CANADA

DEPARTMENT OF MINES

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

MINES BRANCH

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INVESTIGATIONS IN 1921

CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

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By Henri Gauthier.

(Annual Summary Report of the Mines Branch, pp. 253–318.)

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1923

No. 591.

CERAMIC DIVISION

Joseph Keele
Chief of Division

I

OUTLINE OF WORK DONE

The field and laboratory work of the Ceramic Division for the past season consisted in the investigation of raw materials used in the ceramic industries. These include clays, shales, feldspar, quartz, limestone, talc, bauxite, magnesite, etc.

A large number of samples of clays and shales were tested for people in various parts of the Dominion; but as most of these samples were not very intelligently collected, and the localities from which they came not very clearly indicated, the results of the tests are not recorded.

In view of the fact that most people do not know how to examine and sample a deposit of clay or shale, it has been deemed advisable to devote a part of this summary report to giving definite instructions to unskilled prospectors, and others, relative to the proper way to select samples from promising deposits.

The proper sampling of deposits, especially those liable to variation at depth, or those containing impurities, is very important.

Certain clays which might be utilized for the manufacture of pottery were tested in the laboratory, and the results are given in the following pages. These clays are of low grade, but when prepared are quite plastic and smooth, so that they may be used for the manufacture of ornamental pottery, or for instruction in modelling in schools where training in manual arts is given.

Refractory clays are of rare occurrence in Canada, and no new localities for them were recorded during the past season, but the occurrence of semi-refractory clays from new localities in New Brunswick is recorded in this report.

There are large areas in Canada, especially in the province of Ontario, where stony clays abound, and where stoneless clays occur only in small thin patches which are easily exhausted. Many attempts have been made to work stony clays, but very few are successful. A section of this report gives a description of the methods generally used in overcoming the difficulty.

The white scum which sometimes obscures the colour of the surfaces of brick is objectionable if they are to be used for facing purposes, and brick having this defect are frequently rejected by architects. The method most generally used for curing scumming is described in this report.

The field work for 1920 consisted in gathering data for a bulletin on the clay and shale deposits of Ontario. A journey was also made to the Grand Lake coal area in New Brunswick for the purpose of sampling clays in the coal mines.

II

TESTS OF CLAYS FROM VARIOUS PROVINCES

Nova Scotia

Avonport.—A series of experiments was made for Messrs. L. E. Shaw & Co., Avonport, Nova Scotia, on mixtures of plastic brick clay used at their plant, and shale which outcrops in the vicinity.

The object of the tests was to find out if the shale was a suitable material for making clay products, and if it could be used in combination with the clay for making certain wares for which the clay alone was unsuited.

Although the shale when ground to pass a 10 mesh screen was found to be plastic enough when wet to flow through a stiff mud brick die, it was not plastic enough to pass through a hollow block die without tearing, furthermore the burned colour was not good, and hence brick made from the shale alone could not be used for facing brick.

A mixture of equal parts of clay and ground shale was found to give perfect results in working through a hollow die, or for making rough texture facing brick, as the mixture produced a much better red colour than the shale alone.

It is possible to make hollow ware by using two parts of clay to one of shale, thereby lessening the expense of grinding the shale, but for rough texture face brick, equal parts of clay and shale give the best results.

By adding to their equipment a dry pan for grinding shale, this plant was able to make face brick and fireproofing, whereas hitherto it was restricted to the manufacture of common brick and field drain tile. The temperature of burning the new product was not increased to any appreciable extent over that of burning the ware already made.

St. Margarets Bay.—A sample of so-called kaolin was collected by Mr. E. R. Faribault, of the Geological Survey, from a deposit on the property of Mr. David McLean, at the head of St. Margarets bay, Halifax county.

The sample submitted consisted principally of fragments of granite with some yellowish silty clay, and some small lumps and particles of soft white material. The white lumps are probably the magnesium mineral known as saponite.

The sample when washed through a 200 mesh screen yielded only 20 per cent of clay. This clay when made up into bricklets and burned had an excessive shrinkage and a dark red colour. It softens and deforms at a comparatively low temperature.

The material is of no economic value.

New Brunswick

Grand Lake Coal Area

The Carboniferous rocks in the Grand Lake basin contain a thin coal seam which has been mined at several points for a number of years. In order to provide headroom for mining, about two feet of the shale overlying the coal is removed and brought to the surface, where it is piled in waste dumps.

This shale is suitable for the manufacture of red building brick, and possibly for floor tile, or other vitrified products. A detailed report on the shales of this locality is given in Memoir No. 44, Department of Mines, Ottawa, 1914.

Several new openings on the coal seam have been made in the last few years, and the clays and shales at these points have been sampled by Mr. W. B. Evans, of Rothwell, and forwarded to the Mines Branch for examination.

The clays underlying the coal seam are more refractory than those overlying the coal, hence most of the samples were underclays. The underclays were found to vary in colour in the raw state and in working and burning properties. Some of the samples were smooth and plastic and might be classed as stoneware clays, suitable for making pottery. None of the samples were found to be refractory enough to be classed as fireclays, although they stood enough heat to be called semi-refractory, and are useful clays for many purposes, especially for making vitrified wares. The thickness of the underclays is not very great, and as far as could be ascertained do not exceed four feet, and some of them are less. Some of the beds can be obtained near the surface by stripping the overburden, but others are obtained by underground mining and could probably be taken out with the coal.

No. 4.—Clay under coal seams on Alva McMann lot near Newcastle wharf.

This is a soft grey and mottled clay, very plastic and smooth when wet. It burns to a hard, pale red-coloured body at low temperatures, but is vitrified and of a grey colour at higher temperatures. The shrinkages are high. The clay softens and deforms when heated to the bending point of standard pyrometric cone 15 (2,600° Fahr.).

No. 5.—From layer one foot thick, directly under coal on south side of Newcastle creek near saw mill.

This is a soft grey clay which is very plastic and smooth when wet. It burns to a hard cream-coloured body at low temperatures, and forms a grey vitrified body at about cone 7.

The clay begins to soften at cone 20 (2,786° Fahr.) and is the most refractory of the group.

No. 6.—Mottled yellow and grey clay, underlying No. 5, and evidently contains more iron oxide, but its working qualities are similar to No. 5, and it has a slightly higher shrinkage.

It burns to a light red-coloured hard body at the lower temperatures. This clay softens and deforms at cone 15 (2,600° Fahr.) so that while it may be classed as semi-refractory, it does not stand as high a temperature as No. 5. The upper and more refractory part of the bed is too thin, and it would probably have to be mined along with the lower part.

No. 7.—Under coal seam on McDougall property close to northern bank of Newcastle creek.

Dark grey clay carrying particles of coal. It is very plastic when wet and works very smoothly, but its shrinkage in drying is rather high.

It burns to a porous pink body at low temperatures, but becomes vitrified at about cone 7.

This clay softens and deforms at cone 17, so that it has semi-refractory properties.

No. 8.—Under coal seam on shore of Syphers' cove, Grand lake. Brown, grey and rusty mottled clay, containing much grit.

This clay is not quite so plastic and smooth as the others and its shrinkage is less.

It burns to a pale salmon-coloured, porous body at a low temperature.

This clay softens and deforms at cone 10 (2,426° Fahr.) so that it is not even semi-refractory.

No. 9.—Clay under coal seam exposed in ditch along road on hill at south side of Little river.

Soft yellow shale with fairly good plasticity. It burns to a hard red body at low temperatures. This shale has semi-refractory qualities, as it does not deform below the softening point of cone 17 (2,676° Fahr.).

No. 12.—Clay under coal seam on south bank of Little river, one mile above road.

Soft dark mottled clay, fairly smooth and plastic when wet. This clay gave practically the same results in testing as No. 9.

No. 10.—Hard grey shale, five feet thick, under coal seam on the stripped area of Rothwell property.

This shale was ground to pass a 12 mesh screen, but the ground shale has only a low plasticity when mixed with water, so that it was difficult to mould it into shapes. It burns to a porous red body at low temperatures, but will soften and deform at about cone 5 (2,246° Fahr.).

The working qualities of this shale would be improved by the addition of some of the plastic underclays from another locality, and the mixture could possibly be used for making fireproofing, or paving brick.

Summary of Tests.—The results of the tests made in these clays prove that some of them might be used for foundry clays, or for making stove linings and other products in which a high heat resistance is not demanded. Their plasticity, working and vitrifying qualities are good enough to recommend them for the manufacture of sewer pipe, or electrical conduits, but as their shrinkage is rather high they would require to be mixed with some of the hard shales in the district to remedy this defect.

A similar mixture would also be necessary in producing face brick and fireproofing.

Some of the clays would be suitable for making stoneware household articles, and ornamental pottery.

St. Andrews.—A sample of clay from the bank of the St. Croix river at Bayside, 6 miles from St. Andrews, was tested for Mr. B. Kane, Charlotte County Cottage Crafts.

This is a grey, slightly calcareous, silty clay, apparently free from pebbles, or coarse grit. It developed fairly good plasticity when wet and works easily for moulding. The drying qualities are good and the shrinkage on drying is low, being only 4·5 per cent. It burns to a light red and porous but hard body at cone 010, the total shrinkage at this temperature being 6 per cent and the absorption 13 per cent. When burned to cone 06 the test pieces are darker in colour and the body harder, the total shrinkage being 9 per cent and the absorption 6·5 per cent. When burned to still higher temperatures the shrinkage is greater and the material is liable to soften and deform.

This clay would be suitable for making good hard common red building brick by either the soft mud, or the wire cut process, and as its tensile strength in the raw state is good it could probably be used in the manufacture of field drain tile, but it could not be used for making vitrified ware.

Ontario

Kenora.—Six samples of clay and sand were sent by the Keewatin Lumber Company, of Kenora, to the Mines Branch for testing their suitability in the manufacture of brick and drain tile. The materials are glacial lake clays, varying in colour from light grey to black, and the sands are apparently from the raised beaches near the Lake of the Woods.

These clays have fairly good plasticity and working qualities, but their drying qualities are not good. They require the addition of sand in order to reduce the shrinkage and assist in the drying. The clays, however, when mixed with sand are capable of making good red building brick, or field drain tile, but they are not suitable for the manufacture of vitrified ware.

Finmark.—A sample of clay from Finmark was sent for testing by the Division of Development and Resources, Canadian Pacific railway. This was fine-grained reddish calcareous clay, with streaks and layers of grey silt.

This clay is very plastic and has good working qualities, but its shrinkage on drying is 9 per cent, which is rather high.

It burns to a dense hard red body at 1,700° Fahr., but when burned to 1,800° the clay shrinks greatly and is near its softening point.

This clay would probably be suitable for the manufacture of brick and drain tile if about 30 per cent of sand was added to it.

The clay when tested for pottery was found to contain some particles of coarse grit, so that it had to be washed and screened.

The washed clay worked well on the potter's wheel so that any desired shap · could be made, but the shrinkage is rather too great. A mixture of washed clay to which 35 per cent of flint was added gave a good working body, and when coated with a white slip inside, and the whole covered with clear glaze, would be suitable for cooking ware.

Desbarats.—A sample of clay from Desbarats lake was submitted for testing by Mr. Jacob Olsen, of Desbarats. This is a reddish calcareous clay, with white films, and layers of silt, very similar to the clay from Finmark.

This clay is very plastic and stiff when wet and is difficult to work. Its working and drying qualities are improved by the addition of 35 per cent of sand. The mixture yields a good hard building brick of light red colour.

Kingston.—Six samples of clay, loam and sand were submitted for testing, by Mr. W. M. Goodwin, M.E., and were collected on the east half of lot 23, in the fourth concession of Kingston township.

The clays from this locality are very stiff and difficult to work when wet. The shapes moulded from them are difficult to dry and the shrinkage in drying is excessive.

Samples of loamy and sandy clays are low in plasticity but would probably be suitable for making common red building brick by the soft mud process.

Mixtures of the stiff clay, the loamy clay, and sand were used, and resulted in very good common red building brick, but on account of the difficulty in drying, they would have to be dried outdoors on racks and pallets, and not indoors in an artificially heated dryer, as fast drying would result in too many cracked bricks.

III

POTTERY CLAYS

The Summary Reports of the Mines Branch for 1919 and 1920 contained chapters on tests of pottery clays from various parts of the Dominion. A short description of how pottery of various kinds is made, and the compositions of glazes and enamels with which they are coated, is included in the 1919 report. Clays from some additional localities were procured, and tested during the past season, the results of which are given in the following pages.

Surface clays, generally of glacial origin, are the principal materials upon which work was done, as these are the only kind available over the greater part of Canada.

