constituents, and the average composition of the pebbles, together with the impurities present and the shape of the pebbles. These are recorded under the headings Gravel-Pebble Classification and Granulometric Analysis. Abrasion, toughness and cementing value tests are also sometimes made upon gravel samples.

In the case of gravels to be used as aggregate in cement concrete mixtures, in order to obtain information on the probable strength of the concrete, elutriation test for clay and silt, colour test for organic impurities, and mortar tests are made, in addition to those mentioned above.

Gravel Pebble Classification.—Experiments have shown that the percentages of wear increase with an increase in the amount of soft material in gravel, and, from the results obtained in comparing pebble composition and percentage of wear, the rocks are divided according to their average toughness values and percentages of wear, into durable, intermediate and soft. The durable types include igneous and metamorphic rocks having an average percentage of wear of less than 4 and an average toughness over 12. The intermediate types include rocks with an average percentage of wear of from 4 to 6, and an average toughness of from 5 to 12. They are limestone, dolomite, and slightly weathered rocks belonging to the durable kinds of igneous rock with a high percentage of mica, hornblende or other soft mineral. The soft types include rocks having a percentage of wear above 6 and thoroughly weathered stone of all kinds.

By this classification of the material of which the pebbles are composed into durable, intermediate and soft, one experienced in testing rock for road building is able to judge with fair accuracy, without an abrasion test, the ability of the material to resist wear.

Granulometric Analysis.—The ability of gravels to pack well in a road bed, being dependent to a large extent on the proportion of the sand content and on the grading according to sizes of the particles making up the gravel and sand constituents, this test is a very important one. Some engineers contend that this test is unreliable, on the ground that a sample taken at random in a pit furnishes very little information as gravel deposits are always variable in their grading, from point to point, and one mechanical analysis would not, as a consequence, give the grading of the pit run. This is true if the sample collected does not represent a fair average of the whole face from which material is to be obtained. A brief investigation of the working face of any gravel pit by a trained man will give him a good idea of the bulk of the material available for use. In this respect, one method for taking gravel samples that works well is given below.

Abrasion Test.—The abrasion test for gravel is still in the experimental stage. The test is usually made in a Deval abrasion machine, but there are several methods being tried out in connexion with the character of the charge of the gravel to be tested, as results are easily influenced by the grading and shape of the pebbles, that compose the charge.

Two methods have been used in the Mines Branch laboratory. In one, the charge consists of 5,000 grammes of the part of the gravel sample that passes through a 2-inch and is retained on a $\frac{1}{2}$-inch screen. The test is run and the percentage of wear determined in the same way as for stone. The weight of material passing $\frac{1}{16}$-inch mesh, that is worn off in 10,000 revolutions, expressed in percentage of the original weight of the charge, constitutes the measure of abrasion of the gravel and is called the percentage of wear. In the second method the gravel is first screened into the following 5 sizes: $\frac{1}{4}$ to $\frac{1}{2}$ inch, $\frac{1}{2}$ to $\frac{3}{4}$ inch, $\frac{3}{4}$ to 1 inch, 1 to $1\frac{1}{4}$ inch and $1\frac{1}{4}$ to $1\frac{1}{2}$ inch. 500 grammes of each size, aggregating 2,500 grammes, is run in the abrasion machine with 20 steel balls 1 inch in diameter, for 5,000 revolutions, instead of the usual 10,000 revolutions without the balls and the percentage of wear calculated as before. This first method introduces the factor of the influence of grading on the percentage of wear; the second eliminates to some extent that factor. The last-mentioned method was used in the tests made in this investigation.

The results of a large number of tests[1] made in the laboratory of the Bureau of Public Roads, at Washington, on gravels indicated that the abrasion test is not quite satisfactory for general application. The gravel charge for the test is composed of a large number of pieces which, individually, as a rule vary greatly in hardness and toughness.

Misleading results may be obtained by the presence of a comparatively small proportion of pebbles softer or harder than the average, which will raise or lower the percentage of wear. The loss by abrasion also depends to a large extent on the shape of the pebbles. For these reasons a toughness test was added which gives complementary information and may prove to be of great use.

Toughness Test.—Toughness tests were made on a number of gravels collected during this survey. The apparatus used was the Jackson Impact Machine. About this test Mr. Jackson writes as follows:—

"Although called an impact test, however, it must be understood that there is no attempt made to determine the actual resistance to impact or toughness of individual fragments in the same sense that a toughness test of rock is made. The test is designed simply to differentiate between satisfactory and unsatisfactory materials as measured by the ability of each fragment to withstand a single blow of a hammer of known weight, the height of fall being such that only very soft or unsound decomposed pieces will fracture. In other words, the test simply attempts to define in terms of numerical values the usual specifications phrase: Shall be composed of sound, hard, durable particles."

The height of fall of the hammer used for the various sizes of pebbles was as follows:—

Shortest dimension of particle............	$\frac{3}{4}''$	$1''$	$1\frac{1}{4}''$	$1\frac{1}{2}''$
Height of fall of hammer.................	$3''$	$4''$	$5''$	$6''$

The number of pieces used in each test varied from 25 to 50.

The results of this test show that certain gravels, which are fairly resistant to wear, are brittle and break easily by impact.

In most of the samples tested the percentages of pebbles which failed to withstand the blow of the hammer compared satisfactorily with the proportions of soft or weathered pebbles as determined by the Gravel-Pebble Classification.

[1] An impact test for gravel; F. H. Jackson. Proceedings of the A.S.T.M. 1922, p. 362.

Cementing Value Test.—The method used in this test is the same as in the case of stone. The test is made to determine the ability of the rock powder to set when treated with water. This property of rock powder is an important factor in the success of a waterbound macadam, as the binding power developed by the fine material produced by the action of traffic is depended upon to hold the surface together. In the case of gravel it is of less importance.

The usefulness of the test, as it is commonly made, is a matter of debate. Moreover, the test is unreliable, as it does not give concordant results.

The test for the determination of voids in gravel has also proved unreliable. For these reasons these two tests were not made on the samples collected. It is desirable, however, that proper testing methods be devised to determine the cementing value of the total aggregate and the density of gravels as these are apparently important factors in the bonding in gravel roads.

Sampling.—In sampling road gravel for laboratory examination, the material should be collected in such a way as to be representative of the deposit at the place of sampling; from 25 to 50 pounds of material are necessary.

The method of collecting the sample needs careful attention. One method, which works out well on a gravel face that is not too high, is to mark off the face vertically into equal parts and, starting from the top, to pick off from each part equal volumes as nearly as can be judged, catching the gravel on a shovel held against the face.

In the case of gravel pits where a good section is exposed and where there is a noticeable variation in the grading, samples should be collected from each phase of variation that occurs in appreciable quantity in a bank-run product. The samples should be free from surface loam, and should not include any material which would naturally be rejected in excavating the gravel for use.

TABLE I

Results of Physical Tests upon Gravel Samples

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand: Per cent pebbles	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
	Montreal-Toronto Highway:																	
836	Marysville..........	69	31	....	8	19	23	13	17	20	31	20	20	14	7	4	4	From Toping pit; } Such material is giving good service
837	"	49	51	....	6	6	9	15	30	34	22	19	14	19	20	4	2	From Dept. of Highways pit; } Such material is giving good service
826	E. of Shannonville....	38	62	....	....	10	20	10	22	38	21	21	18	17	13	5	5	Applied in thin coat on washboard surface. Even where calcium chloride has been used, corrugations are seen.
831	Smithfield Sta. (W. of Trenton).	28	72	....	....	6	5	18	29	42	14	19	25	18	10	7	7	Used in thin coat for maintenance. Packs fast, but wears washboard.
833	W. of Brighton........	38	62	....	8	0	0	5	14	73	38	27	18	7	4	3	3	Wears washboard, dusty, with much loose pebbles.
823	W. of Colborne........	56	44	....	7	3	9	13	24	44	29	17	23	11	7	6	7	As used in thin layer (2") for maintenance over washboarding surface. Packs well.
832	E. of Port Hope......	52	48	....	....	3	10	17	25	45	47	29	12	5	3	2	2	Does not washboard.
830	Near Clarke, (W. of Port Hope.)	40	60	....	....	12	16	11	19	42	9	9	24	30	25	1	2	Wears very dusty and washboard.
829	E. of Newcastle......	42	58	....	....	8	26	13	25	28	16	12	11	22	22	8	9	Very slow to pack. Thick layer (8") remains loose. Old surface very washboard.
828	E. of Bowmanville....	57	43	....	....	3	15	14	26	42	36	26	15	9	6	6	2	From stock pile. Road surface built of same is firm, without loose pebbles. Wears uneven and dusty but without rut, pot hole, or corrugation.
827	E. of Oshawa.........	29	71	....	....	9	9	13	16	53	21	18	15	24	14	6	2	Does not bind. Ravels. Dusty and loose surface. Where calcium chloride used, is bound smooth.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand: Per cent pebbles	Per cent sand	Pebbles: Per cent retained on screens: 2½″	2″	1½″	1″	¾″	½″	¼″	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
822	N. of Whitby (Whitby-Lindsay Road).	42	58	....	....	15	20	14	20	31	15	23	18	22	14	4	4	Not bound. Much loose pebbles and dust. Wears washboard.
	Toronto-Windsor Highway: Via London and Chatham:																	
820	Paris................	71	29	7	15	21	25	9	11	12	15	12	41	25	3	2	2	Binds well, but such coarse material produces a rough uneven wearing surface.
821	W. of Goble..........	27	73	....	....	....	7	17	27	49	12	10	17	18	24	12	7	From well dragged, smooth surface. Soft material and binder may account for absence of washboarding.
770	W. of Ingersoll........	53	47	....	....	11	21	15	21	32	22	18	23	18	7	3	9	From Dept. of Highways pit. Produces a smooth surface which tends to pit owing to soft aggregate.
819	E. of London.........	55	45	....	6	14	19	14	19	28	25	14	18	31	8	2	2	From pit. Used in re-surfacing. Gives good results.
780	Lambeth............	37	63	....	....	....	18	13	22	47	32	26	15	10	5	7	5	Packs and wears with fairly smooth wheel tracks. Old surface is rough and only slightly washboard.
781	W. of Lambeth.......	21	79	....	....	17	33	7	10	33	27	32	20	10	5	4	2	
779	E. of Melbourne......	46	54	....	4	18	18	10	15	35	19	15	22	31	9	2	2	From stock pile for maintenance. Where same has been used, signs of washboarding appear.

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778	E. of Wardsville......	45	55	....	....	18	26	14	17	25	13	14	31	20	15	4	3	Packs well but wears washboard.
773	Kent Bridge..........	43	57	....	....	7	10	12	23	48	26	16	17	31	8	1	1	River gravel. Used in re-surfacing washboard surface apparently built of similar material.
811	W. of Chatham.......	73	27	20	17	7	16	9	12	19	26	14	16	20	10	5	9	From stock pile.
818	W. of Ringold.........	72	28	14	14	15	17	11	13	16	17	12	18	23	12	6	12	From new road on clay subgrade; packed but uneven and rough with ruts.
815	E. of Tilbury.........	33	67	....	....	16	13	9	13	49	17	21	25	16	13	3	5	
817	Between Comber and Ruscom.	40	60	....	....	7	16	13	19	45	25	32	25	5	4	4	5	
816	E. of Ruscom.........	26	74	....	....	....	9	4	17	70	24	24	19	12	9	6	6	Material used on new clay subgrade. Tracks and depressions are forming, but no washboarding. Coarse sand.
810	E. of Maidstone.......	34	66	....	....	....	10	10	20	60	24	22	20	13	11	5	5	
	St. Thomas-Windsor Highway:																	
775	E. of St. Thomas.....	38	62	....	5	6	24	15	21	29	16	10	13	38	13	5	5	From pit at New Sarum. The road in this locality is washboarded.
784	S. of St. Thomas.....	52	48	....	....	....	20	16	23	41	41	28	17	7	2	3	2	From old surface wearing a little rough but not washboarded.
783	St. Thomas..........	50	50	....	....	....	27	16	22	35	22	17	19	15	10	10	7	From new layer, 6″ thick, applied lately.
786	7 m. W. of Wallaceton	34	66	....	17	7	7	6	15	48	37	26	12	5	17	2	1	From stock pile.
776	W. of Wallaceton......	35	65	....	12	6	9	12	16	45	25	23	17	14	18	1	2	From road in very good condition.
777	9 m. W. of Wallaceton	34	66	....	9	8	12	8	19	44	20	16	21	21	10	8	4	Material used for maintenance.
785	12 m. W. of Wallaceton	56	44	....	20	24	7	9	10	30	31	30	23	10	2	2	2	Used in layer 4″ to 6″ thick, is slow to pack.
792	2 m. W. of Clearville.	20	80	....	....	....	17	7	17	59	19	22	20	14	11	7	7	From washboarded surface.
800	E. of Morpeth.........	57	43	....	....	4	9	10	23	54	42	20	15	14	5	2	2	From pit. Makes good road. Well graded and of good cementing value.
802	Near Guild...........	35	65	....	6	5	15	10	25	39	22	25	26	12	6	3	6	Packs fast but soon becomes washboarded.
801	N.W. of Blenheim....	17	83	....	....	....	13	10	23	54	12	15	17	27	23	3	3	
807	N. of Blenheim.......	38	62	....	....	12	14	10	17	47	28	26	19	10	8	6	3	Used for maintenance on Blenheim-Chatham road.
808	N.E. of Blenheim.....	22	78	....	....	....	4	12	26	58	22	18	25	24	8	1	2	Roads built of same are wearing rutted and dusty.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand		Pebbles: Per cent retained on screens							Sand: Per cent retained on sieves						Per cent passing 200 mesh	Remarks
		Per cent pebbles	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
812	W. of Blenheim.......	12	88	....	....	....	....	15	15	70	16	18	20	18	13	8	7	From washboarded surface.
799	S.W. of Cedar Springs	62	38	....	5	8	20	14	20	33	23	20	23	14	11	4	5	Screened gravel from stock pile in pit. Gives good results.
791	W. of Cedar Springs..	27	73	....	....	7	14	10	20	49	23	20	19	16	11	6	5	From very washboarded surface.
805	Dealtown............	20	80	....	....	15	2	5	18	60	19	21	22	16	12	5	5	" "
809	E. of Romney........	40	60	....	5	3	15	13	21	43	18	16	25	28	8	2	3	From pit. Contains soft material of good cementing quality. Very slightly washboarded road.
806	Between Wheatley and Romney.	46	54	....	....	9	13	13	22	43	22	17	22	21	8	4	6	Makes good road.
814	E. of Wheatley.......	34	66	....	....	....	18	17	25	40	18	16	25	25	7	4	5	From new layer.
813	E. of Wheatley.......	45	55	....	....	6	16	14	26	38	21	16	26	23	8	2	4	Makes good road.
797	W. of Leamington....	30	70	....	....	....	4	10	20	66	24	18	27	22	4	1	4	Binds well, and makes good road. Sandy but binding material.
796	Olinda...............	37	63	....	....	....	6	7	18	69	25	30	30	9	4	1	1	
793	Olinda-Kingsville road	37	63	....	....	10	23	10	20	37	19	12	18	29	10	5	7	Makes fairly good road under light traffic conditions.
798	W. of Kingsville......	25	75	....	....	....	13	12	18	57	26	24	22	10	7	4	7	
794	E. of Arner..........	40	60	....	....	....	21	9	19	51	28	22	26	12	5	3	4	Loose, slow to pack. Light traffic.