The higher grade of clays such as stoneware clays, fireclays and kaolin, are comparatively scarce in this country, and are restricted to a few localities. The principal accessible source of stoneware clay is confined to certain areas of southern Saskatchewan,[1] but a small quantity is also found in Nova Scotia and New Brunswick.

As the glacial clays will not stand a very high fire, the glaze that is applied to them must be easily fusible, otherwise the ware will distort when fired for the second time after the glaze coat is applied.

Nearly all the surface, or glacial clays, contain more or less grit, and are not smooth enough to be shaped on the potter's wheel, consequently, they must undergo preparation which will eliminate the coarse material. This is accomplished either by slaking the clay in water and passing it through a screen, or by drying the clay and pulverizing it, but washing and screening is the method generally employed.

Heavy household pottery, such as butter crocks, mixing bowls and jardinieres, can be made from the washed glacial clays. The only objection to their use is that the body is porous, and when the glaze becomes accidentally chipped off, a spot which gathers dirt results. The stoneware articles are not open to this objection, as even when the glaze chips the vitrified body beneath will not absorb water.

The glacial clays cannot be vitrified, because when the vitrification point of these clays is approached, softening and distortion takes place, consequently the temperature at which the ware is burned is kept well below their vitrification temperature.

While household pottery made from surface clays may not be able to compete with those made from stoneware clay, except in a limited way, there is a large demand for glazed ornamental ware, which has a distinctive treatment both in form, colour and texture, and this demand can be supplied in part by wares made from the common clays.

[1] The Clay Resources of Southern Saskatchewan, by N. B. Davis, Mines Branch, Ottawa.

New Brunswick

Newcastle.—The clay bed lying beneath the coal seam in the vicinity of Newcastle is very soft and plastic and may be used as a pottery clay. The clay is not uniform in quality but varies slightly in different localities, as shown by the results of tests given in another section of this report. The clay contains a few coarse rock particles, and an occasional thin parting of coal, so that it would require to be washed and screened before using. The washed clay has good tensile strength in the raw state and is very smooth, so that it works well on the potter's wheel. The pottery forms made from it become hard at a comparatively low temperature.

Matt glazes maturing up to cone 3 can be used safely, but good pottery covered with bright glazes was obtained when burning to cone 05. This clay can be more easily treated by the washing process if it is dug and allowed to weather for several months.

St. John.—The red surface clay found in the vicinity of St. John and used in some places for making building brick gives very good results as a pottery clay. It is used at the Foley pottery on Loch Lomond road for making flower pots. When tested in the laboratory it was found to be one of the few surface clays which could be used on the potter's wheel without preliminary washing and screening, and a great range of glazes can be applied to the burned body when fired at temperatures ranging from cone 010 to cone 05.

Black ware can be made from this clay by packing the pieces in sawdust placed in saggers. After being fired to cone 06 the ware comes out with an ebon black colour throughout.

Use of Underglaze Colours on Pottery and Tiles

Some of the highly calcareous clays found in various parts of southern Ontario are very good for pottery, as far as working qualities are concerned, but some of them, owing to their high lime content, and the very porous character of the burned body, are difficult to fit with a suitable glaze, or to keep the glaze from sinking into the body during the firing.

It has been found that by dipping the green ware in a slip made with underglaze colour mixed with stoneware clay and then fired, that the coloured slip forms a hard surface. The burned ware is then covered with a transparent coloured glaze and burned the second time. Some very beautiful colour effects were obtainable in this way as the underglaze colour is not entirely concealed by the overglaze.

Underglaze colours are extensively used on pottery and tile made by the classes in manual arts at the Ottawa Public Schools. The underglaze colours are mixed with stoneware clay slip and applied with a brush to the incised or sunk patterns on the tiles and vase forms before they are quite dry. This is a simple method of obtaining colour effects on burned clay which answers very well for educational purposes, but if the piece is to be used it must be subsequently covered with a transparent glaze, as the slip colours, although hard, soon become soiled by handling.

New Potteries

We have frequently called attention to the opportunity that exists in Canada for selling locally made pottery and tile instead of imported articles. People visiting places of interest desire especially to obtain articles of local manufacture which are distinctive in treatment and different from the monotonous and uninteresting mass production of foreign factories.

Three potteries were recently started with the object of taking advantage of this demand.

In Alberta a pottery at Banff is making wares in which pre-historic Canadian Indian designs are adapted for the decoration or the form. The stoneware clays from Saskatchewan are used, as there is no clay available at Banff for this purpose. As the mountain scenery and hot springs at Banff attract a multitude of visitors, it is one of the best points in Canada to display local handicrafts for sale.

A plant at Bowmanville, Ontario, has begun making garden pottery, such as jardinieres, window boxes, etc., using local clay, which burns to a hard buff coloured body and is either finished plain or covered with coloured glazes.

The Charlotte County Cottage Crafts, at St. Andrews, N.B., recently added pottery to their list of handicrafts. This department is under the superintendence of Mr. B. Kane, an English potter. Their object is to make clay wares of simple design and patterns, which cannot be obtained in the ordinary industrial factories. A red burning brick clay from the bank of the St. Croix river is being used at present, but other clays from New Brunswick, or Nova Scotia, will also be used.

IV

KILN SCUM ON FACE BRICKS

Occasionally red brick is much disfigured by light patches on the surface. This bleaching or discoloration, referred to as dryer, or kiln scum, is usually caused by the presence of soluble sulphates in the brick mixture, introduced by the clay or shale, or in the water with which the batch is mixed. During the drying process these soluble salts are concentrated at the surface of the bricks, and later, in the heat of the kiln, react with the iron oxide contained in the brick body causing it to impart a buff colour to the brick instead of the usual red, or the salts may simply form a light coloured opaque film which masks the true colour of the brick.

A bad case of scumming of face brick at their plant caused much trouble and loss to Merkleys, Ltd., at Ottawa, during 1921. Late in the season samples of scummed brick were submitted to the Mines Branch with the request that the source of the trouble be located and, if possible, a means of preventing further scumming be prescribed.

This brick is made from a mixture of Utica-Lorraine shale and marine clay by the stiff mud process. A qualitative analysis of the unburned brick showed the presence of water-soluble sulphates of lime and magnesia in sufficient quantity to account for the scum on the burned ware.

Several samples of shale and clay were then tested for sulphates with the following results. The clays were found to be free from sulphates, but, in all cases, the shale contained such salts. The upper beds of shale, which are much weathered and have been leached by surface waters, contained very little, as did the lowest unweathered shale, while the middle beds which were only partially weathered and from which the sulphate salts produced by the oxidation of pyrite had not been removed by surface water, contained a fairly large percentage.

Since these middle beds are necessarily the source of most of the shale used, it would therefore not be practicable to work on a brick mixture without introducing these trouble-causing sulphates.

The problem then was to determine the best and cheapest means of rendering the sulphate salts harmless.

The water contained in the freshly made brick takes the soluble sulphates into solution, and as the drying process progresses the water flows by capillary action to the surface where it is evaporated, leaving its burden of soluble salts concentrated at the point where they are most harmful.

By the addition of barium carbonate to the brick mixture a reaction takes place between it and the soluble sulphates of lime and magnesia, producing barium sulphate and carbonates of lime and magnesia, all of which are relatively insoluble and therefore not productive of scum.

On analysis, the brick mixture yielded ·023 per cent of sulphur trioxide. By calculation it was found that about three pounds of barium carbonate per 1,000 bricks would be required to completely render the soluble sulphates insoluble.

Test bricks were made up in which this proportion of barium carbonate was incorporated, and burned in the Ceramic Laboratory. They were free from scum. Following this, a trial run of 30,000 bricks containing the barium carbonate was made at the brick plant. These bricks, when burned, were likewise free from scum.

Subsequently, the company installed a machine at the plant to feed the barium carbonate at a uniform rate into the pug mill, and it has been reported that during the early months of 1922 there has been no further trouble from scum.

Other salts of barium might be used in place of the carbonate, but they would have to be under much closer chemical control, lest they themselves cause scum.

Another means by which the scum may be prevented is to greatly increase the rate of drying the green brick. If the drying progresses slowly the evaporation takes place at the surface of the brick and any soluble salts will be concentrated there. If, however, the drying is hastened beyond a certain rate, the surface of the brick quickly becomes dry, and the balance of the moisture in the body is evaporated from below the surface and thus the bulk of the soluble salts will remain below the surface where they cannot produce any scumming.

This method has certain disadvantages. Some clays cannot withstand rapid drying without cracking. At best, surface checking is almost sure to develop. Then, also, in order to obtain rapid drying, alterations in the drying chambers would be necessary in some plants and additional fuel would be required where direct heat is used for drying.

V

WORKING STONY CLAYS FOR BRICK AND TILE

Clays containing pebbles or stones are usually avoided by brick and tile makers when choosing a suitable location for the erection of a plant.

Mistakes have frequently been made in the past in Canada by erecting plants on sites where stony clay occurred, when a thorough preliminary examination of the ground would have proved the futility of such an enterprise.

In some cases however, plants which have been working for years on perfectly stoneless clay, making good burned products, find on extending their clay pits that they are gradually running into a stony variety of clay.

In many parts of southwestern Ontario only a foot or two of the surface clay is stoneless and fit to be used for tile making, as stones invariably are encountered below this depth. A thin sheet of stoneless clay is so quickly worked out that the distance from the clay pit to the machine is constantly increasing, so that tilemakers would like to dig deeper in the vicinity of their plants if they dared to do so.

Over the recently opened agricultural region along the National Transcontinental railway, between Cochrane and Hearst, is a great sheet of plastic stony glacial clay. It is difficult to select a patch here which would be sufficiently free from pebbles for use in brick and tile making, but doubtless enough clean clay could be obtained for a small output. The clay burns to a buff colour, and will make brick or tile of very similar quality to buff or so-called white products in southern Ontario.

There are large masses of plastic yellowish-grey, glacial clay in the vicinity of Hamilton, Ontario, and along the Welland canal, as well as several parts of the Niagara peninsula. Much of this clay appears to be stoneless on a casual inspection, but close scrutiny generally reveals the presence of small rock particles and pebbles. The pebbles being coated with clay are liable to be overlooked in a hasty examination.

If a clay contains only a few scattered pebbles of rock other than limestone or dolomite it may be worked, if its properties otherwise are good. Broken wires may frequently occur in the cutter if stiff mud brick is being made, or an occasional brick will fire check if it contains too large a pebble, but if proper crushing rolls are provided for the clay to pass through, or if a dry pan is used for grinding, the loss of time, due to broken wires, can be stopped.

It is the presence of limestone pebbles that causes the real difficulty in working stony clays.

Palissy, the celebrated French potter, experimenting with various clays in the sixteenth century, and recording his impressions of them, says:—

> There are some kinds of clay which are of evil nature, because among them there are little stones, which when the vessels are baked, the little stones which are in the said vessels are reduced to lime, and suddenly when they come to feel the humidity of the air they swell and cause the said vessel to split in the place where they are enclosed, and this is because the said stones were calcined in the baking, and by this means many vessels are lost, however great the labour one may have employed upon them.

This quotation expresses the experience of all clay-workers from Palissy's time to the present day.

Crushing and Grinding

Many methods have been tried for eliminating the troubles due tc limestone in clay, the simplest probably being that of using a pair of rolls set above the machine.

Rolls designed for crushing stony, plastic clays, reject the rocks or hard portions which are too large to fall within the angle of nip, and grind or pulverize the smaller stones which pass through with the clay.

Another device is to use a dry pan with the mullers set an inch or so above the surface of the pan. This process is supposed to break down the clay and force it through the perforated bottom of the pan while the pebbles stay behind. The pan is stopped occasionally and the stones thrown out.

Another plan is to grind the clay, pebbles and all, in the ordinary way in a dry pan, working continuously, and run the clay over screens so as to reduce the limestone pebbles to a small enough size to be harmless.

In using the dry pan method the clay must be in the dry condition, which involves storage room for drying clays, or else a rotary dryer should be used.

It has been proved that unless limestone in clay is ground finely enough to pass through a 30-mesh screen it will cause trouble by developing soft white specks in the burned bricks, which will cause flaking of the surface. Of course, these grains of lime, unless very plentiful, would not weaken a well-burned brick very materially, yet they would be sure to disfigure brick for facing purposes.

As it is not practical in any of the crushing or grinding processes outlined above to reduce the pebbles to this small size, the trouble with lime grains is not entirely eliminated by them. Furthermore, any of the rough grinding processes, such as passing the clay through rolls, merely accentuates the trouble, since it often breaks up one pebble of limestone into several smaller ones, each of which then becomes active after burning.

Washing

One effective way to treat clays containing limestone pebbles is by a washing process, which would leave the stone behind as a heavy residue and the overflow taking the fine clay down to settling basins.

Washing of high grade clays, such as china clay and paper clays is the common practice, but the poorer grade of clays used for brick and tile are not washed because the value of the product will not offset the extra expense. One plant at least in the United States successfully cleanses glacial clay from limestone pebbles by a washing process; it is situated at Hutcheson, McLeod county, in Minnesota. Its operation is described in the report by Mr. Frank Grout, on the Clays of Minnesota, Bulletin 678, United States Geological Survey, as follows:—

The washing machinery occupies a space not over 20 feet square and 15 feet high, and washes 130 yards of clay in a day. The clay from the bank is hauled by cable car to the washer, where it is mixed with an excess of water and agitated by a series of vertical rods fastened to a rotating cross-beam. The harrow-like motion of these rods tends to throw the larger pebbles towards the centre and leaves the fine clay and sand suspended and distributed throughout the washer pit. A bucket elevator of continuous operation dips into the pit near the center and removes the gravel. The gravel, if cleansed, forms a by-product of considerable value. At the sides of the pit a screen of proper mesh allows the escape of the fine sand and clay to one of a series of open ponds in which they are allowed to settle. After a time some of the water is pumped off and the rest is left to sink into the ground. The sand naturally settles close to the intake of the pond, and the clay is carried to the farther side. After partial drying the material is taken to the stiff-mud machine, where the clay and sand are mixed in approximately the same proportions in which they existed in the drift before the washing. Experiments are now in progress to determine whether the clay is improved by standing in the settling ponds all winter. The gravel is sold for concrete. Both the clay and the sand contain a considerable amount of calcium carbonate, but if care is taken to remove the coarser sand the lime does no harm, and it is certainly less abundant than in the unwashed drift. The plant at Hutcheson uses three round down draft kilns, and plans are made to double the capacity. It has been found possible with this clay to produce a very good drain tile and hollow building block, so that the production of common brick has become secondary.

Some of the glacial stony clays in southern Ontario would yield good tile clays when washed, and a small or medium sized local plant situated in a district where there are no tile plants at present and no stoneless clays available, should have a chance of succeeding.

A brick and tile plant at Perth, in eastern Ontario, made a practice of washing stony clay, which enabled it to produce durable wares which brought a higher price than the ordinary brick yard obtained.[1] The washing was done in the fall when brickmaking has ceased and a deposit of washed clay is ready for the following season's work.

In some cases the stones are loosely held in the clay and separation by washing is comparatively easy, but some boulder clays are so tough, and the stones so firmly embedded, that it is almost impossible to break up the clay and separate the stones by washing.

Such a plant, however, could not ship its products over any considerable territory as it would then meet the competition of plants using clay that is free from limestone pebbles and therefore more cheaply worked.

Burning

Hitherto we have been dealing with the treatment of the raw clay, but there are certain aspects of the burning and of methods of dealing with the burned product which must be considered.

In certain parts of England where clays containing limestone pebbles are worked it is customary to grind the clay as fine as practical, and after the bricks are burned the cars on which they are loaded are drawn through a pool of water so that they are completely immersed and saturated.

This treatment slakes the lime particles quickly and appears to do less damage than if they are allowed to slake and expand slowly from the moisture absorbed in the atmosphere.

At the Don Valley Brick Works, in Toronto, there are certain beds of stony clay interbedded with the stoneless clay, and both are worked together. As the clay drops through the rolls from the pug mill the larger stones are expelled by the rolls, and the small ones go through to the machine and are crushed. This clay is used in the manufacture of end wire-cut brick and burned in an overhead fired continuous kiln. The limestone particles give surprisingly little trouble in the burned product. It seems as if the method of burning had something to do with checking the subsequent activity of the lime particles due to the smoky atmosphere and reducing conditions present in the chambers of the continuous kiln. The reducing condition at high temperatures appears to

[1] Bureau of Mines, Ontario, Vol. XV, Part 2. Clay and the Clay Industry of Ontario., p. 76. M. B. Baker.

cause fusion between the surface of the lime particles and the surrounding clay, and this fused skin prevents the access of moisture to the lime; but whatever the reason is the lime is more effectually killed than it would be after coming through a well oxidized firing.

A plant producing face brick from glacial clays containing a few scattered pebbles of limestone is situated at Rymal, about 4 miles southwest of Hamilton, Ontario. The clay is ground in dry pans, screened, and made up into stiff mud brick. The burning is done in round down draft kilns up to as high a temperature as the bricks will stand without adhering. The product is a hard sulphur-coloured brick which shows no bad effects from the lime grains. In this case the lime grains probably form a fused bond with the clay so that there are no after effects.

Finally we have to consider the addition of some substance to the clay which would prevent the slacking of the lime after burning.

The writer has made many experiments to this end, but found that the only practical method was to add some salt to the water used in tempering.

A set of test pieces of burned clay containing limestone particles to which one per cent of salt was added, have now been standing in the laboratory for about a year and show little or no indication of disintegrating, while similar test pieces made up without the salt have gone to pieces long ago.

Pulverizing

The most satisfactory way to deal with stony clay containing limestone is by pulverizing it finely so that it will pass a 30-mesh screen.

This process involves drying the clay as a necessary preliminary step before pulverizing and this is done by passing the clay through a rotary dryer, or by storing it until it becomes dried out.

Some of the brick and tile plants in Indiana and Illinois, where there is a large demand for these products and where nothing but stony clays are available, use the pulverizing process successfully.

In the *Clay-Worker* for February, 1922, Mr. George M. Krick, of Decatur, Indiana, gives a description of a large plant in which he works stony clay. The clay is excavated with a ditching machine or clay digger, so as to take up the clay in thin layers and not in large lumps, so that it will dry faster. It is then passed through a rotary dryer 7 feet in diameter and 70 feet in length, that has a capacity of 30 tons per hour. The clay from the rotary drier is fed into a ring hammer pulverizer, and then elevated to screens.

Two gravity screens are used. The top screen has eight meshes to an inch and removes all the coarsely ground clay and gives greater capacity to the finer bottom screen, which only allows the dust and particles finer than 30 mesh to pass through. The pulverized clay is run into storage bins and is elevated from these to bins set above the pug mills, and the ordinary processes of brickmaking follow.

Another operator in the same region stores the clay for about six weeks before using. It is then run through a disintegrator and over an 8-mesh screen. The tailings from the screen are put through a Williams pulverizer.

VI

TENTATIVE METHOD FOR SAMPLING CLAY DEPOSITS

The following method of sampling shale and clay deposits is approved by the Committee on Standards, American Ceramic Society:—

(1) *Preliminary Sampling.*

A face of the body of clay to be sampled shall be carefully stripped of loose or foreign materials, and a series of parallel trenches cut, each a straight line, so as to make as nearly as may be a vertical section entirely across the outcrop. In the case of stratified or bedded deposits which are inclined, the direction of these trenches shall be, preferably, across the dip, so that a proportionate amount of clay will be obtained from each individual layer. Each trench shall be about 12 inches wide, and deep enough to produce at least 100 pounds of material. Where natural outcrops are not available for sampling, preliminary trials may be made with a hand auger, and test pits dug to the necessary depth to expose a section (or face) of the clay.

As this may yield more material than is necessary for even a complete series of tests, the clay from the different trenches shall be reduced to lumps not exceeding 2 inches in diameter, mixed together and reduced by quartering to about 100 pounds, which is to be sent to the testing laboratory. The quartering shall be done on a heavy sail cloth at least 8 feet square.

If the deposit shows distinct difference as regards structure, colour or texture, each bed showing these individual differences shall be sampled separately, provided these beds are sufficiently thick to be mined by themselves or can be thrown out if undesirable.

Where the clay is stored in stock piles the sample may be taken from these **provided they are representative.** At least one-half of the sample shall be taken from the lower third of the pile.

In the case of those clays which are being purified a sample of both the crude material and the clay as prepared for the market shall be taken.

The samples collected as outlined above shall be placed in clean, tight-weave strong sacks and carefully labelled by means of two tags each bearing the proper identification marks. One folded tag shall be placed within the sack and the other securely attached to the outside.

(2) *Extended Sampling.*

After a clay proves satisfactory in the preliminary testing, the surrounding tract must be surveyed and systematically sampled. A topographical survey of the tract shall be made. Holes shall be drilled or dug through the deposit not more than 100 feet apart. A record shall be kept of the thickness of each stratum encountered. By plotting these results to scale, the shape, size and dip of the strata can be estimated.

A few larger holes shall be dug at the extremities of the property or at any points of doubtful value in order to get samples large enough for a complete series of tests. These shall be taken under the direction of "Preliminary Sampling".

VII

CLAY-WORKING INDUSTRY

The clay-working industry in Canada is engaged principally in the production of structural materials, such as brick and hollow building blocks, and drain pipes for agricultural purposes. These are made from the surface clays of glacial origin which are so widespread over all the country; but at a few points shales from the older rock formation are the raw materials used. Vitrified structural wares, such as sewer pipes, are made to some extent, but no paving brick are produced, mainly for lack of the proper kind of vitrifying shales employed in their manufacture. Four plants are engaged in the manufacture of heavy household pottery and stoneware goods such as crocks and jars. Two of these plants import their clays from the United States, but the others use the domestic clays in Nova Scotia and Saskatchewan.

White vitrified floor tile are made at one point, and sanitary ware and electric porcelain at three others. All the industries making white bodies import their raw materials from both England and the United States.

The annual value of clay products made in Canada has been steadily increasing during the past few years, and is now almost up to the level of 1912, which is the highest record so far. The production in 1912 was much greater in proportion, but the cost of operation was much less at that time.

The following table shows the value of the principal classes of clay products manufactured in Canada for the year 1920, also the increase over 1919:—

	1919	1920
Bricks	$5,154,381	$6,840,533
Fireproofing and hollow blocks	462,582	940,422
Sewer pipe	1,074,146	1,549,090
Field drain tile	616,510	562,652
Pottery	184,474	209,171
	$7,492,093	$10,101,868

Special Clay Wares

Some of the existing plants throughout Canada, engaged in the manufacture of brick and drain tile, might take up with advantage the making of a more specialized and profitable line of wares wherever they have a suitable clay or shale. There is a large and growing demand for the ordinary red floor tile used in corridors, kitchens, hospitals, and other places, which may easily be made from some of the red brick shales by simply grinding them finely. While these shales may not be suitable for tiles for outdoor use, on account of their porosity, they will give good wear in indoor positions. Roofing tile, and tile for lining digesters in the pulp mills, are other profitable lines for the manufacture, but these would have to be salt glazed.

Porous clay wares, such as iceless refrigerators and water coolers, would have a large sale if any one undertook their manufacture. Vessels of this kind owe their cooling properties to their power to soak up a large quantity of water, and the evaporation of this water as it comes to the surface keeps the contents cool. There is a vast amount of buff burning clay near Lake Erie, and elsewhere in southwestern Ontario, used for making porous drain tile, which would probably be suitable for this kind of ware.

White Table Ware

No table ware, such as white earthenware, semi-porcelain, or china, is produced in this country, the reason probably being due to a dearth of the proper kind of raw material, and the market not being large enough.

The commoner kinds of table ware have hitherto been made so cheaply and so well in European countries that it was impossible for Canada to compete with them. In recent years, however, the prices for these goods have increased fourfold or even more, so that there is now a much better opportunity for manufacturing in Canada at a reasonable profit.

The manufacture of staple lines would be the safest business to undertake at the start. These include: (1) plain white, or, as it is sometimes called, white granite ware; (2) gilt wares, light and heavy, these being simply decorated over the glaze with a gold line, or with a stamped device in gold, the commonest on the market being the clover leaf, but the Canadian manufacturer should stamp his ware with a gold maple leaf or a beaver; (3) ware decorated with a transfer pattern in one colour, generally called printed ware; (4) water jugs, either plain white, or decorated with gilt band, or painted decoration.

There is an enormous quantity of these goods sold in Canada, and any manufacturer producing them at say 20 per cent less than the imported wares would be assured of the greater part, if not all, of the business.

Raw Materials.—A mixture of four kinds of raw material is used in making the above wares, these being: china clay, ball clay, flint, and feldspar. In addition to these, a supply of fireclay is necessary for making the saggers or containers in which the ware is burned.

The present supply of china clay in Canada is limited to one deposit, that of the Canadian China Clay Company, of Huberdeau, Quebec. This deposit is being developed by new mining methods, and a larger output of clay is promised than was formerly available. So far no ball clay has been discovered within reach of transport in Canada. Certain of the white sandstones in eastern Canada, when pulverized, can be used for the flint in pottery.

There is a plentiful supply of high grade feldspar for pottery bodies and glazes in eastern Canada. Any firm doing a large amount of business in white earthenware could purchase the crude feldspar and quartz from the mines, and do their own grinding.