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795	Pit W. of Cottam.....	53	47	....	7	6	12	20	24	31	19	11	17	31	13	3	6	
803	Pit W. of Cottam.....	25	75	....	8	18	6	8	16	44	20	17	18	25	12	6	2	From rough, uneven and washboarded surface.
	London-St. Mary's-Stratford Highway:																	
838	London..............	72	28	7	14	18	20	11	14	16	28	14	13	35	8	1	1	Washed river gravel. Does not washboard but wears dusty and uneven like water-bound macadam.
789	7 m. S.W. St. Mary's.	30	70	....	9	16	25	14	12	24	14	26	37	14	3	2	4	From pit. Such gravel used in new construction is slow to pack. Deep ruts form.
790	5 m. S.W. St. Mary's.	86	14	....	25	15	24	13	12	11	35	19	21	15	3	2	5	Surfaces built of same was packed but uneven, rough, with ruts and loose pebbles. Lacks fines.
788	7 m. W. of Stratford..	73	27	....	....	10	12	10	20	48	61	25	8	2	1	1	2	
787	Between St. Mary's and Stratford.	76	24	....	3	29	20	14	17	17	24	12	21	27	10	2	4	From pit.
	London-Sarnia Highway:																	
772	W. of Poplar Hill.....	20	80	....	8	19	20	11	11	31	21	25	29	14	5	4	2	Wears fast, dusty, and washboarded.
	Toronto-Barrie-Orillia Highway:																	
776	Between Stroud and Barclay.	36	64	....	....	....	29	13	19	39	16	11	15	28	15	10	5	Binds well but wears fast with ruts and dust.
768	Allandale pit..........	60	40	....	....	....	6	31	25	38	18	13	22	30	5	5	7	Has produced well bound surfaces.
767	N. of Barrie (Dunsmore pit).	43	57	....	16	12	26	16	13	17	7	8	25	37	14	6	3	Sections just north of Barrie, built in 1920 and 1921, of material from this pit, are cemented and wearing smooth.
763	E. of Guthrie (McDougall pit).	32	68	....	....	5	18	12	20	45	18	16	20	26	13	4	3	Material used for re-covering sections built in 1921 which have worn rough.
769	S. of East Oro (Shaw pit).	58	42	27	16	15	15	9	8	10	12	12	19	42	10	2	3	Sections built of such material in 1921 are well bound but wearing rough, uneven, and dusty.
764	9 m. S. of Orillia......	34	66	....	....	6	17	12	22	43	20	16	19	14	12	9	10	From new layer, 3″ thick, just put on for maintenance.
762	5 m. S. of Orillia......	48	52	....	....	4	24	14	22	36	20	16	22	25	10	4	3	Put on in 1921 wears dusty but evenly.
765	Pit on town line between Oro and Orillia South.	67	33	....	7	12	20	16	27	18	9	8	23	40	8	6	6	Sample from pit where material was obtained for use south of Orillia.
761	3 m. S. of Orillia......	50	50	....	....	....	20	19	22	39	22	17	20	20	10	5	6	Wears fast, dusty, but evenly. Without ruts or washboarding. Put on in 1922.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand: Per cent pebbles	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
	Ottawa-Pembroke Highway:																	
840	S. of Arnprior.........	62	38	....	....	9	21	14	23	33	25	14	15	22	12	7	5	Binds well and produces fairly even surface.
842	W. of Arnprior........	25	75	....	....	22	14	9	17	38	15	10	17	26	22	7	3	From new road. Layer 12" thick is very slow to pack. Deep ruts form.
843	W. of Arnprior........	41	59	19	0	8	13	7	16	37	22	19	19	19	14	5	2	Not cemented but packed into a fairly smooth surface.
392	W. of Braeside........	60	40	....	3	12	17	14	18	36	32	20	18	19	4	2	5	Cements and produces a smooth surface which shows a tendency to rut and wear like waterbound macadam.
841	On Burnstown-Glasgow road.	56	44	25	15	5	10	12	13	20	20	15	16	19	15	9	6	Too coarse. Much loose stone. Light traffic keeping to single track.
844	W. of Renfrew........	37	63	....	22	0	20	8	15	35	20	15	22	25	11	4	3	Well packed, wearing smooth.
848	E. of Cobden.........	40	60	....	..	11	20	14	21	34	25	18	13	11	17	10	6	Packing well on sandy subsoil.
847	W. of Beachburg......	50	50	....	10	29	17	8	13	23	18	15	20	24	13	5	5	Thin coat applied on clayey subsoil. Packs and wears smooth in wheel tracks.
845	E. of Perretton.......	28	72	....	....	12	10	15	21	42	23	12	19	24	13	6	3	Loose with deep ruts. Apparently put on in the spring.
846	E. of Pembroke.......	24	76	....	30	17	14	8	13	18	9	9	25	30	11	8	8	Packed in wheel tracks. Soft gravel wearing very dusty.
	Levis-Rimouski Highway:																	
875	Below Montmagny...	19	81	....	....	....	8	8	20	64	15	16	17	32	9	5	6	Very slow to compact. Wears with waves.

878	Between Cap St. Ignace and L'Islet.	46	54	40	22	0	10	3	7	18	15	21	27	25	6	4	2	Cemented but rough and dusty.
873	Below St. Jean Port Joli.	43	57	....	....	12	8	10	20	50	28	22	26	14	3	2	5	Fairly smooth but wearing fast and dusty.
872	Below St. Roch.....	20	80	....	....	....	....	4	16	80	22	20	23	24	5	2	4	Wears washboard.
877	W. Ste. Anne.........	51	49	25	0	10	17	14	12	22	19	17	18	24	14	4	4	Good bond but rough surface on account of coarse material contained. Tendency to rut owing to soft aggregate.
876	Near St. Pascal.......	46	54	....	10	20	16	8	16	30	24	27	27	15	3	2	2	Packs well but wears dusty and uneven.
879	Near Ste. Helene.....	26	74	....	....	....	14	11	21	54	26	29	21	13	5	4	2	Wears with ruts, waves and much dust. Soft.
869	2 m. S.E. St. Andre..	30	70	....	....	12	12	22	17	37	14	19	26	18	13	4	6	Packs with smooth wheel tracks wearing fast and dusty.
868	Near St. Andre.......	60	40	11	15	16	22	8	10	18	20	20	30	21	4	3	2	Yields a rough surface.
874	N.W. St. Alexandre...	45	55	....	....	13	16	14	21	36	33	28	18	11	6	2	2	Wears rough with ruts and depressions.
870	Near N.-D. du Portage.	13	87	....	....	....	37	6	17	40	7	8	21	44	11	6	3	Natural soil. Beach gravel. Washboarded road.
857	Between Riv. du Loup and Cacouna.	47	53	....	7	4	19	11	17	42	26	23	17	14	6	5	9	Packs well and cements but wears rough and uneven.
883	4 m. W. of St. Simon.	43	57	....	12	16	22	14	15	21	17	24	29	16	5	5	4	Yields fairly smooth wheel tracks which cut and ravel easily. Dusty road. Needs frequent dragging.
885	Below St. Simon......	40	60	....	....	16	16	11	20	37	24	19	19	19	8	5	6	
884	E. of St. Fabien......	42	58	....	....	10	19	20	23	28	14	18	24	19	11	6	8	As above.
880	5 m. below St. Fabien	30	70	....	20	0	7	8	15	20	20	20	20	20	10	4	6	Compacted wheel tracks, wearing rough, uneven.
856	Rimouski.............	49	51	....	11	14	17	11	15	32	22	20	19	29	8	1	1	Beach gravel. Wears washboard and dusty. Packed but not cemented.
	Riviere du Loup-Edmundston Highway:																	
881	N. of St. Jacques, N.B.	37	63	....	....	3	16	12	21	48	28	17	14	12	11	10	8	Fast wearing surface but remaining even and cemented.
858	9 m. N. of Edmundston	46	54	....	....	3	6	8	25	58	25	19	15	16	10	10	5	
858	S. of Quebec boundary	38	62	....	....	3	11	13	26	47	17	19	24	24	6	7	3	Washboarding.
859	5 m. N. of Quebec boundary.	32	68	....	....	5	8	15	22	50	20	22	24	17	6	4	7	Packed in wheel tracks. Signs of washboarding.
860	1 m. S. Ste. Rose.....	29	71	....	....	....	5	10	20	65	22	20	22	13	7	10	6	Packs but soon becomes washboard.
861	5 m. N. Ste. Rose....	44	56	....	....	2	8	12	23	55	31	24	20	9	4	3	9	Packs and binds but wears with ruts.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand		Pebbles: Per cent retained on screens							Sand: Per cent retained on sieves						Sand: Per cent passing 200 mesh	Remarks
		Per cent pebbles	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
862	S. of N.-D. du Lac....	42	58	....	....	9	14	14	19	44	23	32	29	8	3	2	3	Produces smooth and well bound surface.
863	N. of N.-D. du Lac...	45	55	....	25	27	8	9	9	22	18	20	19	22	10	5	6	From pit. Packs fast on road. Gives smooth surface.
864	W. of St. Mathias.....	54	46	....	....	4	12	13	24	47	28	22	25	18	2	2	3	Packs and cements well to smooth hard surface. Does not cut after heavy rain. Proper grading.
865	1·5 m. W. St. Louis...	47	53	....	6	10	16	7	22	39	27	24	17	10	7	6	9	Binds well. Road without loose material, but wears fast. Tendency to rut and to become rough. A little coarse. (865 and 866)
866	E. of St. Honore......	50	50	....	18	10	24	16	11	21	20	20	21	22	10	3	4	
867	S. of Whitworth......	90	10	15	19	13	24	9	10	10	34	22	14	8	7	6	9	Sample from pit.
871	20 m. S. of Riviere du Loup.	50	50	18	9	7	9	10	15	32	22	19	18	15	10	6	10	Binds well but wears fast with ruts and dust. Soft aggregate.
	Levis-Jackman Highway:																	
928	S. of St. Henri........	14	86	....	....	....	15	15	12	58	13	18	23	25	9	8	4	Washboard road even after rain and dragging. Not cemented.
929	N. of St. Isidore......	44	56	....	....	3	12	15	25	45	22	12	12	30	15	4	5	Ravelling. Loose pebbles.
930	N. Scott.............	46	54	....	....	10	15	15	25	35	19	17	18	17	10	8	11	Packs well into fairly smooth surface. Hardly any washboarding. Better grading, also softer material than above.