Fuel.—As it requires six tons of coal to produce one ton of white table ware, the fuel question would have to be studied closely, and particular attention paid to design of kilns and method of fuel saving. Putting the coal through a gas producer and using the gas for fuel in a tunnel kiln seems to be the practice that is approved by most ceramic engineers.

Location.—The location for a plant making white table ware depends on various factors. The assembling of raw materials, the cheapest place to deliver coal, the transportation facilities for assembling and distribution, and the labour supply are the principal things to be taken into consideration.

Points on the St. Lawrence river up to Montreal have the advantage of ocean freight delivery of supplies of English china clay and ball clay without re-handling, as well as access to the Nova Scotia coal fields. Points on Lake Erie, such as Port Stanley or Port Colborne, are well situated for receiving supplies of coal and fireclay from the United States, and points on the Welland canal have similar advantages for assembling raw materials and distributing finished products.

VIII

BALL CLAY IN SASKATCHEWAN

We have frequently called attention to the occurrence of ball clays in the southern part of the province of Saskatchewan, and tests and analyses were published in 1918.[1]

[1]The Clay Resources of Southern Saskatchewan, Mines Branch, 1918, p. 15.

Professor W. G. Worcester, of the department of Ceramic Engineering, at the University of Saskatchewan, recently made tests on some ball clay beds, and the following is his report on a clay deposit near Willows:—

On Sec. 33, Tp. 7, R. 28, west of 2nd Mer., there is a section of clay approximately 30 feet in depth. The lower 10 feet is greyish white, somewhat stained with yellow along the cleavage lines. Close inspection reveals the presence of many minute iron concretions distributed throughout the mass.

The sample for this report was taken at an opening or cut from which two car loads of material had been taken for shipment to a brick plant a couple of years previous. Naturally a perfect sample could not be obtained due to cave-ins. The best average possible was taken, shipped to the ceramic laboratory at the University of Saskatchewan, where, up to the present, it has been tested as follows:—

Washing Test

	p.c.
Caught on 40 mesh	1·10
" 80 "	1·15
" 100 "	0·03
" 200 "	1·95
Total	4·23

The greater part of the residue caught on the screens is the iron in concretionary form, a little mica and some quartz grains.

The washed sample required 30 per cent of water to produce plasticity.

The drying shrinkage was 7·4 per cent, the trials dried safely without warping or checking.

Burning Shrinkage

	p.c.		p.c.
Cone 1 (2102 F)	5·9	total	13·3
" 3 (2174 F)	6·8	"	14·2
" 5 (2246 F)	6·8	"	14·2
" 7 (2318 F)	7·6	"	15·0

As a ball clay the above per cent of shrinkages are normal and well within commercial limits.

As a comparison two greatly used ball clays are listed.

English ball clay No. 12	total	16·2
Tennessee " 7	"	15·7

These clays were burned in the same kiln and at the same time as the Saskatchewan ball clay. Thus it can be seen that the latter falls in the same class, as far as shrinkage is concerned.

Burned Colour

In order that the colour might be properly guaged or classed, samples of English and American commercial ball clays were obtained. Trial pieces were made of each and burned in the same kiln with the Saskatchewan clay. When cool and removed from the kiln the several samples were arranged according to their respective degrees of whiteness or tints, resulting as follows:—

Saskatchewan ball clay washed	1	best
Tennessee No. 7 ball clay	2	next
" " 9 " "	2	"
Mayfield, Kentucky, ball clay	2	"
Tennessee No. 11 ball clay	3	"
English " 12 " "	4	"
Saskatchewan ball clay unwashed	5	"

In this test the Saskatchewan clay gave a better colour (light cream) than any of the imported standard clays. We can therefore say that it would prove highly suitable in the body mixtures for the manufacture of whiteware and porcelain.

Chemical Analysis

That the chemical properties of the Saskatchewan clay may be compared with the better grades of commercial clays, the following table is given.

<table>
<tr><th>——</th><th>Sask.</th><th>Mayfield, Ky.</th><th>S. Amboy, N.J.</th><th>Wareham, Eng.</th><th>Hall, Eng.</th></tr>
<tr><td>Silica</td><td>59·03</td><td>56·40</td><td>44·89</td><td>55·00</td><td>39·60</td></tr>
<tr><td>Alumina</td><td>25·88</td><td>30·00</td><td>37·27</td><td>29·71</td><td>45·00</td></tr>
<tr><td>Iron</td><td>0·94</td><td>..........</td><td>0·97</td><td>2·14</td><td>..........</td></tr>
<tr><td>Lime</td><td>0·24</td><td>0·40</td><td>0·41</td><td>0·62</td><td>0·10</td></tr>
<tr><td>Magnesia</td><td>3·23</td><td rowspan="2">5·27</td><td>0·19</td><td rowspan="2">3·44</td><td rowspan="2">3·30</td></tr>
<tr><td>Soda and potash</td><td>1·82</td><td>1·44</td></tr>
</table>

It will be observed that the Saskatchewan clay corresponds quite closely with some of the best commercial ball clays of the world, and will without a doubt, prove equally as good in actual use.

The deposit represented by the sample under test is directly alongside the Canadian Pacific railway, and is four miles east of Willows station.

With the single exception, that of having to wash to remove the concretionary iron, the Saskatchewan ball clay is a valuable deposit. Its working properties are good and its burned or final colour ranks but very little below some of the china clays of the world.

Unquestionably, Saskatchewan has a valuable resource in this deposit of material. However, it should be borne in mind that there are undoubtedly other deposits of similar properties and value at other points in the province, but studies of these deposits have not yet been made.

The above clay, however, ranks among the very best of its kind in the province, being up to commercial requirements, and situated close to rail facilities.

ROAD MATERIALS DIVISION

Henri Gauthier

The investigation of road materials during the year covered the examination and sampling of a number of gravel deposits and rock quarries along the Ottawa-Point Fortune highway in Ontario, and the continuation of a road material survey in the Canadian National Rocky Mountains Park in connection with the construction of automobile roads by the Parks Branch of the Department of the Interior.

The object of these investigations was to supply the Ontario Department of Public Highways and the Parks Branch engineers, respectively, with information on the comparative qualities of the available supplies of roadmaking material in the neighbourhood of those highways, the surfacing of which is in contemplation.

In carrying on these two investigations about 25 samples of rock and gravel in Ontario, and over 80 samples of rock, gravel, boulder clay and natural subsoil in the Rocky Mountains Park were collected. These samples were examined and tested in the laboratories of the Division during the winter.

Detailed reports on these two surveys were prepared and sent to the Department of Public Highways of Ontario and to the Commissioner of Dominion Parks. In these reports are given the location and description of the more promising deposits along the roads in question as possible sources of road surfacing material. They also contain the results of laboratory tests on samples collected and a discussion on the comparative value of the various materials examined and tested. These results appear in tables in the following pages.

During the year a number of samples of stone and gravel which were submitted for testing were reported upon. Tests on samples collected in Nova Scotia in 1920[1] were completed. The results of these tests are recorded in the accompanying tables.

An abrasion test on concrete cylinders was also made, in compliance with a request from Mr. E. Viens, Chief of the Laboratory for Testing Materials, Department of Public Works, Ottawa.

This test was made to secure information regarding the comparative value of concrete mixtures made of different types of stone aggregate as to their resistance to wear. For such test, a machine on the plan of the brick rattler is used in the United States. It is called the Talbot Jones rattler.[2] As neither the Public Works nor the Mines Branch laboratories possesses such a machine, it was thought worth while to carry on an experimental test using the road stone Deval abrasion machine. While supplying Mr. Viens with reliable information, the test came under our study of methods of testing materials.

The writer was ably assisted by his confrere, Mr. R. H. Picher, both in the field and in the carrying out of laboratory work.

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[1] Mines Branch, Summary Report of Investigations in 1920, p. 72.
[2] A Method of Making Wear Tests of Concrete, by D. A. Abrams, Prod. American Society for Testing Materials, Part II, 1916.

Acknowledgment is also due to Messrs. R. S. Stronach, superintendent of Rocky Mountains Park, and J. M. Wardle, chief highway engineer, and their assistants, who spared no effort in facilitating the field work, in the matter of transportation, and by rendering other services with unfailing courtesy and kindness.

I

LABORATORY TESTS ON ROAD BUILDING STONE

Tests are made for two purposes—to determine in the materials tested, their characteristic qualities, and whether they conform to a certain previously determined standard established by the test of service. After it has been determined that a certain class of material under the conditions existing on any particular surface is the most suitable for the purpose for which it is employed specifications can be drawn up which will insure that material purchased in the future shall conform to the requirements. Then it can be determined by tests, what material is similar to the types which have proved satisfactory.

Laboratory tests have been devised to enable us to determine these qualities.

After making the tests that show the relative qualities of different kinds of rocks, the highway engineer is in a position to make future classification of similar materials largely by inspection.

There are five standard tests regularly made in the laboratory upon road building rock, which furnish a ready means of judging the comparative value of a rock as road metal. The most important are those for resistance to abrasion (percentage of wear) and for resistance to impact (toughness). The others are for hardness, specific gravity, and absorption.

As a result of comparisons made by engineers between laboratory tests and the wear of the stone in practice, certain limits have been set upon the values for the toughness and percentage of wear of stone that is to be used in macadam construction.

The American Society of Civil Engineers recommended in 1917 that stone used in waterbound macadam roads should have a percentage of wear of not more than 5, and a toughness value of not less than 6. The specifications adopted by the American Society of Municipal Improvement in 1914 require that stone used in the wearing surface of bituminous macadam or bituminous concrete roads shall have a per cent of wear of not more than 3·7 and a toughness of not less than 13. The United States Office of Public Roads sets the minimum limit of toughness for stone used on roads subject to traffic of less than 100 vehicles a day at from 5 to 9, except in the case of bituminous concrete, where the lower limit is 7. On roads subject to traffic of 100 to 250 vehicles a day, the minimum toughness is 10 for waterbound macadam and bituminous macadam, and 13 for bituminous concrete.

Tests Made upon Gravel

Because no two gravels have the same composition and character, engineers have found it difficult to draw specifications within narrow limits for road gravel. However, there are certain requisites which have been recognized as necessary to give satisfactory results.

Gravels are examined to determine their adaptability for the construction of gravel macadam or for concrete roads, and to obtain some knowledge of their ability to resist wear and to bind in a macadam surface; also to obtain information on the probable strength of concrete in which they might be used as the aggregate.

In the examination of gravels, estimates are made of the average composition of the pebbles, the relative proportion of the various sizes, the shape of the pebbles, and the nature of the impurities present. The tests made are, granulometric analysis, colorimetric tests for impurities, and mortar test.

Explanation of Tests

Granulometric Analysis.—The ability of gravel to pack well in a road bed is dependent to a large extent on the proportion of the sand content, on the amount of clay and silt present in the sand, and on the grading according to size of the particles making up the gravel and sand.

The results obtained from the granulometric analysis give an idea of the texture of the sand and gravel with regard to its grading in size of grain.

Sand, gravel and boulder clay deposits are variable in their grading from point to point. Consequently one analysis cannot determine the grading of the material. If the sample, however, has been carefully collected as representative of the average run of the bank the figures recorded in this test will furnish a general indication of the material available in the deposit in question.

General limiting values for the interpretation of granulometric analysis of road surfacing gravels has been adopted by the United States Office of Public Roads as follows:—

(*a*) All to pass a 1½-inch screen and to have at least 55 and not more than 75 per cent retained on a ¾-inch screen.

(*b*) At least 25 and not more than 75 per cent of the total coarse aggregate to be retained on a ¾-inch screen.

(*c*) At least 65 and not more than 95 per cent of the total fine aggregate to be retained on a 200-mesh screen.

From 8 to 15 per cent of the sand content in gravel should be clay or similar binding material such as oxide of iron. The binding or cementing value of gravel is also improved by an appreciable amount of calcium carbonate. Angular pebbles have a tendency to compact under traffic more rapidly than rounded pebbles and therefore are likely to produce a firm road surface in a shorter time.

Fineness Modulus.—The fineness modulus is a measure of the size and grading of the aggregate. It is the sum of the percentages given by the granulometric analysis, divided by 100.

This is determined by using the following sieves from the Tyler Standard series: 100, 48, 28, 14, 8 mesh. A well graded coarse sand up to 4-mesh sieve will give a fineness modulus of about 3·00. A fine sand such as drift sand may have a fineness modulus as low as 1·50. A coarse aggregate for concrete, graded from ¼ inch to 1½ inch, will give fineness modulus of about 7·00; a mixture of the above with coarse sand of fineness modulus 3 in proper proportions for a 1: 4 mix will have a fineness modulus of about 5·80.[1]

Percentage of Clay and Silt.—In the method employed the percentage of clay and silt is determined by elutriation. A 100 gram sample of sand is placed in a glass vessel and subjected to a rising current of water of constant head, which carries off the silt and clay. When the discharge water becomes clear, the washed sand is dried and weighed. The loss in weight represents the percentage of silt and clay in the sample.

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

Mortar Tests.—Tensile and compression tests are made, according to standard methods, on a mixture of three parts of sand to one of cement, gauged with distilled water and using 2″ × 4″ cylinders for the compression test. Test pieces of mortar made of standard Ottawa sand are made with each set of samples and all are broken at the end of seven and twenty-eight days. The results for the sands under test are expressed in percentages of strength relative to that of the standard sand.

Although in many cases the strength of sand mortars, as expressed in terms of percentage of strength of the standard mortar, are lower for the twenty-eight day break than for the seven day, the actual strength in pounds per square inch are almost invariably higher. This is due to the fact that the increase in strength on ageing is greater in the standard mortar than in the case of these particular sand mortars.

An examination of the results obtained shows that the finer sands make poor concrete material. As a rule a sand which has 75 per cent retained on the 48 mesh, or a fineness modulus of about 3, will make good concrete.

Sands containing a percentage of clay and silt above 10 per cent proved that they would not make satisfactory cement mortars and would not be safe to employ in important work.

Specifications for fine aggregates to be used in cement concrete for pavements require that not more than 10 per cent of the sand grains below the ¼-inch size shall pass a sieve having 50 meshes to the linear inch, and not more than 2 per cent shall pass a sieve having 100 meshes to the linear inch.[2]

[1] Design of Concrete Mixtures, by Duff A. Abrams, Bulletin I, Structural Materials Research Laboratory, Lewis Institute, Chicago, 1919.
[2] Report of Com. III, 1914, Nat. Conf. Concrete Road Building, U.S.

Colorimetric Test for Organic Impurities.—The presence of certain organic matter in sands and gravels has a decided weakening effect on concrete made from them.

A colorimetric test for organic impurities has been devised at the Structural Materials Laboratory, Lewis Institute, Chicago, and is described as follows.[1]

A sample of sand is digested at ordinary temperature in a solution of sodium hydroxide. If the sand contains certain organic materials, thought to be largely of a humus nature, the filtered solution resulting from this treatment will be found to be of a colour ranging from light yellow through the reds to that which appears almost black. The depth of colour is measured by comparison with proper colour standards. The depth of colour produced by digesting a sand with a 3 per cent solution of sodium hydroxide has been found[2] to bear a relation to the compressive strength of mortar made with this sand and is about as follows:—

Colour values	Reduction in compressive strength of 1: 3 mortar per cent
250	10—20
500	15—30
1,000	20—40
2,000	25—50

II

REPORT ON THE INVESTIGATION OF A NUMBER OF ROCK QUARRIES AND GRAVEL DEPOSITS IN PRESCOTT AND RUSSEL COUNTIES, ONTARIO

In the early part of the summer of 1921, in compliance with a request from the Department of Public Highways of Ontario, an investigation of road materials was carried on in Russel and Prescott counties.

Because of the lack of available staff and want of time a complete survey could not be conducted by the Road Materials Division. However, one week was spent going over some of the more important deposits of stone and gravel, considered as possible sources of road-building material for the surfacing of the Ottawa-Point Fortune highway or the construction of main county roads.

In carrying on this work, information supplied by Mr. F. A. Senecal, county road superintendent, and Mr. F. Brinkman, resident engineer in charge of the Ottawa-Point Fortune highway, as to the location of the deposits to be examined, was made use of.

The work consisted in examining the deposits, in estimating the probable amount of available material, and in taking samples for examination in the laboratory of the Division.

ROAD MATERIALS AVAILABLE

Bed-rock and gravel constitute the materials in Russell and Prescott counties which can be used in road construction. The bed-rock consists of Trenton and Chazy limestones.

Outcrops of limestone and deposits of gravel are not plentiful, but they are found at intervals, and constitute a sufficient supply for local road work,

[1] Colorimetric test for Organic Impurities in Sands, by Duff A. Abrams. Circular No. 1. Structural Materials Research Laboratory, Lewis Institute, Chicago, 1917.

[2] 1916 Report of Committee C-9 of the American Society for Testing Materials.

Bed-rock

Because of their more general occurrence along the Ottawa-Point Fortune highway, and because of the ease with which they can be quarried, limestones have been and will probably be the chief source of road material for that main provincial road.

These limestones, however, are of only moderate durability and are not suitable for roads subjected to heavy traffic, except when used with a bituminous or portland cement binder.

The durability of limestones varies with their composition and texture. The finer and more even-grained varieties, as a rule, are the more durable. A tough, hard limestone can give as satisfactory results in some cases as the most durable igneous rock, but the great majority of limestones are soft and wear rapidly. Most of the limestones, however, cement with ease in a road bed, and under light traffic conditions have given good service.

The best road-making limestone is probably that of an even, fine-grained texture, which is unweathered, and which contains a minimum of black shale and of clayey partings so frequently encountered in that kind of stone.

The limestones occurring in Russell and Prescott counties are of medium hardness, and the result of tests on their physical properties compare with the average values obtained for stone of the same geological formations occurring in the neighbourhood of Ottawa.

Stone from the various deposits examined has been used to a certain extent in the construction of waterbound and bituminous macadam roads, on some stretches of the Ottawa-Point Fortune highway, and within the limits of a number of towns. It has made fairly good roads under light traffic conditions, but roads built with similar stone in the vicinity of Montreal and Ottawa, and carrying a heavy automobile traffic, have proved to wear away fast even where a bituminous binder is used.

A description of a few of the more important deposits of limestones visited is given below. In Table I are given the results of laboratory tests performed upon samples collected from these deposits.

Description of Bed-Rock Deposits

I. Paradis Quarry, Plantagenet

Location.—Lot 9, con. III, North Plantagenet township. Between main road and South Nation river, about 1 mile west of Plantagenet.

Description.—The quarry lies on the edge of a ledge which forms quite a scarp facing the South Nation river to the north. The size of the excavation is small, but much stone is available. The exposure above the actual quarry floor consists of 10 to 12 feet of limestone.

The stone in the upper 5 feet is thin-bedded, flaggy, and contains shaly partings. It is uneven in texture, varying from fine to medium-grained, with secondary calcite crystals. It is dark-coloured. Some of it is weathered, but the greater part is fresh.

The lower stone occurs in thicker layers and is of a more uniform texture.

These beds are nearly flat-lying; they dip but very slightly to the south. Some of the upper layers are much shattered, but the lower beds are only moderately jointed. The overburden is from 1 to 2 feet thick, but apparently becomes thicker away from the edge of the outcrops towards the south. A 20-foot working face could be exposed and large quantities of stone obtained without drainage trouble. See sample 1, Table I.

II. Lambert Franche's quarry, 2 miles south of Wendover

Location.—Lot 32, con. II, North Plantagenet township.

Description.—Stone has been quarried to a small extent for road-building material from an important ridge of limestone, which can be traced for several miles eastward. The ridge is for the most part thickly covered, but in places outcrops are seen on its northern slope with good opportunity for quarrying.

On the Franche farm, a small quarry has been worked in the upper part of the steep slope, just south of the concession road. The top of the ridge at that point is over 75 feet above the flat to the north. In the excavation not less than 20 feet of limestone is exposed, and a working face much higher than that could be had along the cliff.

The stone resembles somewhat that in the Paradis quarry, near Plantagenet, except that it contains less shaly partings. It is thin-bedded, flat-lying, dark-coloured, fossiliferous limestone. It is uneven in texture, with thin, wavy, irregular streaks of shaly material. The stone is fresh, except in the upper 2 to 4 feet, in which it is much shattered and weathered. The amount available here is practically unlimited. It is close to the road. See sample 2, Table I.

III

Outcrops are also seen farther east along the ridge above described, on lot 13, con. III. The limestone is specially well exposed on the farm of L. E. McCormick, in a small opening near the top of the ridge, just east of the road, and in a cliff at least 25 feet high along the escarpment a short distance from the road. The stone exposed near the road is fresh and resembles that seen in the Paradis quarry. The material exposed in the cliff is thin-bedded and uneven in texture. It is much shattered and not as fresh as the stone outcropping near the road and on top of the ridge.

Large quantities of limestone can be easily quarried here.

IV. J. Brisebois' quarry, Alfred Centre

Location.—Lot 6, con. IV, Alfred township.

About 2 miles north of the Ottawa-Point Fortune highway.

Description.—The quarry, which is only a few hundred feet south of the concession road, is located on the north side of an extensive ridge of limestone over 1½ mile long, running nearly east-west. There are many outcrops which could be developed along this ridge. The stone has been quarried to a small extent at several points, but the Brisebois quarry is the most important. It is opened in the face of the ledge, which is over 25 feet high at that point. The quarried wall was over 100 feet long and not less than 15 feet high at the time of our visit. Quarrying operations had just been started, and large quantities of stone for road purposes were to be obtained during the summer.

The character of the limestone is dark blue, fine-grained, with small crystals of brown calcite. It is hard and brittle and breaks very irregularly. From bottom to top of the exposure the stone is uniform. It is fresh and occurs in massive beds from 6 inches to a couple of feet thick. Vertical joints are frequent. The material in the upper 2 or 3 feet is shattered and somewhat weathered. Large quantities of stone are available, with fair opportunity for quarrying. See sample 3, Table I.

V

At the west end of the deposit above mentioned, the stone has been quarried to a small extent on the farm of Jas. P. Lett.

Just west of the north-south road, massive beds of fresh stone are exposed to a depth of 10 feet in a small opening, and outcrops are seen over a width of 125 feet.

VI

On lot 8, on the farm of Jos. Robillard, there is an old quarry by the road. Quick lime was produced there at one time. The quarried wall is 10 feet high, but a working face of twice that height is possible. The stone resembles in character that in the Brisebois quarry; it belongs to the same ridge.

VII. House quarry, L'Orignal

Location.—Lot 20, L'Orignal, Longueuil township.

The quarry lies about 1½ mile southwest of the town of L'Orignal, on the west side of the Cassburn road and is opened in the face of a bluff overlooking Hill creek.

Description.—The bluff is about 50 feet high in places, and is continuous for quite a distance in a northeast direction. This is on the western edge of a plateau extending to the east. The upper layers have been worked for building stone and road material to a depth of 10 feet over an area of 35 yards by 20 yards.

Much variation is noticeable in the character of the stone exposed. It ranges from fine, even-grained, to uneven, coarse-textured and highly fossiliferous limestone. It is, as a rule, fresh and of a dark bluish colour. The stone occurs in irregular layers, varying in thickness from 1 inch to 1½ feet. The bedding is much disturbed, and joints are frequent at various angles. The amount available without drainage trouble is large.

Stone from here was used in the construction of a macadam road through the town of L'Orignal. That road was in fairly good condition last year after several years of service.

Laboratory tests have shown that this limestone is a comparatively durable road metal. See sample 4, Table 1.

VIII. James Ross quarry, Little Rideau

Location.—Lot 28, con. I, East Hawkesbury township. This is an old quarry located in a bush immediately west of the crossroad and about 1 mile south of the Ottawa-Point Fortune highway.

Description.—About 15 feet of limestone are exposed in an excavation 75 yards by 50 yards. The stone is thick-bedded, coarse to medium-grained, bluish-grey and highly fossiliferous. It contains numerous calcite crystals, breaks very easily, and is rather soft for road purposes. The beds show little weathering, are horizontal and not much jointed. Geologically they belong to the Chazy formation.

The deposit forms an extensive ridge running northeast across the road, and is partly covered with bush and a thick overburden. Large quantities of stone have been obtained here in the past, particularly for purposes of heavy construction. The amount to be had is still large. The surface beds have been worked over a large area, and many thousands of cubic yards of stone can be obtained from piles of debris. The probable value of this stone as road metal is closely comparable with the rock in place. See sample 5, Table 1.

TABLE I

Results of Laboratory Tests upon Limestones

Sample No.	Locality	Physical Properties						Remarks
		Per cent of wear	French coeff. of wear	Tough-ness	Specific gravity	Absorption in lbs. per cu. ft.	Hard-ness	
1.......	Paradis quarry, Plantagenet.....	4·24	9·4	8	2·71	0·24	14·4	Dark grey, fine to medium-grained limestone.
2.......	Franche quarry, Plantagenet.....	4·67	8·6	8	2·71	0·22	14·5	Dark grey, fine-grained limestone, with shaly partings.
3.......	Brisebois quarry, Alfred Centre..	4·37	9·2	4	2·70	0·18	15·0	Brownish grey, fine, uneven-grained limestone, brittle.
4.......	House quarry, L'Orignal.........	3·36	11·9	7	2·70	0·47	15·2	Light brownish grey, medium-grained uneven textured limestone, with calcite crystals.
5.......	Ross quarry, Little Rideau......	4·20	9·5	5	2·72	0·64	11·0	Light coloured, coarse-grained limestone, with calcite crystals.