931	Near Scott..........	38	62	....	15	11	16	8	15	35	19	18	25	22	7	5	4	Washboard. Much loose. Packs but does not bind.
932	S. of Scott...........	34	66	....	....	....	8	10	25	57	27	17	19	20	7	5	5	Same as above. Very washboardy.
933	S. of Ste. Marie.......	22	78	....	....	....	8	14	23	55	13	19	30	24	7	3	4	
891	N. of Beauceville.....	64	36	....	....	10	21	15	22	32	32	19	13	12	9	7	8	Not cemented hard, but fairly smooth surface when dragged.
890	S. of Beauceville......	51	49	....	....	19	18	11	20	32	20	17	18	20	12	8	5	Packs well. Wears a little rough but not wavy.
889	Near St. Georges.....	45	55	....	6	21	20	11	13	29	24	17	22	27	8	1	1	Sample from stock pile for maintenance. Packs well but wears a little rough. Does not cement into hard surface.
888	S. of Jersey Mills.....	48	52	....	....	10	10	15	25	40	23	20	21	17	9	5	5	Packs well but wears fast and uneven. No washboarding.
887	S. of St. Côme........	15	85	....	....	....	20	8	20	52	12	12	24	32	13	5	2	Used for maintenance on coarse well bound but rough surface. Packs but shows tendency to wave.
886	N. of Armstrong......	33	67	....	....	10	16	15	17	42	20	18	20	22	13	4	3	From stock pile. Road surface even and well bound. A few depressions.
	Sherbrooke-Valley Jct. Highway:																	
974	Between Cookshire and East Angus.	37	63	....	....	14	27	12	16	31	18	14	15	27	11	10	5	Packed but not cemented. Much dust and loose material on sides. Ravels and gets corrugated.
975	N. of East Angus.....	26	74	....	24	14	10	7	17	28	11	14	28	41	2	2	2	Used for maintenance. Surface without new covering is well bound but wearing with pot holes.
976	7 m. N. of East Angus	35	65	....	22	16	12	7	13	30	16	15	22	29	4	7	7	Binds well but yields rough surface owing to coarse pebbles contained.
977	E. of Marbleton.......	32	68	....	15	14	12	9	15	35	15	13	15	27	16	7	7	Produces smooth, well bound surface which tends to rut. Soft material.
978	W. of Weedon.........	32	68	....	17	15	15	15	14	24	12	14	18	23	18	8	7	Binds well. Produces hard surface with coarse in relief.
979	N. of Weedon.........	35	65	....	....	14	18	9	17	42	25	19	17	15	8	7	9	Packed and bonded in wheel tracks. Wearing uneven and rough.
980	N. of Garthby........	22	78	....	....	....	24	6	15	55	16	18	21	23	12	6	4	Packing well. Very little corrugation. Soft material.
981	N. of D'Israeli........	40	60	....	5	15	22	12	18	28	18	17	19	20	12	7	7	Packs into hard surface wearing a little rough but without corrugation or washboarding.
982	S. of Coleraine........	74	26	....	....	22	25	12	15	26	18	21	20	17	10	10	4	Well bound. Coarse surface, but without waves or ruts.
983	N. of Coleraine.......	54	46	17	9	15	7	8	12	32	40	23	12	6	5	5	9	Packs well, but yields coarse surface which wears rough. Pot holes and ruts forming.
973	N. of Black Lake.....	34	66	....	....	4	3	9	19	65	36	25	16	11	5	3	4	Washboard road.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand: Per cent pebbles	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
990	S.W. of Broughton....	38	62	....	22	11	13	9	14	31	20	17	19	21	10	7	6	From surface fairly well bound but a little coarse. Signs of washboarding in places.
989	Between Broughton and East Broughton	37	63	....	12	10	15	9	17	37	23	22	20	10	7	8	10	Packing well but wearing with ruts and uneven.
984	2 m. N.E. of East Broughton.	38	62	17	0	12	11	7	15	38	27	21	18	15	8	6	5	Lots of loose. Packing in wheel tracks. Wears uneven and rutted.
988	3 m. S.W. of Tring Jct.	45	55	....	14	12	8	10	17	39	27	26	19	13	7	4	4	Packs well into fairly smooth surface but not cemented hard. Soon becomes uneven, rough, and dusty.
986	3 m. W. of Valley Jct.	31	69	....	....	12	14	11	18	45	25	22	16	13	9	8	7	Packs but does not cement. Some washboarding. Lots of loose pebbles and sand.
985	W. of Valley Jct...... (Top of hill).	45	55	....	....	14	15	22	19	30	17	19	22	18	8	8	8	Packs hard but wears a little coarse, uneven. No washboarding.
	Sherbrooke-Beauceville Highway:																	
927	W. of Birchton........	29	71	17	8	6	13	4	10	42	29	23	16	11	8	8	5	Ravels. Fines washed out leaving coarse in relief. Washboarded and rough surface. Lacks binder.
926	E. of Cookshire.......	49	51	10	15	9	11	12	16	27	23	20	15	12	7	10	13	Well bound, smooth surface. Shows tendency to rut. Is well dragged.
925	9 m. S.W. of Gould...	25	75	....	....	....	20	13	20	47	16	22	27	17	4	5	9	A little loose in horse path and at the sides but well bound and smooth in the wheel tracks.
898	4 m. S.W. of Gould...	37	63	....	....	3	12	18	22	45	28	23	20	13	5	5	6	

899	4 m. S. of Stornoway..	42	58	....	25	12	17	8	13	25	16	17	29	21	5	3	9	Representative of material being used in building new road between Gould and Stornoway.
897	3 m. N.E. of Stornoway.	30	70	20	13	13	5	17	10	22	11	13	16	18	15	10	17	Old road needs new material and dragging. Loose in horse path. Packed, but rough and ravelling in wheel tracks.
896	2 m. N. of St. Vital...	41	59	....	12	17	6	11	14	40	28	25	15	10	7	7	8	Makes fairly smooth and well bound surface but wears fast and dusty.
895	S.W. of St. Evariste..	40	60	28	10	13	10	11	10	18	12	15	22	21	13	10	7	Does not wear washboarded but ruts. Soft material.
894	3 m. N. of St. Evariste	62	38	....	6	3	10	10	24	47	33	24	21	13	3	2	4	Road 6 years old built of same shows well bound fairly smooth surface wearing with ruts in wheel tracks.
893	1 m. S. of St. Ephrem	38	62	....	15	2	10	10	18	45	25	23	13	12	10	7	10	Packs and binds well. Wears evenly. Traffic keeping to centre of road. Wheel tracks slightly rutted.
892	Just W. of St. Victor..	27	73	....	....	....	11	12	27	50	18	15	18	19	9	9	12	Well bound surface wearing smooth, with shallow ruts in wheel tracks.
	Sherbrooke-Derby Line Highway:																	
958	South of Lennoxville..	25	75	....	....	....	20	10	20	50	18	18	16	30	4	8	6	Very washboarded surface.
959	2 m. N. of Waterville.	56	44	9	0	10	17	14	16	34	34	28	16	8	3	4	7	From stock pile. Surface made of same is packed but ravels. Much loose. Wears rough and uneven.
960	S. of Fork to North Hatley.	49	51	....	13	13	9	11	14	40	31	29	15	7	4	4	10	Binds well but wears uneven and rough.
961	About 2 m. N. of Massawippi.	43	57	13	0	20	10	15	14	28	20	20	25	19	8	3	5	From stock pile. Surface built of same binds fast but wears rough and uneven.
962	Between Massawippi and road to Ayer's Cliff.	26	74	16	11	10	9	5	12	37	17	30	30	11	3	3	6	New material lately applied. Packs well but surface soon gets washboarded.
963	About 8 m. N. of Stanstead.	53	47	18	17	9	19	8	11	18	14	16	25	29	8	3	5	From stock pile, unscreened.
964	N. of Stanstead.......	32	68	....	....	5	5	14	21	55	21	18	22	17	6	6	10	Screened material used for maintenance. Washboarded surface where same is used.
965	1 m. N. of Stanstead..	33	67	....	....	4	22	14	25	35	15	21	24	17	6	10	7	From very washboarded surface with much loose pebbles.
	Sherbrooke-Coaticook Highway:																	
957	North end of road near Lennoxville.	33	67	....	....	22	9	11	20	38	20	20	25	25	3	3	4	Packs fairly well but does not bind. Wears washboard with much loose pebbles, and with the coarser pebbles in relief in dusty wheel tracks.
956	About 4 m. S. of Lennoxville.	31	69	....	12	19	17	9	13	30	12	14	18	31	10	8	7	

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of pebbles to sand: Per cent pebbles	Per cent sand	Pebbles: Per cent retained on screens: $2\frac{1}{2}$"	2"	$1\frac{1}{2}$"	1"	$\frac{3}{4}$"	$\frac{1}{2}$"	$\frac{1}{4}$"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
954	About 7 m. S. of Lennoxville.	50	50	12	11	2	17	10	16	32	24	19	16	17	12	7	5	Packs well but produces uneven surface on account of coarseness.
953	N. of Compton........	30	70	12	0	9	19	8	15	37	21	26	26	17	6	2	2	From stock pile for maintenance. Road surface well bound but wearing rough and uneven. Coarser pebbles sticking out of wheel tracks.
955	3 m. S. of Compton...	20	80	....	....	....	....	10	25	65	15	14	17	19	10	8	17	Binds well. No loose material. Very smooth where dragged. Where coarser pebbles are contained they stick out of bound surface.
952	2 m. N. of Coaticook.	39	61	....	7	10	17	12	15	39	25	18	15	17	8	5	12	Well bound surface wearing with ruts and coarse pebbles in relief. Soft material.
	Montreal-Sherbrooke Highway:																	
855	N.E. of Petit Lac Magog.	43	57	....	....	15	26	12	17	30	25	23	19	14	8	7	4	Fairly well bound and smooth road.
948	Between Magog and lake Magog.	29	71	....	8	4	16	8	18	46	21	24	29	16	4	3	3	Packs well. Fairly smooth to slightly washboarded surface.
949	Between Magog and Orford Lake.	54	46	....	15	9	16	10	17	33	34	24	19	10	5	3	5	Packs hard. Wears a little uneven. Coarser pebbles loosened up, are raked off to side of road.
950	West of Eastman......	34	66	....	9	24	8	12	17	30	15	17	23	25	11	3	6	Packed but not cemented. Washboarded wheel tracks with loose material.
945	Near Mt. Shefford W. of Waterloo.	40	60	25	0	5	8	9	17	36	25	25	19	12	10	5	4	Packed but not cemented. Wearing uneven. Holes and ruts forming. Too coarse material in wearing surface.

944	3 m. W. of Granby....	71	29	13	19	5	14	11	15	23	28	22	17	11	11	7	4	Packed but wearing uneven with tracks. Too coarse. Yields a rough surface.
946	3 m. E. of St. Césaire.	32	68	....	14	14	16	11	15	30	12	10	17	33	18	6	4	Wears washboard with holes and rough surface. Soft material.
947	Between Rougemont and Marieville.	25	75	....	....	....	18	14	19	49	10	10	19	30	21	5	5	Packed, without much loose, but wearing uneven, rough, and washboarded.
	Sherbrooke-Richmond Highway:																	
972	N. of Sherbrooke.....	50	50	....	5	16	18	12	16	33	36	23	14	10	5	5	7	Fairly well bound. Wearing a little rough but hardly any washboarding.
971	S. of Bromptonville...	32	68	....	....	....	17	10	15	58	24	13	15	30	5	5	8	Much loose. Wears washboard and dusty.
970	Halfway Bromptonville to Windsor.	33	67	....	....	16	15	10	22	37	25	20	19	21	5	5	5	Packed in wheel tracks only. Wears washboard. Does not bind.
969	N. of Windsor........	29	71	....	....	22	19	12	17	30	17	20	20	28	4	6	5	Used over rough coarse surface for maintenance. Packs but does not cement. Loose pebbles and some washboarding. Dusty.
968	S. of Richmond.......	40	60	....	15	10	15	13	18	29	20	14	18	32	5	7	4	
966	4 m. E. of Richmond on road to Victoriaville.	28	72	....	....	15	26	7	17	35	15	10	10	15	14	16	20	Well bound and smooth surface. Lighter traffic.
967	10 m. E. of Richmond on road to Victoriaville.	47	53	....	22	7	14	6	15	36	32	26	15	12	5	5	5	Well bound. Not as even surface as above.
	Verchères-Sorel Highway:																	
942	Above Contrecœur ...	47	53	....	5	13	19	14	19	30	17	12	14	54	1	1	1	Packing but not cementing. No washboarding. Fairly good when dragged. Much loose material brought to centre of road by drag. Binding where calcium chloride applied.
943	4 m. below Contrecœur.	40	60	....	8	32	9	13	13	25	10	7	17	57	4	2	3	Very slow to pack. Wearing with washboarded tracks. Loose outside tracks.
940	2 m. N.W. of St. Roch	35	65	....	8	14	16	10	18	34	17	16	19	23	15	6	4	From older surface than above. Is packed but wears with rough wheel tracks except in shade through bush where fairly even.
941	Near St. Roch........	43	57	....	....	7	14	12	25	42	15	10	15	40	10	5	5	Packed hard in wheel tracks. Ravels and wears rough and uneven. Much loose, in places.
939	About 4 m. N. of St. Ours.	48	52	8	4	11	12	12	19	34	20	10	15	31	14	5	5	Packs but does not bind. Does not get washboarded but ravels. Wears with ruts and dust. Rough. Much loose material.

TABLE I—*Concluded*

Results of Physical Tests upon Gravel Samples—Concluded

Sample No.	Location	Granulometric Analysis																Remarks
		Proportion of pebbles to sand		Pebbles							Sand							
				Per cent retained on screens							Per cent retained on sieves						Per cent passing 200 mesh	
		Per cent pebbles	Per cent sand	2½″	2″	1½″	1″	¾″	½″	¼″	8	14	28	48	100	200		
	Montreal-Mont Laurier Highway:																	
853	N. of Ste. Thérèse....	54	46	....	5	30	28	10	12	15	12	21	28	22	10	5	2	Binds well. Wears fast with dust and ruts. Needs frequent dragging. Wears like a broken stone road.
938	Between St. Jérome and Shawbridge.	69	31	....	....	7	10	11	24	48	44	14	2	8	17	9	6	From stock pile for maintenance. Binds well, wears dusty with ruts. Fairly good when dragged.
934	Between Shawbridge and Piedmont.	46	54	....	25	12	12	8	13	30	24	17	23	19	7	5	5	Packing but wearing uneven with tracks. Tends to ravel.
935	N. Ste. Adéle.........	52	48	....	....	5	25	15	20	35	23	18	15	14	11	10	9	Produces a smoother surface than sample above. Better grading and more binder.
937	S. Val Morin (Cote du Sauvage).	50	50	....	12	7	13	9	19	40	34	25	16	10	7	4	4	On steep hill remained loose during 1922. Packing with calcium chloride at end of summer, 1923.
936	3 m. S. of Ste. Agathe	36	64	....	9	12	11	15	18	35	16	16	18	23	12	8	7	Packs well. Smooth in wheel tracks. Very little loose except in horse path.