It is obvious from the results contained in Table I that while the majority of the limestones tested comply with the specifications for the physical properties of broken stone for waterbound macadam with light traffic, they fail to show sufficient ability to resist wear and impact required in bituminous macadam or bituminous concrete, or even in waterbound macadam with a traffic of over 100 vehicles a day.

As a class, limestone of the type occurring in Russell and Prescott counties is a rather poor road metal, but it should not be rejected as unsuitable for road purposes. Local conditions have to be taken into account, and because it is the only available class of bed-rock in that district, it can be economically used if the roads built of it are properly maintained. In areas where gravel is scarce, this stone can be advantageously used as coarse aggregate in concrete mixtures for the construction of concrete roads. However, the best results cannot be expected with the use of this stone in concrete pavements. Service and laboratory tests on concrete have shown that the nature of the stone aggregate used in a concrete mixture has some influence on its resistance to wear, especially if the concrete is subjected to continuous and severe abrasive action. In practice, a French coefficient of wear of 10 is considered as a minimum value for stone to be used in concrete roads.

GRAVEL

In the following pages the character of the deposits of sand and gravel visited is briefly described. Such information as can be gathered from laboratory examination of samples upon the suitability of the material for road surfacing or concrete purposes can be obtained by referring to Tables II and III.

On account of the short time available, only a few of the deposits of gravel were examined. There are many other deposits in that district from which suitable material may be had. Gravel is cheap in first cost, and easily handled. It is especially suitable for the improvement of county or secondary roads, as a gravel macadam is more economically constructed and easier to maintain than a broken stone construction.

Description of Gravel Deposits

PRESCOTT COUNTY

I. Belanger pit, Point Fortune

Location.—Lot 1, con. I, East Hawkesbury township. Pit located along southern edge of deposit, about one mile south of the town and immediately west of cross road.

Description of deposit.—The deposit forms an extensive ridge running in an east-west direction; it covers an area of approximately one mile by one-quarter mile and rises to about 25 feet in places.

The amount excavated is 25 yds. × 15 yds. × 4 yds. = 1,500 cu. yds. Maximum height of wall = 12 ft.

Character of material.—The exposure about the centre of the main wall which faces south, is as follows from top to bottom of bank:—

(*a*) Overburden and weathering part........3 to 8 feet thick.
(*b*) Fine gravel and coarse sand............2 feet.
(*c*) Coarse gravel.........................3 to 5 feet.
(*d*) Fine gravel coarser than (*b*)............2 feet.

Balance covered with talus.

Samples of layers (*b*) and (*c*) were collected.

The weathered part contains yellowish loam. There are very few boulders over 6 inches in size, but coarse gravel occurs in larger proportion than fine gravel. The pebbles are round in shape and composed of granites, gneisses, quartzites, limestones and sandstones. The material is fairly clean, but in certain layers weathered pebbles are found in large quantity. The amount of gravel available in this deposit is considerable, but not without a good deal of stripping. The overburden is apparently thick and there are also a few trees on top of the deposit.

The actual pit has been worked in the past in a careless manner.

See the results of analyses of samples 1 and 2 in Tables II and III.

II

Exposures of gravel can be seen on the northern edge of the ridge above described in cuts along the road leading to the C.P.R. station just south of the town of Point Fortune.

The deposit, which extends also to the east of the road, forms quite a hill here. From 6 to 8 feet of gravel can be seen. One sample was taken. See No. 3 in Tables II and III.

III. Oscar Cousineau's pit. West of Point Fortune

Location.—Lot 9, con. I, East Hawkesbury township. The pit is situated in a pasture about one-half mile south of the main road.

Description of deposit.—Lense shaped deposit approximately 150 yards wide by 300 yards long, trending northeasterly. The deposit rises only very slightly above the general level of the surroundings. The gravel has been excavated to a depth of 9 feet and the actual size of the pit is 65 yards by 35 yards = 6825 cubic yards.

Character of material.—Medium gravel, carrying very fine sand. At the northwest corner of the excavation clean yellow medium sand occurs while gravel with all pebbles under 1½ inches in size is seen in the northern bank. Good fine gravel, interbedded with fine yellow sand is exposed along the east wall of the pit. The walls on the west side are covered with talus. The overburden, which consists of gravelly loam, is thin but some weathering is noticeable to a depth ranging from 2 to 2½ feet. Several thousand cubic yards of material are available from this deposit with very little stripping, but there is a long haul to the main road over a rough farm road.

One sample of the bank run on the east side of the excavation was taken. See No. 4 in Tables II and III.

IV. Dan. Kirby's pit, Chute à Blondeau

Location.—Lot 17, Broken Front concession, East Hawkesbury. Pit located just north of main road.

Description of deposit.—Small deposit forming a knoll near farm buildings. About 6 feet of gravel is exposed in an irregular shaped excavation at the southwest corner of the deposit. Size of pit: 35 yds. × 30 yds. × 2 yds. = 2,100 cu. yds.

Character of gravel.—Bouldery gravel. Many large boulders over 2 feet in diameter lying in pit. The gravel contains a large percentage of material between 2 inches and 6 inches in size. There is very little stripping to be done, but section of exposure shows much weathered gravel carrying loam.

The amount available is small.

One sample representing the finest material in the bank was taken. See the results of analysis of sample No. 5, Tables II and III.

V. Dandy pit, 5 miles west of Little Rideau

Location.—Lot 36, Broken Front concession, East Hawkesbury township. Pit located in a pasture, between the main road and the river shore.

Description of deposit.—Flat-topped ridge of small extent rising to about 8 feet above the surroundings and running parallel to the river. Size of pit: 50 yds. × 30 yds. × 2 yds. = 3,000 cu. yds. Average depth of excavation = 6 feet.

Character of material.—Fairly well-graded gravel is exposed in walls from 4 to 6 feet high. The material is horizontally stratified and packed hard. Flat water-worn pebbles, largely composed of Chazy sandstone. Boulders occur in lesser quantity than in the Kirby pit, but stones over 3 inches are more frequently encountered than in the other pits of the locality.

The overburden consists of 1 to 1½ feet of loamy and somewhat weathered gravel.

Two samples were taken, Nos. 6 and 7. They respectively represent the coarsest and finest materials of this occurrence.

The probable amount easily available is over 20,000 cubic yards, with a haul of only a few hundred feet to the main road.

VI. Vankleek Hill pit, 2 miles southwest of the town

Location.—Lot 14, con. VI, West Hawkesbury township.

Description of deposit.—The deposit forms an important sharp ridge trending in a northeast direction across the road between concessions VI and VII. There are two pits opened immediately north of the road, at two different levels. The excavation near the top of the ridge is 100 yds. × 35 yds. × 2 yds. = 7,000 cu. yds. in size, and the pit at the foot of the slope is 50 yds. × 25 yds. × 3 yds. = 3,750 cu. yds. The extent of the area over which there are good gravel surface indications is at least 300 yds. × 100 yds., with an elevation of about 30 feet.

Character of material.—In the upper level pit, a 5-foot wall shows well stratified layers of rounded gravel under 3 inches in size, interbanded with layers 1 to 1½ feet thick of finer material. The amount of boulders over 3 inches is small, but there are streaks of loam in the gravel. Marine shells are also found, but in small amount. Walls are standing up straight.

In the lower pit, coarser material occurs. The percentage of boulders over 6 inches in diameter is, however, low. The gravel lacks fine material under ¼ inch in size, which has apparently been washed away. The pebbles are coated with calcium carbonate. They are mostly limestone. Straight sand is absent in this exposure. Samples of both the coarse and the fine material were collected. Good road gravel can be had from either pit.

The amount available here with only very little stripping is large. It can be safely estimated at over 100,000 cubic yards. See samples Nos. 8 and 9 in Tables II and III.

RUSSELL COUNTY

VII. Devlin pit, Clarence Point

Location.—Pit located on the Ottawa-Point Fortune highway at a point 1 mile south of the town of Clarence.

Description of deposit.—The deposit occupies the triangular area between the main road and the road running south to Clarence Creek. The top of the deposit is only a few feet higher than the road level and the thickness of the gravel is apparently not more than 6 to 8 feet. The amount of material taken out along the road is approximately 1,000 cubic yards.

Character of material.—The exposure consists of a few feet of gravel overlain by a thin overburden. The gravel is of fine texture and interbedded with sand. The amount of weathering ranges from 2 to 2½ feet from the surface, but underneath clean fine concrete gravel is exposed. There are a few big boulders lying in the excavation, but no coarse gravel exposed.

Several thousand cubic yards of fine gravel can be had here without trouble. Chances are that a 6 to 8-foot working face can be developed by the road.

Sample No. 10 was taken.

VIII. Rathwell pits, Bearbrook

Location.—Lot 18, con. IV, Cumberland township. About 1½ mile south of Leonard station.

Description of deposit.—Extensive ridge of sand and gravel running in a southeasterly direction along the Leonard-Bearbrook road.

The deposit, which parallels, and at its northern end is cut by the Leonard-Bearbrook road, forms a prominent ridge, over 30 feet high and a few hundred yards wide for a distance of nearly one-quarter of a mile to the east of the road.

There are two main excavations.

Character of material.—*Pit A.*—Pit at northern end of deposit, immediately east of road.

Size of excavation, 40 yds. × 30 yds. ×2 to 10 yds. = 7,200 cu. yards. The main wall is 30 feet high. The overburden consists of 1 to 1½ feet of sandy loam. In the upper 6 to 8 feet stratified fine yellow sand is exposed. It is underlain by interbedded layers 2 to 4 feet thick of sand and gravel. The gravel is rather coarse and contains boulders up to 10 inches in size. In the total height of the exposure, sand occurs in larger proportion than gravel. Large quantities of gravel have apparently been obtained from this pit, but judging by the actual sections exposed along the main wall and in a nearby smaller excavation the material is nearly exhausted. The deposit becomes one of sand.

Samples of the sand and of the gravel were collected, see Nos. 11 and 12, Tables II and III.

Pit B.—Located a short distance south of pit A, above described. This is the more important of the two pits as regards the amount available and the quality of gravel for road purposes.

The pit is opened on the western slope of the ridge, which is quite steep and over 30 feet high at that point. The actual size of the excavation is 40 yds. × 20 yds. ×6 yds. =4,800 cu. yds. The maximum height of wall developed is 35 feet.

The exposure consists entirely of rather coarse gravel occurring in the form of a huge pocket or a thick lense. Stratification is not apparent and layers of straight sand are absent. The walls stand up straight and the material is apparently packed hard and cementing. The percentage of pebbles between 3 and 10 inches in diameter is large, but boulders over 10 inches are scarce. The depth of weathering and overburden of loamy gravel is only 1 foot. The pebbles are composed mainly of limestone with sandstone and shale. The amount of good road gravel to be had from this deposit is large. It is hard to tell how far back the gravel pocket extends. There may be a sharp passage from gravel into straight sand, as such is seen in the northern pit. However, the amount available may be roughly estimated as several times the quantity already taken out.

The results of analysis of sample No. 13, which represents the average bank run, are given in Tables II and III.

IX. Leonard station, C.P.R. pit

Location.—Immediately north of the C.P.R. line, one-quarter of a mile east of Leonard station.

Description of deposit.—Elongated, rather low, flat-topped ridge lying in a northwest direction. The deposit extends over an area of approximately 1 mile × ¼ mile. The main pit from which ballast material was formerly obtained is now abandoned. It is over 500 yards long and its average width is 60 yards. The height of the banks ranges from 5 to 25 feet. Just west of the entrance to this main pit, near the railway tracks, there are a few small excavations from which several hundred cubic yards of gravel were obtained for road work.

Character of material.—Part of the banks in the main pit are covered with talus, but the various sections of exposure show that in the northern half of the deposit sand for the most part occurs. In the west bank of the southern half of the excavation good gravel is exposed. It is horizontally stratified with yellow sand. As a rule the sand is coarse, carrying a low percentage of pebbles. The gravel is bouldery but the amount of large boulders lying in the pit or seen in the bank is comparatively small. The depth of weathering varies from 1 to 3 feet. That portion of the bank where gravel occurs is standing up fairly well but the material in it is not packed very hard.

The composition of the pebbles includes several types of igneous rocks, limestones, sandstones, etc., and the proportion in which these various constituents are found varies a great deal from place to place in the deposit. The percentage of weathered and soft rocks is also large. The pebbles are partly coated with calcium carbonate and sand grains adhere to them.