TABLE II

Results of Physical Tests upon Gravel Samples

Sample No.	Location	Character of material					Results of tests		Remarks
		Composition of pebbles			Shape of pebbles	Per cent clay and silt (a)	Abrasion per cent of wear	Toughness per cent of pieces broken	
		Durable	Intermediate	Soft					
	Montreal-Toronto Highway:								
836	Marysville...............	25	60	15	Subangular...	1·2	....	....	
837	"	15	75	10	"	1·0	6·7	14	
826	E. of Shannonville.......	5	95	0	"	3·1	....	....	
831	Smithfield Sta. (W. of Trenton).	0	90	10	"	5·0	....	....	
833	W. of Brighton...........	10	90	0	Fairly well rounded.	1·9	....	....	
823	W. of Colborne...........	5	95	0	"	3·1	....	....	Durable includes igneous rocks largely gneisses, granite, and quartz. Intermediate includes fresh limestone. Soft includes weathered rock and shaly limestone. In the case of samples 836 and 831, the limestone pebbles are coated with lime carbonate.
832	E. of Port Hope..........	10	90	0	"	1·0	....	....	
830	Near Clarke (W. of Port Hope).	5	95	0	"	1·2	....	....	
829	E. of Newcastle..........	20	75	5	"	5·2	....	....	
828	E. of Bowmanville.......	20	80	0	"	0·9	4·2	27	
827	E. of Oshawa............	5	95	0	"	1·4	....	....	
822	N. of Whitby (Whitby-Lindsay Road).	0	100	0	"	2·3	5·0	26	Limestone with small proportion of sandstone.

(a) The per cent of clay and silt is the amount by weight of material passing the 200-mesh sieve and is calculated as percentage of the total aggregate.

TABLE II—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Shape of pebbles	Per cent clay and silt (a)	Results of tests: Abrasion per cent of wear	Toughness per cent of pieces broken	Remarks
	Toronto-Windsor Highway via London and Chatham:								
820	Paris	30	70	0	Rounded	0·6	4·8	6	Durable includes granitic and quartzitic rocks. Intermediate is composed of limestone and dolomite.
821	W. of Goble	5	45	50	Subangular	5·1	....	....	Largely sandstone, partly weathered.
770	W. of Ingersoll	10	30	60	Rounded	4·2	7·4	32	Soft mostly weathered shaly limestone and dolomite.
819	E. of London	35	60	5	"	0·9	....	....	Granite, traps, quartzite, gneiss, limestone, dolomite and sandstone.
780	Lambeth	10	75	15	Subangular	3·1	....	....	Limestone, dolomite and sandstone.
781	W. of Lambeth	20	70	10	"	1·6	5·5	12	Some lime carbonate coating the pebbles.
779	E. of Melbourne	25	70	5	Rounded	1·1	....	....	
778	E. of Wardsville	25	55	20	"	1·6	....	....	
773	Kent Bridge	0	40	60	Subangular	0·6	....	....	About half of the soft are shales. Contains shells.
811	W. of Chatham	10	50	40	Rounded	2·4	....	....	Largely limestone and dolomite, partly weathered.
818	W. of Ringold	5	70	25	"	3·4	....	....	
815	E. of Tilbury	50	35	15	"	3·3	....	....	Durable is quartzite and gneiss. Intermediate includes limestone, with small amount of dolomite and sandstone. Clay binder.
817	Between Comber and Ruscom.	30	45	25	"	3·0	....	....	
816	E. of Ruscom	40	50	10	"	4·4	....	....	
810	E. of Maidstone	35	65	0	"	3·3	....	....	

	St. Thomas-Windsor Highway:								
775	E. of St. Thomas........	5	70	25	Subangular...	3·1	....	....	Durable includes igneous rocks (traps, quartzite, granite gneiss).
784	S. of St. Thomas........	5	90	5	"	1·0	....	....	Intermediate is fresh limestone and dolomite.
783	St. Thomas..............	10	65	25	Rounded.....	3·5	....	....	Soft includes sandstone and weathered rocks.
777	9 m. W. of Wallaceton....	40	60	0	"	2·6	3·4	3	Same as above. Intermediate includes small percentage of tough sandstone.
785	12 m. W. of Wallaceton...	30	70	0	"	0·9	....	....	Same as above.
786	7 m. W. of Wallaceton....	50	50	0	"	0·7	....	....	" "
776	W. of Wallaceton.........	5	70	25	"	1·3	....	....	
792	2 m. W. of Clearville.....	10	75	15	"	5·6	5·1	28	
800	E. of Morpeth............	20	70	10	"	0·9	....	....	Same as above. Soft includes weathered rocks and shales. Intermediate being almost entirely composed of limestone.
802	Near Guild..............	40	45	15	"	3·9	....	....	
801	N.W. of Blenheim.......	20	45	35	Subangular to rounded.	2·5	....	....	
807	N. of Blenheim..........	40	50	10	"	1·9	....	....	
808	N.E. of Blenheim........	15	35	50	Rounded.....	1·6	....	....	Soft composed of weathered sandstone and shales.
812	W. of Blenheim..........	50	45	5	"	6·2	....	....	
799	S.W. of Cedar Springs....	55	30	15	"	1·9	....	....	
791	W. of Cedar Springs......	40	50	10	"	3·6	....	....	Quartz, traps, granite, fresh limestone, partly weathered dolomite and shaly limestone and black shales.
805	Dealtown...............	50	45	5	Subangular...	4·0	....	....	
809	E. of Romney...........	20	40	40	"	1·8	....	....	
806	Between Wheatley and Romney.	10	45	45	"	3·2	....	....	Same as above. Limestone predominate and is partly weathered. Some lime carbonate coating the pebbles.
814	E. of Wheatley...........	10	60	30	"	3·3	11·5	12	
813	E. of Wheatley...........	10	50	40	Subangular and flat.	2·2	....	....	Soft composed of thin black shales.
797	W. of Leamington........	20	50	30	Subangular...	2·8	....	....	
796	Olinda..................	10	75	15	Rounded and flattened.	0·6	5·1	11	Largely limestone and dolomite.

TABLE II—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Character of material					Results of tests		Remarks
		Composition of pebbles			Shape of pebbles	Per cent clay and silt (a)	Abrasion per cent of wear	Toughness per cent of pieces broken	
		Durable	Intermediate	Soft					
793	Olinda-Kingsville road..	80	10	10	Subangular...	4·4	4·3	11	Granite, quartzite, and trap rocks.
798	W. of Kingsville.........	30	40	30	Rounded.....	5·2	....	....	
794	E. of Arner.............	15	75	10	"	2·4	....	....	
795	Pit W. of Cottam........	25	25	50	Subangular...	2·8	....	....	Durable as above. Intermediate composed of limestone. Soft composed of weathered dolomite or shaly limestone.
803	Pit W. of Cottam........	55	20	25	"	1·5	....	....	
	London-St. Mary's-Stratford Highway:								
838	London.................	10	85	5	Rounded.....	0·3	4·4	....	
789	7 m. S.W. St. Mary's....	5	85	10	"	2·8	3·6	8	
790	5 m. S.W. St. Mary's....	0	80	20	"	0·7	....	....	Durable includes igneous rocks. Intermediate includes fresh limestone. Soft includes silty and shaly limestone, weathered sandstone, and shales.
788	7 m. W. of Stratford....	5	90	5	Subangular...	0·5	3·2	18	
787	Between St. Mary's and Stratford.	20	60	20	"	0·9	6·8	....	
	London-Sarnia Highway:								
772	W. of Poplar Hill........	10	60	30	Rounded to subangular.	1·6	8·8	....	Durable includes gneisses and quartzite. Intermediate includes fresh limestone and soft includes weathered gneisses and shaly limestone.

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	Toronto-Barrie-Orillia Highway:								
766	Between Stroud and Barclay.	5	95	0	Subangular...	3·2	....	....	Durable includes quartz, granite, granite gneiss, biotite gneiss, and mica schist.
768	Allandale................	15	70	15	Rounded and subangular.	2·8	....	....	
767	N. of Barrie (Dunsmore pit).	10	80	10	"	1·7	....	....	Intermediate includes dense to fine-grained limestone, hard but brittle, partly coated with lime carbonate.
763	E. of Guthrie (McDougall pit).	5	90	5	"	2·0	7·7	40	Soft includes weathered igneous rocks.
769	S. of East Oro (Shaw pit)	5	90	5	"	1·3	....	....	
764	9 m. S. of Orillia.........	5	90	5	Subangular...	6·6	....	....	
762	5 m. S. of Orillia.........	20	50	30	Rounded and subangular.	1·6	10·0	47	
765	Pit on town line between Oro and Orillia South.	5	90	5	Rounded and flattened.	2·0	6·0	34	
761	3 m. S. of Orillia.........	25	75	0	Rounded and subangular.	3·0	....	....	
	Ottawa-Pembroke Highway:								
840	S. of Arnprior...........	80	15	5	Rounded and subangular.	1·9	7·4	15	Quartz, granite gneiss, trap, with small amount of dolomite and limestone.
842	W. of Arnprior...........	70	5	25	"	2·2	....	....	Same as above.
843	W. of Arnprior...........	85	5	10	"	1·2	8·5	22	" "
392	W. of Braeside...........	0	100	0	Angular and flat.	2·0	....	....	Dark, fossiliferous, rather soft shaly limestone, coated with lime carbonate.
841	On Burnstown-Glasgow road.	95	5	0	Rounded to subangular.	2·6	....	....	Same as 840.
844	W. of Renfrew...........	85	0	15	"	1·9	....	....	Reddish granitic and gneissic rocks, partly weathered.
848	E. of Cobden............	100	0	0	Subangular...	3·6	5·4	31	Same as above. Fresh.
847	W. of Beechburg.........	20	70	10	Rounded to subangular.	....	....	....	
845	E. of Perretton..........	5	5	90	Rounded.....	2·2	....	....	Largely silty limestone and dolomite, more or less weathered, with small percentages of igneous rocks and sandstone. Some lime carbonate coating the pebbles.
846	E. of Pembroke..........	15	15	70	"	6·0	16·9	36	

TABLE II—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Shape of pebbles	Per cent clay and silt (a)	Results of tests: Abrasion per cent of wear	Toughness per cent of pieces broken	Remarks
	Ottawa-Kingston Highway:								
834	N. of Joyceville..........	75	20	5	Subangular...	4·1	9·0	8	Quartz, granite and gneiss.
825	N. of Morton...........	0	50	50	"	4·5	....	....	Sandstone, partly weathered.
835	E. of Ashton............	10	80	10	"	7·5	9·8	47	Largely fresh limestone, with small per cent of igneous rocks and weathered silty limestone. Pebbles coated with lime carbonate.
824	E. of Ashton............	5	90	5	Angular.......	2·6	....	....	
	Ottawa-Point Fortune Highway:								
839	E. of Hawkesbury.......	60	30	10	Angular.......	2·4	....	....	Crushed gravel. Largely granite and gneiss, with some sandstone, dolomite and shaly limestone.
	Levis-Rimouski Highway:								
875	Below Montmagny.......	0	50	50	Angular and flat.	4·9	....	....	Sandstone and shales.
878	Between Cap St. Ignace and L'Islet.	0	0	100	"	1·1	....	....	Shales (tuff like).
873	Below St. Jean Port Joli.	0	90	10	"	2·8	....	....	Quartzite, slate and sandstone.
872	Below St. Roch..........	0	60	40	"	3·2	....	....	Sandstone and shales.
877	W. St. Anne.............	0	50	50	Subangular...	2·0	10·0	22	Quartzitic rock partly weathered.
876	Near St. Pascal..........	0	50	50	Angular and flat.	1·1	....	....	Sandstone and shales.
879	Near Ste. Helene........	0	0	100	"	1·5	....	....	Siliceous shale or sandstone (tuff).
869	2 m. S.E. St. Andre.....	0	80	20	Subangular...	4·2	....	....	Sandstone partly weathered.