The total amount of sand and gravel available in this deposit is approximately over 200,000 cu. yds., but the chances are that the quantity of suitable road gravel will not be over 20 per cent of this yardage. Two samples (Nos. 14 and 15) of gravel and one sample (No. 16) of the underlying sand, were taken from two different places a few hundred feet apart along the west bank near the entrance of the pit. The results of the analysis will be found in Tables II and III.

X. Walsh pit, Leonard station

Location.—A short distance east of the C.P.R. station. The pit is opened beside the road just north of and parallel to the railway. This is on the southwestern margin of the deposit described in Section IX.

Character of material.—Good road gravel of medium size. Some of it has been used for road work. The amount taken out is small, the excavation being only 35 yds.×20 yds.×2 yds.= 1,400 cubic yards.

In a 6-foot wall, interbedded layers of gravel and coarse sand are exposed, both materials occurring in about equal amount. The overburden is thin and the amount of boulders present is small. More material is to be had from this pit.

One sample was taken. See No. 17, Tables II and III.

XI. G. C. Hayes' pit, Cumberland

Location.—Lot A, concession IV, Cumberland township, 2 miles south of the town of Cumberland.

Description of deposit.—The deposit, which is approximately 400 yds. by 100 yds. in extent, overlies the bed-rock. It lies in the western slope of an extensive ridge of limestone trending northeasterly. The dimensions of the pit are 75 yds.× 75 yds.× 2 yds. = 11,250 cu. yds. It is doubtful whether the gravel reaches a depth of more than 6 to 8 feet.

Character of material.—This is an erosion limestone gravel containing very little fine. The sand part is composed of limestone particles and lumps carrying earthy material of a dark colour. The limestone pebbles are well rounded and white coated with calcium carbonate. The material is not packed hard, and there are streaks of gravel from which all of the fine material has been washed away. Clay and loam occur mixed with the fine, but in moderate quantity. Boulders over 6 inches in diameter are very few. The overburden consists of 10 inches to 1 foot of weathered gravel and loam. The amount of material still available is small.

Four samples were taken. Three (Nos. 18, 19, and 20) from the west wall of the pit at various depths from the surface, and one (No. 21) from the northern part of the excavation. The results of analyses are given in Tables II and III.

Results of Tests on Gravel Samples

The results of granulometric analyses of 21 samples of sand and gravel collected are given in Table II. Table III contains information on the character of the material, on the proportion of gravel (material over $\frac{1}{4}$ inch) to sand (material under $\frac{1}{4}$ inch), on the composition of pebbles as to their durability, and on the amount of impurities present.

It may be said that most of the gravels examined are clean and unweathered. Even those carrying more than 20 and less than 50 per cent of soft material will generally be suitable for light country traffic such as exists on county roads in this part of the country.

TABLE II

Results of Tests on Gravel Samples, Russell and Prescott Counties, Ontario

Granulometric Analysis

Sample No.	Location	Gravel: Per cent retained on screens							Sand: Per cent retained on sieves						% passing 200	Remarks
		2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
1......	Bélanger pit. Point Fortune.......	....	....	....	2	4	10	84	16	10	37	25	9	3	2	From layer B.
2......	Bélanger pit. Point Fortune.......	43	14	15	9	5	5	8	10	13	38	26	8	3	2	From layer C.
3......	Cut along road. Point Fortune....	49	4	10	7	8	12	11	16	14	28	22	11	6	3	
4......	Cousineau pit. W. of Point Fortune.	21	25	18	12	9	10	5	4	2	3	14	58	13	6	
5......	Kirby pit. Chute a Blondeau.....	35	18	12	10	6	8	11	15	19	27	17	8	5	9	
6......	Dandy pit. Little Rideau........	40	7	6	18	4	9	15	18	11	21	29	10	4	6	
7......	Dandy pit. Little Rideau........	....	10	21	18	7	11	31	16	16	26	25	10	4	3	
8......	Vankleek Hill pit. 2 m. S.W. of town........................	51	14	12	9	3	4	6	28	17	18	13	7	4	13	
9......	Vankleek Hill pit. 2 m. S.W. of town........................	....	2	10	21	15	21	32	18	23	28	17	3	3	7	
10......	Devlin pit. Clarence Point........	....	....	6	10	12	20	52	16	16	20	30	12	3	3	
11......	Rathwell pit. Bearbrook.........	....	....	....	....	....	....	....	....	....	1	2	51	40	6	From sand pit.
12......	Rathwell pit. Bearbrook.........	45	8	11	14	6	6	10	11	21	37	18	5	3	5	Pit A.
13......	Rathwell pit. Bearbrook.........	41	22	7	10	7	6	8	30	18	14	12	9	7	10	Pit B.
14......	Leonard Sta. C.P.R. pit..........	32	9	19	18	7	6	10	8	28	38	13	4	2	6	Upper part of wall.
15......	Leonard Sta. C.P.R. pit..........	9	....	2	16	19	21	32	9	11	22	28	21	7	3	Lower part of wall.
16......	Leonard Sta. C.P.R. pit..........	....	....	....	28	....	32	40	3	17	44	24	6	2	4	Underlying sand.
17......	Walsh pit. Leonard Sta...........	5	5	15	22	13	20	21	11	12	25	32	11	4	5	
18......	Hayes pit. Cumberland..........	....	11	14	35	15	17	8	10	9	13	15	17	17	19	Southwest bank. 1 ft. from surface.
19......	Hayes pit. Cumberland..........	....	9	23	43	9	10	6	19	11	13	16	13	11	17	West bank, 1½ ft. from surface.
20......	Hayes pit. Cumberland..........	....	9	18	23	17	16	17	16	20	30	22	7	2	3	West bank, 4 ft. from surface.
21......	Hayes pit. Cumberland..........	....	....	10	7	9	27	47	40	15	13	9	7	6	10	Northern wall.

TABLE III

Results of Tests on Gravel Samples, Russell and Prescott Counties, Ontario

Character of Gravel

Sample No.	Proportion of gravel to sand per cent of		Composition of pebbles per cent of			Colour test	Remarks
	Gravel	Sand	Durable	Intermediate	Soft		
1........	15	85	33	46	21	100	Very fine gravel. Good concrete aggregate. Per cent of material between ¼-inch and 1 inch too low, and proportion of sand too large for top course gravel. Binder content also very low.
2........	75	25	12	39	49	100	Gravel is coarse; sand is fine. Too large per cent of material over 1 inch. High per cent of soft material.
3........	65	35	33	38	29	0	Fairly well graded gravel. Contains pebbles over 2½ inches to be raked off if used in surfacing.
4........	75	25	30	43	27	100	Gravel rather coarse; sand too fine.
5........	65	35	9	33	58	200	Coarse gravel. Well graded sand. High per cent of soft material. Moderate amount of impurities.
6........	85	15	15	61	24	100	Small proportion of sand. Large per cent of pebbles over 2½ inches.
7........	55	45	15	70	15	200	Well graded for surfacing purposes.
8........	90	10	15	79	6	200	Lacks fine material. Sand well graded and containing proper amount of clay binder, but its proportion to gravel content is low.
9........	60	40	9	80	11	200	Properly graded for road surfacing. Enough binder.
10........	35	65	10	80	10	100	Well graded, but high per cent of sand.
11........	....	100	....	....	....	100	Too fine sand for concrete.
12........	50	50	12	54	34	0	Fairly well graded road gravel. Clean.
13........	85	15	9	67	24	50	A little low in sand, but suitable for use in the base course of gravel roads.
14........	45	55	30	27	43	0	Sand too uniform and in too large proportion for surfacing. Good concrete aggregate.
15........	30	70	10	67	23	50	Better grading than No. 14 for road work, but too much sand.
16........	5	95	26	53	21	50	Poorly graded sand for concrete.
17........	55	45	10	60	30	0	Well graded road gravel. Suitable for use in top course.
18........	90	10	....	80	20	500	Well graded limestone gravel. The per cent of sand is low, but on account of a high content of clay and organic matter, this material should bind well. (Nos. 18–21)
19........	90	10	....	75	25	500	
20........	55	45	....	95	5	500	
21........	85	15	....	90	10	500	

TABLE IV

Results of Tests on Gravel Samples, Russell and Prescott Counties, Ontario

Sand Mortar 1:3 mix

Sample No.	Locality	Fineness modulus	% clay and silt	Colour test	% water used	Per cent of strength relative to that of Standard Ottawa sand (1)				Remarks
						Tensile strength		Compressive strength		
						7 days	28 days	7 days	28 days	
1	Bélanger pit, Point Fortune.......	2·84	5	100	13	110	126	127	124	Good.
2	" "	2·76	5	100	11	141	148	166	145	Good.
3	" "	2·75	8	0	12	129	140	168	164	Good
4	Cousineau pit, W. of Point Fortune.	1·23	15	100	16	88	102	65	79	Too fine for concrete.
5	Kirby pit, Chute à Blondeau......	2·74	10	200	14	104	111	130	126	Fairly good.
6	Dandy pit, Little Rideau.........	2·70	8	100	13	125	136	141	136	Fairly good
7	" "	2·83	10	200	17	95	106	93	70	Low, probably due to impurities.
9	2 miles S.W. of Vankleek Hill.....	3·06	10	200	11	140	146	171	155	Very good, though colour test shows presence of impurities.
10	Devlin pit, Clarence Point........	2·76	5	100	12	79	110	122	101	Rather low.
11	Rathwell pit, Bearbrook..........	0·58	6	100	20	47	79	44	55	Unsuitable for concrete.
12	" "	2·91	5	0	12	127	166	138	144	Very good.
13	" "	2·97	15	50	16	119	121	145	119	Good.
14	C.P.R. pit, Leonard station.......	2·99	6	0	12	129	142	130	134	Good.
15	" "	2·29	3	50	12	93	147	128	115	Rather low, due to fineness and un-uniform grading.
16	" "	2·69	4	50	12	104	91	93	105	Rather low, due to fineness and un-uniform grading.
17	Walsh pit, Leonard station........	2·53	5	0	13	108	115	120	137	Rather low, due to fineness and un-uniform grading.

(1) Ottawa standard sand, strength of 1 : 3 mortar:
- Tensile 7 days— 234 lbs. per sq. in.
- " 28 days— 282 lbs. per sq. in.
- Compressive 7 days—1,510 lbs. per sq. in.
- " 28 days—2,600 lbs. per sq. in.

Amount of water used—10%

III

ROAD MATERIALS SURVEY IN ROCKY MOUNTAINS PARK

In compliance with a suggestion from the Department of the Interior, investigations of road materials were undertaken in the Rocky Mountains Park in 1919,[1] and continued during the summer of 1921.

These investigations were carried on in co-operation with the Parks Branch highway engineers.

The work consisted in locating, examining, sampling, testing and reporting on the comparative road-making qualities of the material occurring along various park roads under construction, so that the most suitable material may be chosen for their surfacing.

Up to date, materials along the Banff-Lake Louise road, a distance of 35 miles, were examined and investigations were also carried on along the Banff-Windermere road.

When the examination of materials along these roads was commenced in 1919 by Dr. K. A. Clark,[1] the road grade on the Banff-Lake Louise road ended a few miles west of Castle, and on the Banff-Windermere road only that portion of the proposed road from Castle southward to the Vermilion summit was opened, a distance of about 17 miles. Since then, construction work has been completed between Castle and Lake Louise and the road opened for traffic during the early part of the 1921 season. The completion of this highway gives to motorists from Calgary and Banff access to the beautiful Lake Louise and Lake Moraine districts.

The road material survey along the final 11 miles of this important highway was resumed and completed this year.

The grading of the Castle-Windermere road is not yet completed, but construction work is proceeding, and before the end of next summer the road will likely be opened to tourist traffic. This road, which forms a link connecting the Bow valley road with the Columbia river highway, will open up a loop route through the Canadian Rockies connecting our national parks with the United States park-to-park system of highways. With its completion, it will be possible for tourists to motor from the prairies via Calgary and Banff, to Windermere, B.C., in the Columbia valley, to Lethbridge, and back to the plains. American motorists will also be able to travel from the national park-to-park highway and the United States Glacier park via Macleod and Calgary through our Canadian Rockies via Banff, Windermere, Cranbrook and back to the United States, thence via the Sunset and Pacific coast highways, to California.

This road undoubtedly means much to the future of the Rocky Mountains park, as it will render its attractive scenic beauties accessible to motor traffic from both east and west.

The distance from Castle to the Columbia valley is about 75 miles. From Castle the road leads to the Vermilion summit, thence to the Kootenay valley, and through the Sinclair pass to the Columbia valley.