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868	Near St. Andre.........	0	80	20	"	0·8	....	....	" " "
874	N.W. St. Alexandre......	0	80	20	"	1·1	10·6	22	Sandstone and shales weathered.
870	Near N.-D. du Portage..	0	100	0	Angular.......	2·6	....	....	Quartzite.
857	Between Riv. du Loup and Cacouna.	0	0	100	Angular and thin.	4·8	....	....	Rusty shales.
883	4 m. W. of St. Simon.....	0	80	20	Subangular...	2·3	11·6	27	Sandstone and shales.
885	Below St. Simon.........	0	75	25	Angular and flat.	3·6	....	....	Sandstone, partly weathered.
884	E. of St. Fabien.........	0	25	75	Angular.......	4·6	....	....	Weathered quartzite and shales.
880	5 m. below St. Fabien...	0	75	25	Subangular...	4·2	....	....	Sandstone and shales.
856	Rimouski...............	20	0	80	Rounded and Subangular...	0·5	12·0	20	Granitic and quartzitic rocks. Typical beach gravel.
	Riviere du Loup-Edmundston Highway:								
881	N. of St. Jacques, N.B..	0	0	100	Thin, flat.....	5·0	....	....	Rather sound but brittle, siliceous shales.
882	9 m. N. of Edmundston..	0	0	100	"	2·7	....	....	Weathered blue to greenish siliceous shale.
858	S. of Quebec boundary...	0	0	100	"	1·9	....	....	" " "
859	5 m. N. of Quebec boundary.	0	20	80	"	5·0	....	....	Blue to greenish siliceous shales.
860	1 m. S. Ste. Rose........	0	0	100	"	4·3	....	....	Blue to greenish siliceous shales. Fairly fresh but brittle.
861	5 m. N. Ste. Rose........	0	50	50	"	5·0	....	....	Blue to greenish siliceous shales.
862	S. of N.-D. du Lac.......	0	0	100	"	1·7	8·5	29	" " "
863	N. of N.-D. du Lac......	20	30	50	Subangular and flat.	3·3	16·0	12	Quartz and siliceous shales. Partly weathered.
864	W. of St. Mathias........	0	60	40	Subangular...	1·4	....	....	Sandstone, and siliceous shales. Partly weathered.
865	1·5 m. W. of St. Louis....	0	40	60	Angular and flat.	4·8	....	....	Quartz, quartzite, sandstone, and shales partly weathered.
866	E. of St. Honore.........	0	65	35	Subangular...	2·0	....	....	" " "
867	S. of Whitworth.........	0	75	25	"	0·9	18·0	27	Largely sandstone.
871	20 m. S. of Riviere du Loup.	10	30	60	Rounded, subangular, and flat.	5·0	....	....	Largely sandstone; weathered.

TABLE II—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Shape of pebbles	Per cent clay and silt (a)	Results of tests: Abrasion per cent of wear	Toughness per cent of pieces broken	Remarks
	Levis-Jackman Highway:								
928	S. of St. Henri..........	25	40	35	Rounded and flat.	3·4	....	....	Largely sandstone. Quartz, quartzite, siliceous shale.
929	N. of St. Isidore.........	25	30	45	"	2·8	....	....	" " " Partly weathered.
930	N. of Scott.............	5	20	75	Subangular to angular.	5·9	....	....	Quartz, quartzite, siliceous shale and sandstone. Largely shales, mostly weathered.
931	Near Scott.............	10	50	40	Rounded and flat.	2·4	....	....	Quartz, quartzite, siliceous shales and sandstone.
932	S. of Scott..............	50	0	50	Rounded and subangular.	3·3	....	....	" " " Sandstone and shales weathered.
933	S. of Ste. Marie..........	0	50	50	"	3·0	11·7	30	Quartz, quartzite, siliceous shale, sandstone.
891	North of Beauceville.....	10	40	50	Rounded to subangular.	2·9	....	....	" " " Rotten shales contained.
890	South of Beauceville.....	5	95	0	Subangular and flat.	2·4	7·5	....	Quartz, quartzite, siliceous shale and sandstone. Largely shales, rather sound.
889	Near St. Georges........	10	90	0	Rounded, and flat.	0·5	12·5	....	Quartz, quartzite, siliceous shale and sandstone. Washed river gravel. Largely fresh sandstone.
888	S. of Jersey Mills........	0	25	75	Subangular and flat.	2·6	....	....	Sandstone and shales. Weathered.
887	S. of St. Côme..........	0	100	0	Subangular...	1·7	....	....	75% sandstone, 25% shale, fairly fresh.
886	N. of Armstrong.........	0	100	0	Thin, flat.....	2·0	....	25	Siliceous shales, fairly fresh.

	Sherbrooke-Valley Jct. Highway:								
974	Between Cookshire and East Angus.	35	45	20	Rounded......	3·1	6·5	14	Quartzite and gneissic rocks, sandstone and shales.
975	N. of East Angus........	10	70	20	Subangular...	1·5	....	....	" " "
976	7 m. N. of East Angus...	30	20	50	Rounded and subangular.	4·5	....	....	" " "
977	E. of Marbleton..........	0	30	70	Subangular and flat.	4·7	....	....	Sandstone and siliceous shale, weathered.
978	W. of Weedon...........	10	60	30	Subangular...	4·7	....	....	Quartz, quartzite, siliceous shale and sandstone. Partly weathered.
979	N. of Weedon...........	5	35	60	Rounded to subangular.	5·8	15·9	17	About same as above. Weathered.
980	N. of Garthby..........	5	30	65	Subangular...	3·1	....	....	About same as above. Very much weathered.
981	N. of D'Israeli..........	50	15	35	Subangular to angular.	4·2	....	....	About same as above. Much less weathered.
982	S. of Coleraine..........	75	20	5	"	1·0	7·2	20	Quartz and quartzite. Fairly fresh.
983	N. of Coleraine..........	0	25	75	"	4·1	27·6	36	Quartz rocks, porous and partly weathered. Soft friable metamorphic rocks.
973	N. of Black Lake........	25	25	50	"	2·6	....	....	Quartzite and serpentine rocks. Sandstone and shale. Partly weathered.
990	S.W. of Broughton.......	60	20	20	"	3·7	....	....	Quartz, quartzite, sandstone and shale.
989	Between Broughton and East Broughton.	5	35	60	Rounded to subangular and flat.	6·3	....	....	Quartz, schistose siliceous rocks, sandstone. Weathered.
984	2 m. N.E. of East Broughton.	0	30	70	Subangular to angular.	3·1	....	....	Quartz rocks porous and partly weathered, sandstone and shale.
988	3 m. S.W. of Tring Jct...	35	25	45	Subangular and flat.	2·9	....	....	Quartz, quartzite, sandstone and shale.
987	N. of Tring Jct..........	10	10	80	Subangular, thin, flat.	2·2	....	....	Quartzitic and schistose siliceous rocks. Weathered and friable.
986	3 m. W. of Valley Jct....	30	50	20	Subangular...	4·8	....	....	} Quartz rocks, quartzite, and weathered sandstone.
985	W. of Valley Jct......... (top of hill).	10	40	50	Rounded......	4·4	....	....	}
	Sherbrooke-Beauceville Highway:								
927	W. of Birchton..........	75	20	5	Rounded to subangular.	3·5	....	....	Quartz, quartzite, serpentine rocks and sandstone.
926	E. of Cookshire.........	10	10	80	"	5·1	....	....	Largely weathered sandstone and shale.

TABLE II—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Character of material					Results of tests		Remarks
		Composition of pebbles			Shape of pebbles	Per cent clay and silt (a)	Abrasion per cent of wear	Toughness per cent of pieces broken	
		Durable	Intermediate	Soft					
925	9 m. S.W. of Gould......	20	25	55	Subangular and flattened	6·7	....	....	Quartzite, sandstone and shale.
898	4 m. S.W. of Gould......	25	40	35	Rounded to subangular.	3·8	10·5	....	About same as 927 with shale.
899	4 m. S. of Stornoway.....	40	25	35	Subangular to angular.	5·2	11·9	12	Granitoid and schistose rocks and shale. Weathered.
897	3 m. N.E. of Stornoway..	25	65	10	Rounded to subangular.	11·9	....	....	Granite, sandstone and shale.
896	2 m. N. of St. Vital......	0	0	100	Rounded and flat.	4·7	....	....	Sandstone and shale, mostly weathered.
895	S.W. of St. Evariste......	0	5	95	Mostly flat...	4·2	....	....	" " "
894	3 m. N. of St. Evariste..	0	10	90	Subangular...	1·5	....	....	" " "
893	1 m. S. of St. Ephrem....	0	10	90	" .... to angular and flat.	6·2	16·1	37	" " "
892	Just W. of St. Victor.....	0	10	90	"	8·7	....	....	" " "
	Sherbrooke-Derby Line Highway:								
958	S. of Lennoxville.........	60	35	5	Subangular to rounded.	4·5	....	....	Quartz, quartzite and sandstone.
959	2 m. N. of Waterville....	15	10	75	"	3·1	17·5	....	Same as above. Soft includes large per cent of weathered shale.
960	S. of Fork to North Hatley.	10	15	75	"	5·1	18·2	20	Same as above.
961	About 2 m. N. of Massawippi.	10	10	80	"	2·8	....	....	"

962	Between Massawippi and road to Ayer's Cliff.	10	55	35	"	4·4	....	....	Same as above with small per cent of limestone.
963	About 8 m. N. of Stanstead.	50	40	10	"	2·3	7·7	12	Quartzite predominates.
964	" " "	50	20	30	"	6·8	....	....	Quartzite predominates. Soft includes weathered pebbles.
965	1 m. N. of Stanstead.....	50	50	0	"	4·7	5·1	20	Quartz predominates.
	Sherbrooke-Coaticook Highway:								
957	N. end of road, near Lennoxville.	65	15	20	Rounded to subangular.	2·7	8·0	23	Quartz, quartzite, sandstone and shale.
956	About 4 m. S. of Lennoxville.	50	40	10	"	4·8	....	....	Quartzite and sandstone.
954	About 7 m. S. of Lennoxville.	60	10	30	"	2·5	8·0	15	Quartz, quartzite, partly weathered sandstone and thin slate.
953	N. of Compton..........	90	....	10	"	1·4	7·0	....	Quartz, quartzite, conglomerate with slate or shale.
955	3 m. S. of Compton......	90	....	10	Subangular...	13·6	7·8	....	Quartz, quartzite, sandstone and shale.
952	2 m. N. of Coaticook.....	20	....	80	" .... to rounded.	7·3	....	....	Quartz, granite and weathered sandstone.
	Montreal-Sherbrooke Highway:								
855	N.E. of Petit Lac Magog	30	20	50	Subangular and flattened	2·3	....	....	Quartzite, sandstone and schistose rocks. Partly weathered.
948	Between Magog and lake Magog.	0	40	60	Subangular...	2·1	13·0	31	Altered siliceous sedimentary rocks, sandstone and shale, weathered.
949	Between Magog and Orford Lake.	75	15	10	Partly rounded.	2·3	7·7	20	Quartz rocks, sandstone and schistose rocks and shale.
950	West of Eastman.........	40	30	30	"	4·0	....	....	Same as above. More weathered rocks.
945	Near Mt. Shefford, W. of Waterloo.	0	70	30	Rounded.....	2·4	....	....	Quartzitic and gneissic rocks, sandstone and shale, partly weathered.
944	3 m. W. of Granby.......	80	20	0	" .... and flattened	1·2	5·5	....	Quartzite, quartz and sandstone.
946	3 m. E. of St. Césaire....	0	50	50	Rounded to subangular.	2·7	....	....	Quartzite and gneissic rocks, sandstone, and shale, partly weathered.
947	Between Rougemont and Marieville.	0	30	70	"	3·7	13·3	31	Same as above, more weathered.

TABLE II—*Concluded*

Results of Physical Tests upon Gravel Samples—Concluded

Sample No.	Location	Character of material					Results of tests		Remarks
		Composition of pebbles			Shape of pebbles	Per cent clay and silt (a)	Abrasion per cent of wear	Toughness per cent of pieces broken	
		Durable	Intermediate	Soft					
	Sherbrooke-Richmond Highway:								
972	N. of Sherbrooke........	75	20	5	Rounded.....	3·5	5·1	14	Mostly quartzite with some quartz, sandstone and limestone.
971	S. of Bromptonville......	....	20	80	" and flattened.	5·4	....	....	Quartzite, sandstone and shale. Weathered.
970	Halfway-Bromptonville to Windsor.	65	....	35	Subangular to rounded.	3·3	10·0	18	" "
969	N. of Windsor............	50	30	20	"	3·5	5·5	30	" "
968	S. of Richmond..........	60	15	25	Rounded.....	2·4	....	....	Same as above with gneiss and shale.
966	4 m. E. of Richmond, on road to Victoriaville.	25	45	30	Subangular...	14·4	....	....	Quartz, sandstone and shale.
967	10 m. E. of Richmond on road to Victoriaville.	55	....	45	"	2·6	10·9	18	Quartz, quartzite, and weathered green shale.
	Verchères-Sorel Highway:								
942	S. of Contrecœur	60	30	10	Rounded......	0·5	6·0	....	Quartz, granite-gneiss, quartzite and sandstone. Fairly fresh.
943	4 m. below Contrecœur..	30	30	40	"	1·8	12·0	32	Same as above. More weathered. Gneiss is soft.
940	2 m. N.W. of St. Roch...	50	30	20	"	2·6	10·8	....	Quartz, granite, gneiss, sandstone and shale.
941	Near St. Roch...........	60	30	10	"	2·8	....	....	" " "
939	About 4 m. N. of St. Ours	70	20	10	"	2·6	10·8	....	" " "

	Montreal-Mont Laurier:								
853	N. of Ste. Thérèse.......	0	100	0	Rounded......	0·9	5·0	....	Fresh limestone.
938	Between St. Jérome and Shawbridge.	50	50	0	Subangular...	1·9	....	....	Rusty gneisses very schistose, partly weathered.
934	Between Shawbridge and Piedmont.	55	30	15	Rounded to subangular.	2·7	9·0	20	Granite, syenite, rusty gneisses and anorthosite rocks, partly weathered.
935	N. of Ste. Adéle.........	55	30	15	"	4·3	....	....	Same as above.
937	S. of Val Morin.......... (Cote du Sauvage).	50	45	5	"	2·0	5·6	....	"
936	3 m. S. of Ste. Agathe...	45	35	20	"	4·5	....	....	"
	Miscellaneous Roads:								
	Two Mountains District:								
850	Oka-La Trappe..........	65	15	20	Rounded to subangular.	6·4	....	....	Largely gneiss with small amount of sandstone and weathered dolomite.
849	N.W. of St. Benoit.......	55	40	5	Subangular...	3·3	8·9	18	Syenite, anorthosite, rusty gneisses and sandstone.
851	N.E. of St. Hermas......	0	75	25	Rounded to subangular.	2·4	....	....	Rusty gneisses, anorthosite and sandstone. Partly weathered.
852	N.W. of St. Hermas.....	70	30	0	Subangular...	1·0	10·5	25	Granite-gneiss, hornblende-gneiss, trap and sandstone.
	Three Rivers-Grand' Mere Road:								
854	S. of Almaville..........	80	20	0	Subangular...	2·7	9·1	8	Granite-gneiss. Fresh but much foliated.
	Soulanges District:								
951	St. Zotique.............	0	30	70	Rounded to subangular.	7·1	....	....	Largely weathered dolomite and shaly limestone with some sandstone.

VI

ROAD MATERIALS IN NOVA SCOTIA AND NEW BRUNSWICK

R. H. Picher

In continuation of the investigation of road materials in Nova Scotia, all the sources of supply for these materials were examined along the Sydney-Baddeck-Inverness-Hawkesbury highway, the Shag Harbour-Yarmouth-Digby highway, parts of the Annapolis Valley and Windsor-Truro highways, the Truro-Parrsboro highway and the Truro-Oxford-Amherst highway. A number of deposits in other parts of the province were also examined and fifty-five samples were collected for laboratory tests.

The work in Nova Scotia, as outlined in the beginning of 1922, is completed for the present, and information is now available on the most important road material deposits of the province. The southeastern part of the mainland, and the northern part of Cape Breton, less thickly settled than the rest of the province, have not yet been examined.

In New Brunswick a thorough examination was not undertaken, owing to the lateness of the season when the Nova Scotia work was completed. Only deposits on which information had been specially requested were visited, and sixteen of these were sampled for laboratory tests.

The main types of materials investigated consist of gravel, boulders, bedrock, and blast furnace slag. Gravel is by far the most commonly used material in road surfacing. It is used, wherever available, in preference to any other kind of material, except in places where the amount of traffic demands the use of a more permanent kind of surfacing. For this reason much time was spent in examining gravel deposits and attention was given to other materials only when they seemed to be of exceptionally good quality, or in areas where gravel was scarce.

GRAVEL

Gravels are fairly common throughout the province, but are far from being uniformly distributed. Within the areas surveyed in 1923, they are of most common occurrence in central Cape Breton and between Truro and Parrsboro in the northern part of the mainland. They are very scarce in parts of eastern and western Cape Breton and in the part of the mainland north of the Cobequid hills. Along the west shore road, from Shag Harbour to the head of St. Mary's bay, there are only a few bank gravel deposits of small extent, although from Yarmouth, north, sea beach gravel is found at many points. The coarsest material is found as a rule in the upper part of a deposit, the lower part being very often nearly all sand. Many of the gravels carry a few large boulders and a large proportion of material that is under $\frac{1}{4}$ inch in size, not taking into account the sand that makes up the lower part of most of the deposits. The gravels in central Cape Breton are coarse and have about the right proportion of pebble to sand. Nearly all the Annapolis Valley gravels carry too much sand, as do most of the gravels found in the white granite country, southeast of the valley. The beach gravels vary widely in coarseness within very small areas. In nearly every case the coarser and more bouldery material is found in the upper part of the beach, that is, in the part nearer the dry land, and the finer material nearer the water; but the gradation from coarse to fine is far from being regular. Moreover, the gravel found at the same level, on the beach, varies widely in size within short distances.

The pebble composition of the gravels generally is closely related to the character of the underlying rocks. As a rule, the gravels carry a large number of pebbles of the same kind as the local bedrock, particularly in the hard rock areas. The gravels of central Cape Breton and between Truro and Parrsboro, are largely composed of various igneous and metamorphic rocks. The many beach gravels found along the western coast between Yarmouth and Weymouth are almost exclusively made up of quartzite pebbles, some of them micaceous. In the Annapolis Valley deposits, the most common rocks are quartzite, slate, granite, and trap, their relative proportion varying in the different deposits.

In the table of the results of tests on gravel samples, the "durable" pebbles include:—

Granites and syenites: Cape Breton; between Truro and Parrsboro; between Upper Ninemile River and Milford.

Porphyries: Cape Breton.

Felsites: Cape Breton; between Truro and Parrsboro; between Upper Ninemile River and Milford.

Diorites: Cape Breton; a few places in the Annapolis valley.

Traps: Cape Breton; between Truro and Parrsboro; Annapolis valley.

Quartzites: eastern Cape Breton; many places on the mainland.

Metamorphosed slate: from the Annapolis valley southeast to the Atlantic coast.

The "intermediate" includes all the above-named rocks, when partly weathered, and the following:—

Coarse, white granite: in nearly every gravel deposit from Halifax west to Yarmouth.

Slaty, foliated or micaceous quartzite: western Nova Scotia.

Schist: central Cape Breton; between Truro and Parrsboro; western Nova Scotia.

Gneiss: central Cape Breton; southwestern Nova Scotia.

Amygdaloidal trap: Annapolis valley.

Slate, not splitting readily: central and western Nova Scotia.

Hard sandstone: almost everywhere throughout the province.

Limestone: very scarce in the Nova Scotia gravels, common in New Brunswick gravels.

The "soft" includes the intensely weathered rocks of any type and the following:—

Sandstone: everywhere throughout the province.

Slate: central and western Nova Scotia.

Shale: Cape Breton.

The classification of the pebbles into "durable", "intermediate", and "soft" is based on their ability to resist wear and impact. The durable kinds include rocks having an average percentage of wear of less than 4 and an average toughness of over 12; the intermediate types, an average percentage of wear of from 4 to 6 and an average toughness of from

5 to 12; the soft kinds, an average percentage of wear of over 6 and an average toughness of less than 5. The kind of rock that makes up the soft pebbles is of particular significance, owing to the fact that most of the wear on a gravel bears on the softer material. An abrasion test was made on most of the gravels included in the table[1], and it was found, as was expected, that the percentage of wear was, as a rule, higher for gravels having a large proportion of "soft" pebbles, but with wide variations from this general rule in some cases, due largely to the degree of softness of the soft pebbles. In fact the soft pebbles show all ranges of wear from 6 to 100 per cent.

The composition of the soft pebbles is also an important factor in the cementing quality of a gravel. As already stated, most of the Nova Scotia gravels have very little fine binding material, such as clay or loam; but, after they have been applied on a road surface, the softer particles crumble under traffic and form a powder that cements the gravel surface more or less strongly according to the composition of the crumbled particles. Traps, slates and shales yield a powder which binds well and quartzites, hard sandstones and some of the granites form very poor binders.

In table I boulders include all stones retained on 3″ screen; gravel, stones passing 3″ screen and retained on ¼″ screen; sand, everything passing ¼″ screen. Specifications usually call for a road gravel passing a 3″ screen and containing not less than 25 and not more than 50 per cent of material that will pass ¼″ screen.

Table III shows the results of tests made on gravels to determine their suitability as aggregates in concrete work. Only the material passing a ¼″ screen (sand or fine aggregate) is used for this test. The fineness modulus is an indication of the fineness of the sand; the finer the sand the lower will be its modulus. The importance of the fineness factor lies in the fact that for a given mix, a coarse aggregate will require a lower proportion of water than a fine one, to produce a concrete of a given plasticity; and that for a given plasticity and the same mix, a coarse aggregate will produce greater strength of concrete than a fine one.

[1] The results have not been inserted in the table on account of the test not being recognised as standard.

TABLE I

Results of Physical Tests upon Gravel Samples

Sample No.	Location	Granulometric Analysis: Proportion of gravel to sand: Per cent gravel	Per cent sand	Gravel: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200	Remarks
	Nova Scotia—																	
1	2 m. N.W. of Coxheath.	70	30	0	13	16	23	12	16	20	21	19	27	22	6	2	3	Very coarse river gravel, but part of the pebbles crumbles into fine on road. Used with very good results.
2	1 m. W. of North Sydney.	54	46	0	5	15	12	11	18	39	39	31	18	7	3	1	1	Irregularly graded beach gravel, high in sand. Has given good results on clay roads.
3	1¼ m. N.E. of Big Bras d'Or.	70	30	7	1	5	13	12	28	34	32	15	17	22	10	2	2	Very coarse beach gravel but on roads crumbles partly into sand. Satisfactory on light trafficked roads.
4	Big Bras d'Or........	44	56	0	11	26	14	10	16	23	15	11	11	14	18	17	14	Very bouldery and with very fine, rusty sand. Very poor surfacing material.
5	1⅓ m. N.E. of Baddeck Bay.	37	63	0	3	25	18	14	12	28	11	13	16	18	15	13	14	Weathered ferruginous conglomerate. Very good as binder but too fine and too soft to be used alone.
6	3 m. S.W. of Baddeck	35	65	0	0	4	16	12	21	47	15	17	20	19	13	9	7	Same as No. 5.
7	1 m. S. of Middle River.	73	27	13	7	23	21	8	13	15	25	19	22	16	9	4	5	Varies in size from place to place; generally coarse and bouldery. Although not durable, should give good results on local roads.
8	⅔ m. N. of Middle River.	72	28	11	18	21	13	10	12	15	24	21	22	17	8	4	4	Same as No. 7.
9	5¾ m. S.E. of North-east Margaree.	65	35	0	13	9	17	11	16	34	39	30	14	6	4	3	4	Coarse and very regularly graded. Unsuitable on account of pebbles crumbling too readily into fine.
10	3 m. S.E. of North-east Margaree.	74	26	0	3	9	26	14	19	29	41	19	13	10	7	4	6	Same as No. 7.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Continued

Sample No.	Location	Granulometric Analysis: Proportion of gravel to sand: Per cent gravel	Per cent sand	Gravel: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200	Remarks
11	Northeast Margaree..	68	32	8	10	23	19	11	13	16	24	20	23	20	6	2	5	Coarse, regularly graded. Much used with good results. Somewhat deficient in binding material.
12	¾ m. S.E. of Margaree Forks.	48	52	10	0	8	20	16	23	33	21	22	25	21	7	2	2	Irregularly graded and very fine. Sample coarser than average. Suitable only for light trafficked roads.
13	Southwest Margaree..	58	42	0	3	12	19	14	21	31	27	25	26	12	4	2	4	Medium fine, regularly graded. Very good.
14	½ m. S.E. of Dunvegan	45	55	0	0	3	16	19	22	40	18	23	34	19	3	1	2	Fairly uniform and of good quality, although somewhat fine. Deposit shows much more sand than gravel.
15	3 m. N.E. of Inverness	42	58	0	0	11	18	12	19	40	21	25	27	16	5	3	3	Same as No. 14.
16	2 m. E. of Inverness..	63	37	0	10	12	21	16	17	24	22	13	13	17	18	10	7	Medium fine, very rusty gravel. Very good.
17	Craignish............	61	39	0	4	2	22	16	20	36	37	24	18	11	4	3	3	Very regularly graded. Used with very good results.
18	½ m. S. of Troy.......	50	50	8	6	14	11	11	16	34	32	33	19	8	4	2	2	Beach gravel, varying in size from place to place. Much now being used on main road. Would probably give very good results with some binder added.
19	Hubley..............	34	66	13	25	7	15	4	10	26	17	18	20	16	10	8	11	Mostly boulders and very fine sand. Makes a good surface when dry, but not durable.
20	East Chester.........	50	50	8	15	18	17	8	12	22	22	26	33	16	2	0	1	Medium coarse, irregularly graded, rusty. Now being used on main road. Should prove satisfactory.
21	¾ m. S.E. of Mill Village.	74	26	0	16	20	17	10	16	21	39	23	16	10	6	2	4	Fine, regularly graded. Used on main shore road. Takes long to compact. Should be very good with binder added.

22	1½ m. E. of Greenwood	59	41	12	24	16	19	7	9	13	17	12	10	9	8	10	34	Irregularly graded and very bouldery. Too much material passing 200. Makes a smooth surface when dry, but not durable.
23	1½ m. E. of Yarmouth	39	61	0	15	9	19	9	14	34	19	28	34	13	3	1	2	Irregularly graded and somewhat too fine; a little rusty. Used with fair results; binds well. Only bank deposit near Yarmouth.
24	3 m. N.E. of Yarmouth.	58	42	0	8	20	21	12	17	22	21	12	12	11	10	10	24	Sand part too fine. Much used for roads; has proved quite good.
25	Meteghan River......	......	......	....	....	....	....	....	....	....	..	..	..	..	....	....	......	Fairly uniform; fine beach gravel, much used for roads. Durable, although does not compact readily.
26	Gilbert Cove.........	34	66	0	0	3	17	16	22	42	18	13	11	16	28	8	6	Irregularly graded beach gravel. Sample finer than average. Much used on roads with very good results.
27	Digby................	43	57	0	5	5	7	8	18	57	32	14	8	17	22	6	1	Mostly sand. Sample coarser than average. Too fine for durable road surfacing.
28	1 m. N. of Digby.....	......	......	....	....	....	....	....	....	....	..	..	..	..	....	....	......	Very uniform, coarse beach gravel. Should prove very good for roads.
29	Clementsvale.........	40	60	0	11	9	10	7	13	50	20	18	17	16	13	10	6	Regularly graded, very fine. Wears well on light trafficked roads.
30	1½ m. N.E. of Round Hill.	9	91	0	0	0	6	12	7	75	35	32	20	6	4	2	1	Mostly very coarse sand. Too fine for durable road surfacing.
31	1½ m. S.E. of Lawrencetown.	59	41	6	6	13	18	12	17	28	34	28	24	10	2	1	1	Medium coarse, very bouldery in places. Has given good service on roads.
32	2 m. S.E. of Brickton.	60	40	13	5	10	14	13	19	26	22	22	30	19	5	1	1	Very irregular as to size, from bouldery to very fine. Sample from regularly graded layer. In use for one year with good results. Should be screened.
33	½ m. E. of Coldbrook.	64	36	10	10	19	16	13	14	18	23	26	31	12	4	2	2	Rather poorly graded, but uniform. Has given good service for years on main road. Although not durable, it is the best gravel between Kentville and Berwick.
34	Melanson............	67	33	11	6	7	20	13	20	23	29	19	25	22	4	1	0	Very uniform. Should prove very good.
35	½ m. W. of Upper Nine-mile River.	63	37	8	2	13	27	11	16	23	22	27	24	13	5	3	6	Fairly regularly graded and of good wearing quality.
36	1 m. S.E. of Upper Nine-mile River.	64	36	9	9	16	18	14	16	18	19	32	34	6	3	2	4	About the same as No. 35, but a little softer. Used on roads with good results.
37	1 m. S.W. of Hardwood Lands.	45	55	0	0	11	24	16	23	26	12	17	42	22	3	2	2	Fairly regularly graded, but too fine. Has given satisfactory service on roads for several years.
38	1 m. N. of Truro......	66	34	10	17	22	11	12	12	16	19	16	26	25	8	3	3	Too high proportion retained on coarser screens. Used for years on roads with very good results.

TABLE I—*Continued*

Results of Physical Tests upon Gravel Samples—Concluded

Sample No.	Location	Granulometric Analysis: Proportion of gravel to sand: Per cent gravel	Per cent sand	Gravel: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200	Remarks
39	2 m. E. of Glenholme.	61	39	7	3	10	19	15	18	28	26	17	21	23	8	3	2	Coarse, very uniform. Extensively used for roads. Very good.
40	Glenholme..........	73	27	9	10	18	19	11	14	19	33	21	21	15	5	2	3	Very irregular in size, from bouldery to very fine. Used on roads for several years with good results. Should be screened.
41	2 m. N. of Great Village.	67	33	....	....	....	....	....	....	....	..	..	..	..	....	....	......	About the same as No. 39.
42	½ m. W. of Montrose..	41	59	0	6	7	16	13	20	38	18	18	21	22	12	5	4	Regularly graded and uniform but too fine. Could be used as good cementing medium on road surfaced with coarser and harder material.
43	Bass River..........	66	34	16	11	12	14	13	14	20	22	22	30	19	4	1	2	Coarse, regularly graded. Used on roads for several years with good results, although the gravel takes long to compact.
44	1 m. N.E. of Parrsboro.	59	41	0	7	11	14	10	22	36	39	31	16	7	2	1	4	Fine, fairly regular. Now being used on roads. Should prove very good.
45	Oxford...............	71	29	0	0	1	14	18	27	40	42	16	13	16	8	2	3	Deposit over ¾ sand. Sample of material retained on 0·3 in. sieve. (Inclined sieve in pit; material damp when sampled). Used with good results on clay roads.
	New Brunswick—																	
46	2 m. N.W. of Memramcook West.	65	35	0	0	7	21	14	25	33	34	22	17	9	5	4	8	Weathered rusty conglomerate. Much used on roads and quite suitable for that purpose.
47	2½ m. W. of Gagetown	34	66	0	0	0	3	16	27	54	20	23	24	23	5	2	3	Very uniform, but too fine for durable road work. Used with fair results on local roads under light traffic.

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48	1½ m. N.W. of Upper Gagetown.	60	40	0	9	10	29	8	14	30	26	20	26	18	5	2	4	Coarse, rather irregular in size. Has given very good service for years on roads.
49	1 m. W. of Babbits...	62	38	0	7	6	14	12	19	42	36	26	23	9	3	1	2	Proportion retained on ¼" and 8 mesh too high. Used on local roads with very good results.
50	Opposite Nashwaak..	63	37	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Medium fine, regularly graded. Apparently very good.
51	2 m. E. of Boiestown.	60	40	10	3	7	27	12	18	23	18	14	33	31	4	1	0	Coarse, irregularly graded. Has proved very good for road surfacing.
52	6 m. W. of Devon, (near Fredericton).	44	56	0	0	7	16	18	23	36	25	23	21	15	8	5	3	Fine, very regular in size. Too soft for durable road surfacing.
53	2 m. S.E. of Newmarket.	48	52	0	15	8	11	14	20	32	21	28	30	11	3	2	5	Very irregular in size. Very poor for roads.
54	3 m. S.E. of Newmarket.	63	37	0	12	12	29	13	15	19	23	18	21	14	8	8	8	Regularly graded, fairly coarse. Used with very good results. Gravel not very durable, but binds very well.
55	1 m. S.E. of Thomaston.	54	46	4	19	24	21	8	9	15	20	26	34	16	2	1	1	Very bouldery and coarse; coarse part very irregularly graded. Much used on roads with fair results. Should be screened.
56	"The Barony", 3 m. N.E. of Pokiok.	65	35	0	0	2	26	20	24	28	33	18	13	17	15	2	2	Very uniform, medium fine. Sand rather irregularly graded. Has given very good service on roads for several years.
57	1 m. W. of Allandale (Grant's Pit).	45	55	0	0	0	3	14	28	55	31	22	14	16	13	3	1	Irregularly graded very fine. Sample from regularly graded, coarser than average. Makes a good and smooth road surface, although not very hard; too much sand.
58	Lower Woodstock....	71	29	0	5	4	9	11	32	39	29	18	19	15	6	4	9	Very irregular in size, from very fine to very bouldery. Used with fair results on roads. Should be screened.
59	1½ m. W. of Woodstock	69	31	0	0	20	24	16	17	23	37	30	20	7	2	1	2	Very irregularly graded, with thick sand layers. Some gravel layers very regular in size, and quite suitable for roads.
60	2 m. N. of Hartland..	84	16	4	13	9	22	12	19	21	41	8	6	9	10	14	11	Very irregularly graded. Low in sand, but on road, part of the soft crumbles readily into fine, good binding material. Sample coarser than average. Suitable for light trafficked roads.
61	2 m. S. of Perth......	69	31	0	5	10	27	18	18	22	21	9	21	41	6	1	1	Medium coarse, very regularly graded. Apparently very good surfacing gravel.

TABLE II

Results of Physical Tests upon Gravel Samples

Sample No.	Location	Character of Material				Remarks
		Composition of pebbles			Shape of pebbles	
		Durable	Intermediate	Soft		
	Nova Scotia—	%	%	%		
1	2 m. N.W. of Coxheath..	45	25	30	Angular.......	Ferruginous trachyte, the weathered pebbles acting as a very good cementing medium on roads. About 3,000 cu. yd. available close to the road, also many thousand cu. yd. of bank gravel, the latter rather too fine.
2	1 m. W. of North Sydney	55	25	20	Angular.......	Soft part is all sandstone of fair binding quality. Amount very large.
3	1¼ m. N.E. of Big Bras d'Or.	10	20	70	Rounded and some flat.	Largely sandstone of fair binding quality. Small amount available above water level.
4	Big Bras d'Or..........	0	0	100	Angular.......	All very friable sandstone. Subsoil made up of this drift for over 15 miles along road.
5	1⅓ m. N.E. of Baddeck Bay.	10	20	70	Subangular...	Sandstone and very fine igneous. Binds very strongly but otherwise poor. Very large amount here and a few other places.
6	3 m. S.W. of Baddeck...	25	35	40	Angular.......	About the same as No. 5. Deposit covered with 2 to 4 ft. of sand.
7	1 m. S. of Middle River.	45	27	28	Angular.......	Soft part is friable schist and sandstone. Should bind fairly well. Very large amount.
8	⅔ m. N. of Middle River.	52	30	18	Angular.......	About the same as No. 7.
9	5¾ m. S.E. of Northeast Margaree.	5	10	85	Angular and flat.	Largely shale, slate and schist; nearly all very soft. Same material for several miles along road.
10	3 m. S.E. of Northeast Margaree.	25	45	30	Angular.......	About the same as No. 7.
11	Northeast Margaree.....	60	27	13	Subangular...	Granite, syenite, felsite, over half very hard. Of rather poor binding quality. Very large amount.
12	¾ m. S.E. of Margaree Forks.	43	24	33	Angular.......	Over half granite and syenite, a small part friable. Should bind fairly well. Over 20,000 cu. yd. available.
13	Southwest Margaree.....	40	40	20	Angular.......	Soft largely sandstone. Small amount of loam. Probably over 10,000 cu. yd. available.
14	½ m. S.E. of Dunvegan..	21	27	52	Subangular...	Soft composed of sandstone, felsite and shale, nearly all fairly sound. Amount of gravel unknown; deposit mostly sand.
15	3 m. N.E. of Inverness..	25	30	45	Angular.......	Same as No. 14.

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16	2 m. E. of Inverness	42	24	34	Angular	Sandstone, forms ⅓ and trap ½ of total. Binds very well. Amount unknown, probably over 10,000 cu. yd.
17	Craignish	49	27	24	Subangular	Sandstone, fine igneous and metamorphic. Binds fairly well, Several deposits; amount very large.
18	⅓ m. S. of Troy	82	18	0	Subangular	Fine igneous and sandstone. Very hard gravel, deficient in binder. Many thousand cu. yd. available along shore.
19	Hubley	0	100	0	Angular	All rather soft, coarse granite. This drift forms the subsoil nearly all the way from Halifax to Chester.
20	East Chester	64	33	3	Angular	Quartzite ⅓; metamorphic slate ⅓; coarse granite ⅓. Weathered slate should act as a very good binder. Amount available probably large.
21	¾ m. S.E. of Mill Village.	80	10	10	Angular	All quartzite, mostly very hard. Deficient in cementing power. About 5,000 cu. yd. available.
22	1½ m. E. of Greenwood	100	0	0	Angular	All very hard quartzite. This drift forms the subsoil for many miles along the road.
23	1½ m. E. of Yarmouth	40	40	20	Angular and some flat.	Quartzite, mica schist, the soft schist forming a fairly good binder. Probably 5,000 cu. yd. available.
24	3 m. N.E. of Yarmouth.	35	50	15	Angular	Same as No. 23.
25	Meteghan River	75	25	0	Subangular	Mostly quartzite. Deficient in cementing material. Gravel found nearly anywhere along shore.
26	Gilbert Cove	45	34	21	Angular and some flat.	Quartzite schist and slate. Durable gravel, cementing well on road. Found nearly anywhere along shore.
27	Digby	60	30	10	Subangular	Trap, felsite, quartz, sandstone. Amount very large, but mostly sand.
28	1 m. N. of Digby	58	36	6	Subangular	Over half trap, of good binding quality. Found nearly all along the shore of Annapolis basin, but of better quality here than elsewhere.
29	Clementsvale	45	43	12	Angular	Over half of pebbles under ½ in. are coarse granite; larger pebbles mostly quartzite and slate. Hard gravel, binding fairly well. Several deposits; many thousand cu. yd. available, including more sand than gravel.
30	½ m. N.E. of Round Hill	25	70	5	Angular	Mostly coarse, rather soft granite. Very large amount, mostly sand.
31	1½ m. S.E. of Lawrencetown.	82	12	6	Angular	Granite, quartzite, sandstone. Fairly hard gravel of rather poor binding quality. Over 50,000 cu. yd. available.
32	2 m. S.E. of Brickton	67	33	0	Angular	Metamorphosed slate, quartzite, granite. Hard gravel, binding fairly well on roads. Amount apparently very large, 3 ft. of sandy loam as overburden.
33	⅓ m. E. of Coldbrook	9	39	52	Flat and subangular.	Slate and trap; small proportion of intensely weathered pebbles. Binds very well on roads. Amount probably over 50,000 cu. yd.
34	Melanson	33	34	33	Angular and some flat.	Trap, quartzite, sandstone. Few friable pebbles. Amount unknown, probably over 10,000 cu. yd. 2 to 4 ft. of fine sand as overburden.
35	½ m. W. of Upper Nine-mile River.	43	21	36	Subangular	Fine igneous and metamorphic. Binds very well on roads. Amount about 5,000 cu. yd., probably includes much sand. Covered with 3 to 4 ft. of sand in places.
36	1 m. S.E. of Upper Nine-mile River.	33	21	46	Subangular	Granite, sandstone, limestone, shale. Binds very well on roads. Many thousand cu. yd. available. Upper 2 ft. of deposit intensely weathered and not to be used.

TABLE II—*Continued*

Results of Physical Tests upon Gravel Samples—Concluded

Sample No.	Location	Character of material				Remarks
		Composition of pebbles			Shape of pebbles	
		Durable	Intermediate	Soft		
		%	%	%		
37	1 m. S.W. of Hardwood Lands.	40	25	35	Angular.......	Fine igneous, sandstone, shale. Of very good binding quality. Amount available over 10,000 cu. yd.
38	1 m. N. of Truro.........	55	25	20	Subangular...	Granite, syenite, sandstone. Very hard gravel, of low binding power. Many thousand cu. yd. available.
39	2 m. E. of Glenholme....	85	5	10	Angular.......	Largely trachyte. Very hard gravel, of rather low binding power. Amount over 50,000 cu. yd.
40	Glenholme.............	88	9	3	Angular.......	Largely trachyte and trap. Very hard gravel of fair binding quality. Several deposits; very large amount.
41	2 m. N. of Great Village	73	18	9	Angular.......	Granite, syenite, trap, felsite. Very hard gravel, of fair binding quality. Amount over 50,000 cu. yd.
42	½ m. W. of Montrose.....	70	12	18	Angular.......	Fine igneous and sandstone. All the durable pebbles are very small in size. Ferruginous material, of very good cementing quality, but very fine. Several deposits; very large amount.
43	Bass River............	95	5	0	Angular.......	Fine igneous, nearly all very hard. Does not bind readily on roads, but better than the beach gravel found south. Amount practically unlimited.
44	1 m. N.E. of Parrsboro..	52	33	15	Angular.......	Soft part sandstone and shale. Fairly hard gravel; should bind well. Amount about 5,000 cu. yd. Other deposits to the north.
45	Oxford.................	33	52	15	Angular.......	Half of pebbles coarse granite. Soft part sandstone and granite. Binds well on clay roads. Very large amount. Another deposit of coarser and as good gravel 1½ miles south of Oxford.
	New Brunswick—					
46	2 m. N.W. of Memramcook West.	73	6	21	Rounded.....	Quartz and felsite. Soft part all weathered felsite, crumbling readily on road, and acts as a good binder. Amount very large.
47	2½ m. W. of Gagetown...	36	15	49	Angular.......	Soft part mostly sandstone. Ferruginous gravel of good binding quality but rather soft. Amount about 10,000 cu. yd.
48	1½ m. N.W. of Upper Gagetown.	49	15	36	Subangular...	Soft part sandstone and intensely weathered stones. Fairly hard and good cementing gravel. Ridge parallel to road; amount practically unlimited.

49	1 m. W. of Babbits......	64	24	12	Angular.......	Fine igneous and metamorphic; soft all sandstone. Fairly hard and binds well. Amount probably very large. Deposit covered with light bush.
50	Opposite Nashwaak.....	60	18	22	Subangular...	Fine igneous and metamorphic; soft all sandstone. Fairly hard and binds well. Amount about 2,000 cu. yd. A large deposit 1 m. to the north shows very poor gravel.
51	2 m. N.E. of Boiestown..	70	20	10	Angular.......	Fine igneous and metamorphic; soft all sandstone. Hard and binds well. Amount practically unlimited.
52	6 m. W. of Devon (near Fredericton).	49	6	45	Subangular...	Largely quartz and sandstone, the latter soft and ferruginous. Binds fairly well on roads, but too soft. Amount apparently large. Covered with 3 ft. of silt as overburden.
53	2 m. S.E. of Newmarket	21	18	61	Angular.......	Quartzite, sandstone, shale. Holds some clay. Of good cementing quality but too soft. Amount apparently large, but deposit holds probably much sand and boulders.
54	3 m. S.E. of Newmarket	40	27	33	Angular.......	Fine igneous and metamorphic and sandstone. Binds very well. Amount of gravel unknown, apparently over 25,000 cu. yd.
55	1 m. S.E. of Thomaston.	52	21	27	Angular and subangular.	Granite, quartzite; soft part sandstone and fine-grained rocks, partly weathered. Fairly hard gravel of poor binding quality. Amount very large. Another deposit to the northwest shows mostly sand.
56	"The Barony", 3 m. N.E. of Pokiok.	58	27	15	Subangular...	60 per cent of pebbles quartzite. Soft part intensely weathered rocks. Very good, hard gravel, cementing well on roads. Very large amount.
57	1 m. W. of Allandale (Grant's Pit).	52	36	12	Subangular...	Soft part largely schist or slate. Fairly hard, but too fine and does not bind strongly. Amount very large. Covered with 3 to 4 ft. of sand as overburden.
58	Lower Woodstock.......	46	24	30	Subangular...	Quartzose rocks, limestone; soft part nearly all calcareous shale, fairly sound and of very good cementing quality. Small amount of clay and $CaCO_3$. Amount of gravel very large.
59	1½ m. W. of Woodstock..	21	33	46	Angular and flat.	About the same as No. 58. Deposit carries much sand in places.
60	2 m. N. of Hartland.....	12	15	73	Angular and flat.	Soft part calcareous shale, a small proportion friable. Rather soft gravel, of very good binding quality. Small amount of clay and $CaCO_3$. Amount of gravel very large.
61	2 m. S. of Perth.........	12	67	21	Subangular and flat.	Over half fresh, hard limestone. Good hard gravel, binding very well on roads. Small amount of $CaCO_3$. Amount of gravel very large.

TABLE III

Results of Physical Tests upon Gravel Samples

No.	Fineness modulus	[1]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....	3·12	13	131	160	198	232	Hard, angular grains; pieces of spruce twigs and leaves in the sand
2....	3·90	10	156	160	198	196	Very coarse; composed of hard, angular grains, over half quartz; pieces of weeds and shells
3....	3·25	12	138	153	234	242	Sandstone and quartz grains; large amount of vegetable matter and a few pieces of shells
8....	3·12	13	123	134	196	227	Fairly large amount of mica
11....	3·15	13	124	124	226	217	Angular feldspar and quartz grains; very small amount of vegetable matter
18....	3·69	10	179	188	181	193	Very hard, angular grains; very clean
20....	3·47	12	117	125	138	186	Clean, angular quartz sand; small amount of iron oxide
21....	3·59	13	125	155	226	273	Very clean, angular, hard quartzite sand
24....	2·21	18	65	75	81	131	Unsuitable; too fine and carries large amount of schistose grains and some mica
26....	2·35	16	0	64	0	42	Very poor; too fine and contains clay; had not set in 7 days
27....	2·96	13	120	112	189	240	Angular, hard grains, including some quartz; somewhat too fine, but quite suitable
30....	3·79	12	102	117	164	228	Mostly angular quartz, with some feldspar; large proportion of mica retained on 100 and 200 sieves
31....	3·77	11	139	127	177	203	Very clean, coarse, angular quartz sand
33....	3·40	12	118	126	126	137	Small amount of iron oxide and twigs
38....	2·94	14	139	142	211	213	Angular, hard grains; small amount of iron oxide
39....	3·15	11	151	149	264	277	Same as No. 38
44....	3·83	14	54	91	60	151	All grains coated with clay; small amount of vegetable matter and iron oxide; unsuitable
46....	3·32	21	0	39	0	21	Very poor; too much iron oxide and clay; had not set in 7 days
61....	2·96	13	136	181	155	211	Hard limestone sand, irregularly graded, but quite suitable

[1] The standard test referred to in the table is made on a mortar composed of 1 part cement and 3 parts standard Ottawa sand. All gravels showing results of at least 100 per cent of the standard n mortar tests, are assumed to be suitable for concrete works.

BEDROCK AND DRIFT BOULDERS

Although bedrock exposures are numerous throughout the province as a whole, most of them are so far from a main highway that they cannot be considered as possible sources of road material at the present time. With the exception of the trap range of North mountain, northwest of the Annapolis Valley main road, important outcrops of good road stone close to the main highways are few. Drift boulders are very numerous, except in eastern Cape Breton and north of the Cobequid hills.

Very little bedrock is being used for road purposes and no systematic investigation was undertaken of that material. All rock exposures along or close to main highways were visited, but only those that looked fairly promising were carefully examined and sampled. Some rocks, which underlie large areas and are exposed at many places, were sampled at more than one point, in order to ascertain the variation in their road making quality and to arrive at an average for the rock as a whole.

Among the most common types met with is the white, so-called Devonian granite, which underlies nearly half of western Nova Scotia. This rock is generally very coarsely porphyritic in texture, with feldspar phenocrysts over two inches in size. The several samples taken (Table IV, Nos. 2, 6; also sampled in 1922), represent a finer phase of the same granite. It is durable enough for surfacing light traffic roads, for which the more coarsely crystalline phase is unsuitable. The importance of the granite as a road material is lessened by the fact that the finely crystalline phase is found in proximity to other more durable rocks.

Slate and quartzite are generally found associated together and underlie more than half the mainland. The slate is fairly fresh and hard, but splits readily in thin sheets and for that reason is not considered suitable for road work. The metamorphosed slate found near Halifax, across the Northwest arm, and at several points in the western interior, is fairly sound, and one of the best surfacing materials, (Table IV, No. 1). It should not be confused with the ordinary black slate underlying the city of Halifax, which is of no value as road material, except, perhaps as a binder. Quartzite is exposed in many places, most of the outcrops being of relatively small extent. North of Halifax, and between Chester and Jordan Falls, along the south shore road, the stone is generally massive, fine grained and in places slightly micaceous, but west of Jordon Falls it varies greatly in texture, from the ordinary massive even-grained phase to a schistose phase. The schist is unsuitable for road surfacing, but the massive quartzite is a very good road metal. It has rather poor cementing power, and would give better results on roads if used with a bituminous binder. Quartzite boulders are more economically available than the bedrock and are just as durable. (Table IV, No. 3; boulders and bedrock also sampled in 1922 and 1920).

Trap forms a prominent ridge over a hundred miles long and from two to four miles wide, between the Annapolis valley and the bay of Fundy, and occurs in the form of isolated, very steep hills between Truro and Parrsboro. In many exposures, the stone shows two very distinct phases, both in the form of horizontal or slightly inclined sheets, alternating with each other. One is a massive, holocrystalline trap, and the other a very finely crystalline, amygdaloidal trap, the amygdules being commonly white and consisting of zeolites. The massive trap is an excellent material for road surfacing and has given good service as waterbound macadam. It is very easy to quarry owing to its columnar structure, and is available in very large amount all along the Annapolis Valley main road and at several points along the Truro-Parrsboro road. Trap boulders, on account of being more weathered than the bedrock, are much less desirable (Table IV, No. 7; boulders and bedrock also sampled in 1922 and 1920). The amygdaloidal trap, wherever exposed, is intensely weathered and is quite unsuitable for roads. Several samples of the stone were taken, but the rock crumbled so easily that satisfactory test pieces even could not be prepared for some of the tests.

Diabase, occurring as dikes, close to the south shore road between Cherry Cove and Shelburne, and diorite, outcropping as dikes and sheets between Bear Cove and Digby and immediately south of the Annapolis valley, are two very good road stones, suitable either for waterbound or bituminous macadam construction. (Table IV, Nos. 4, 5, 8, 9; also sampled in 1920).

Altered or metamorphosed sandstone, which occurs as a somewhat regular belt running south of the Annapolis valley between Gaspereau and Inglisville, outcrops at many points. It is a very hard and tough rock; but has very poor cementing power and should only be used with an artificial cement in road surfacing (Table IV, No. 10).

Drift boulders are very common throughout the province, except north of the Cobequid hills, where they are nearly absent, and in eastern and western Cape Breton and the Annapolis valley, where they are rare. They are very numerous all along the south shore road from Halifax southwest to Shag Harbour, north of Halifax, and in several parts of central Cape Breton. As a rule, the composition of the boulders is the same as that of the gravels of the same locality. Exceptions to this rule are found in a few places in the quartzite country along the south shore road, where the boulders are mostly granite, and the gravel is almost exclusively quartzite. Boulders are not generally considered desirable material for waterbound macadam surfacing on account of their heterogeneous character. If they are gathered and crushed for roads without discrimination, an uneven wear is likely to result, owing to the unequal durability of the different rocks. In places where a durable type predominates over all other kinds, boulders may constitute a valuable source of supply of road stone, especially if the more desirable rocks are easily distinguishable in the fields and can be picked out by an ordinary labourer from other kinds. Where boulders of a durable character occur, usually gravel of good quality is also to be found, and the latter is used by preference. North of Halifax, and at many points along the south shore road, however, there are very large amounts of durable quartzite boulders, while good gravel deposits are either very scarce or totally absent. Here, crushed quartzite boulders have been used for road surfacing with very good results.

Large quantities of blast furnace slag from Sydney and Londonderry have been used locally for road surfacing. From the results of tests made on this material (Table IV, No. 11; also sampled in 1922) it is undoubtedly too soft to be used as aggregate in waterbound macadam surfacing, but on account of its high cementing power, it would act as a good binder in either gravel or waterbound macadam roads. If used in this way it should not be mixed in large fragments with the gravel or broken stone, but should be crushed into fine screenings and applied in a thin layer on top of the gravel or broken stone, then sprinkled and rolled in the same way as with ordinary stone screenings in waterbound macadam construction.

TABLE IV

Results of Tests upon Bedrock and Slag

No.	Location	Rock Type	Physical properties						
			Wear, per cent	French coefficient of wear	Toughness	Hardness	Cementing value	Specific gravity	Water absorbed, lbs. per cu. ft.
1	Near Halifax	Metamorphosed slate	2·44	16·4	21	17·7	74	2·82	0·39
2	Near Halifax	Granite	3·24	12·3	9	18·4	69	2·71	0·39
3	5 m. N.E. of Liverpool	Quartzite	1·74	23·0	17	17·7	27	2·71	0·41
4	2 m. E. of Liverpool	Diabase	2·97	13·5	11	16·5	47	3·15	0·40
5	3 m. N.W. of Shelburne	Diabase	2·46	16·3	18	18·3	162	2·91	0·52
6	Shag Harbour	Gneissic granite	2·86	14·0	10	18·0	61	2·72	0·52
7	1 m. N.E. of Rossway	Trap	2·72	14·7	14	16·6	129	3·02	0·92
8	3 m. S. of Digby	Diorite	2·55	15·7	22	17·7	87	2·94	0·65
9	1½ m. W. of Nictaux	Diorite	2·52	15·9	26	18·8	88	2·99	0·29
10	4 m. S.E. of Kentville	Altered sandstone	1·62	24·7	35	19·5	9	2·66	0·27
11	Londonderry	Blast furnace slag	17·27	2·3	......	......	300	......	....
12	6 m. W. of Devon (near Fredericton, N.B.).	Dolerite	2·20	18·2	32	18·4	88	2·91	0·45

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