An examination of the material occurring along this highway was carried on last summer. This survey included two sections of the road—at the north end, the Vermilion river division, that is from Marble canyon, just south of the Vermilion summit, southward along the Vermilion river

[1] Mines Branch, Summary Report, 1919, pages 139–147.

to Hawk creek, a distance of about 10 miles; at the southern end of the road, the Sinclair Pass-Kootenay Valley division, that is from the Columbia river highway northward to near where the road crosses the Kootenay river to enter a pass to the Vermilion valley. The distance covered at that end of the road is approximately 21 miles. There still remain about 25 miles of this road to be surveyed for road materials. With this work accomplished, complete information regarding the available road materials for this road will be at the disposal of the engineers and contractors in charge of its surfacing. In this examination, fairly suitable material has been located at intervals within economical hauling distance.

SOURCES OF SUPPLY OF ROAD MATERIAL

In mountainous country such as Rocky Mountains Park the roads naturally follow, as much as possible, the courses of the valleys, or are built on the side of the foothills.

These valleys, as a rule, are filled with drift material, and sand and gravel is of general occurrence along the stream channels. The foothills are generally made up of unconsolidated materials which vary from sand and gravel to stony soils, boulder clay and clay. Rock outcrops are seldom met with along the roads in the flats, but they are plentiful in the passes where extensive cutting is often involved.

The Banff-Lake Louise road, which runs up the Bow valley from Banff, keeping to the right hand side of the river, is constructed partly in the valley flat, and partly in side cuts along the foothills.

The Castle-Windermere road, owing to the nature of the country it traverses, is for its greater part built on hillsides which necessitated very heavy work, particularly through the Vermilion and the Sinclair passes.

Because of the nature of the country, materials for the surfacing of these roads must be immediately accessible from the right of way. The different kinds of unconsolidated material and rock employed in highway construction in mountainous country are rarely transported for long distances, local sources of supply being usually drawn upon. The problem was to locate the best material exposed from place to place along the right of way, rather than to seek the most desirable type of material which might occur at a distance from it. It therefore devolves upon the engineer to carefully examine these local sources with reference to the quality, quantity, and accessibility of the materials available. Generally, at short intervals these roads cut through shoulders of gravelly material, which in some cases, is fairly satisfactory for surfacing purposes. Such material includes stone, sand and gravel, and boulder clay.

ROAD STONE

Rock outcrops along the Banff-Lake Louise road from Castle to Laggan are few, the only occurrences of extent being one of grey slate and one of much weathered rusty sericite schist, a short distance east of the railroad crossing. Both rocks are unsuitable for road work.

Crushed stone, however, if desired for surfacing, could be obtained from boulders which are to be found in sufficient quantity along most parts of the road. These boulders occur in large quantities in the boulder clay, and, as a rule, they are sound and of such size as to permit handling in a small crusher without preliminary breaking. The aggregate is mainly composed of hard and tough limestone and quartzite.

On the Castle-Windermere road, any amount of stone for road work could be quarried from rock cuts along the right of way throughout the Vermilion and the Sinclair passes, but on the other sections of this road that were visited there are very few opportunities for quarrying. There, again, boulders from bouldery soils and coarse gravels could be used for the production of crushed stone. The bulk of this material along the Vermilion and Kootenay rivers and in the Sinclair pass is limestone and dolomite.

Among the more important outcrops from which stone could be obtained are the following:—

Sinclair Canyon

Cliff-over 75 feet high of fine-grained, buff-coloured limestone, partly fresh, partly weathered. The amount easily available is unlimited.

About one-quarter mile north of Sinclair Canyon

On either side of the pass, which is very narrow at this point, there are outcrops of uneven textured, greyish limestone, containing veinlets of calcite. Some of this stone is fairly tough but much of it is weathered and soft. Large quantities of loose material composed of rock fragments are to be found in talus just south of the above mentioned rock outcrops. The stone resembles in character that of the bed-rock but is much more weathered. Most of these fragments are of small size and could be used in road foundation work, or even in the lower course of macadam without being run through a crusher. One sample was taken and tested. See Table V. The ability of this material to resist wear is comparable to that usually shown by medium soft limestone.

Immediately north of Radium Hot Springs

Buff-coloured limestone or dolomite is exposed in rock cuts along the road. Material for crushed stone could be easily obtained.

Red Bluff, about one-quarter mile north of Radium Hot Springs

Brick red to pink dolomite forming huge cliff. The stone is iron stained and contains geodes and veinlets of secondary calcite. It is somewhat weathered and rather soft.

Very large quantities of this material are readily available from a talus over 50 feet high just south of the cliff. The disintegrated rock constitutes an aggregate which is fairly well graded from dust to gravel sizes and could be used as gravel for road surfacing purposes. The results of analysis of one sample collected are given in Tables XI and XII. See No. 56.

Abrasion and cementing tests on this stone have shown that it is not resistant to wear but that it binds well. The road surface along the talus where this material occurs is well compacted and apparently wears uniformly, but it is dusty in dry weather.

South of bridge, three-quarter mile north of Radium Hot Springs

Big rock cut, on road. Fresh, dark coloured limestone, very fine-grained, with numerous irregular shaly partings and veinlets of calcite. Breaks very irregularly with sharp edges. This limestone is harder and wears more slowly than the red dolomite and the lighter coloured limestones occurring in the southern portion of the pass. Large quantities of it could be obtained from debris or quarried without trouble. One sample was taken and tested. See Table V.

Similar limestone is well exposed in rock cuts in several instances, at short intervals along the road, between mile $3\frac{1}{4}$ and mile $5\frac{1}{4}$.

From Summit Lake to Kootenay Valley

Rock outcrops are frequently encountered along the right of way, but they cannot be regarded as possible sources of road material. The exposures are either of black, rusty, thinly foliated shales, or whitish talcous schist, both classes of rock being unsuitable for road work.

GRAVEL

Gravel is of pretty general occurrence along the Banff-Lake Louise road, and in the Sinclair pass and Kootenay sections of the Banff-Windermere road.

From Castle to Laggan the gravel, as a rule, occurs in the valley flats, but how thick the deposits are cannot be told without boring or test-pitting. Insofar as could be observed in borrow pits made in connection with the grading of the road, these surface gravel deposits are only of small thickness and are underlaid by the clays. They carry in most cases loam, clay or silt, but in rather small proportion.

The gravels to be found along the Vermilion section of the Banff-Windermere road occur in pockets or in strata through the boulder clay. The deposits often carry stratified layers, lenses or lumps of clay. The clay and silt content of these gravels is therefore generally much higher than that of the gravels in the Bow valley.

In the Sinclair pass and along the Kootenay valley the amount of fine material passing 200 mesh carried by the gravels is also quite high, but of a more silty nature.

In carrying on this road material survey nearly all the gravel occurrences encountered were sampled. These samples number over 40. They were examined and tested as to their suitability as road surfacing material or as concrete aggregate.

BOULDER CLAY

Along the above-mentioned sections of road boulder clay deposits in which the proportion of stone content to that of clay is high, were noted and sampled. This material is seldom just what is required to provide a really suitable surfacing material. It is often too coarse or unevenly graded, deficient in fine material, or full of silt and clay. However, some of the deposits examined contain material that might furnish a fairly good aggregate. Similar material was used in road surfacing and fairly good results were obtained. A glance at the results of analysis which are recorded in Tables VII to XII will show that some of the boulder clay samples compare well with the gravels of the same locality.

For the purpose of comparison, values obtained in the granulometric analysis of 60 samples of gravel, 20 samples of boulder clay and a number of samples taken from gravel road surfaces in Rocky Mountains Park, have been condensed in a table by Dr. K. A. Clark.[1] His figures are partially reproduced in Table VI, together with the limits shown by the screen analysis of the samples collected during 1921.

The limits for analysis of samples of good gravel road surfaces can be taken as reference limits in the comparison of the various materials as to their suitability for road surfacing purposes. The road making quality of an aggregate such as gravel or boulder clay is largely dependent on the following factors, fineness modulus, per cent of coarse, per cent of cement (material passing 200 mesh), and physical properties of cement. With reference to these factors, the difference in the proportion of material passing 200 mesh is probably the most important when comparing gravels or boulder clays, as it is this fine material that in the case of a gravel road makes the difference between a compacted and a loose surface, while in boulder clay roads it makes the surface hard when dry, but renders it muddy and slippery when wet.

[1] Mines Branch, Summary Report, 1919, Road Materials in Rocky Mountains Park, page 145.

TABLE V

Results of Physical Tests upon Bed-rock. Rocky Mountains Park

Locality	Rock type	Physical properties							Remarks
		% wear	French coef. of wear	Tough-ness	Hard-ness	Specific gravity	Absorp-tion in lbs. per cu. ft.	Cement-ing value	
¼ mile N. of Sinclair canyon (Banff-Windermere road).	Limestone	4·7	8·5	Low	....	2·76	0·5	....	Uneven textured. Rock fragments. Talus material. Partly weathered.
North of Radium Hot Springs.	Dolomite	5·4	7·3	Low	....	2·65	1·2	77	Brick red to pink altered rock. Forms big cliff. Fairly well graded aggregate to be had from talus.
About ¾ mile north of Radium Hot Springs.	Limestone	4·10	9·7	Medium	16	2·71	0·3	24	Fresh, dark coloured fine-grained limestone with veinlets of calcite and irregular shaly partings.

TABLE VI

Summary of the Results of Granulometric analyses of samples from surfaces of Gravel Roads and of samples from Gravel and Boulder Clay Deposits

Location	Number of samples	Per cent of gravel (material over ¼ inch,) in total aggregate		Per cent passing 200 mesh in material under ¼ inch.	
		Limits	Average	Limits	Average
1919 survey—					
Gravel from gravel road surfaces.......	7	35 to 60	....	25 to 35	
Gravel from deposits along various park roads..............................	60	40 to 75	....	5 to 30	
Boulder clay deposits along various park roads..............................	20	20 to 60	....	25 to 50	
1921 survey—					
Gravel along Castle-Laggan road.......	21	10 to 85	50	2 to 45	12
Boulder clay Castle-Laggan road.......	8	35 to 60	45	25 to 55	35
Gravel along Vermilion section of the Windermere road....................	8	35 to 80	55	8 to 55	25
Boulder clay along Vermilion section of the Windermere road................	12	30 to 65	50	25 to 65	45
Gravel along Sinclair pass-Kootenay section of the Windermere road.......	13	40 to 80	60	10 to 35	25
Boulder clay along Sinclair pass-Kootenay section of the Windermere road..	11	35 to 70	55	25 to 55	35

TABLE VII

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF—LAKE LOUISE ROAD (Eldon-Laggan Division)

Sample No.	Location of deposit (chainage)	Type of material	Granulometric analysis: Proportion of gravel to sand		Gravel: Per cent retained on screens							Sand: Per cent retained on sieves						Sand	Remarks
			Per cent grav.	Per cent sand	2½″	2″	1½″	1″	¾″	½″	¼″	8	14	28	48	100	200	% passing 200	
1	340	Gravel........	60	40	0	9	8	32	13	16	22	14	14	21	29	15	5	2	Fairly well graded for road work
2	340–345	Boulder clay..	......	100	....	....	....	....	....	....	....	9	10	10	12	18	21	20	Yields a firm foundation. Needs little gravel on top.
3	360–365	Gravel........	60	40	0	4	3	20	12	25	36	32	15	11	15	15	7	5	Well graded.
4	400–405	Gravel........	65	35	44	10	9	15	6	6	10	14	18	19	18	14	9	8	Not as good grading as above, but contains more binder.
5	465	Gravel........	45	55	0	12	24	19	9	16	20	8	12	18	22	18	11	11	High clay content.
6	465	Gravel........	85	15	0	25	33	26	6	6	4	6	8	11	14	14	17	30	Very high clay content.
7	466	Gravel........	57	43	0	9	17	24	13	16	21	17	12	14	24	23	7	3	Could be used for concrete.
8	500	Gravel........	60	40	25	7	9	15	8	13	23	21	22	29	19	6	2	1	Lacks binder, to be used as surfacing material.
9	500	Boulder clay..	45	55	11	4	20	16	11	15	23	14	10	11	14	22	19	10	Will pack well in a road bed but surface will be dusty.
10	500	Boulder clay..	58	42	25	20	15	13	7	8	12	8	13	15	19	24	14	7	
11	525	Gravel........	70	30	22	8	20	15	10	10	15	21	11	19	33	10	3	3	Suitable for concrete.
12	550	Gravel........	73	27	0	0	7	26	13	22	32	32	6	2	6	32	14	8	Loamy.
13	558–560	Gravel........	58	42	0	16	9	19	14	16	26	15	16	26	23	7	5	8	
14	585–590	Gravel........	–	–	21	14	11	21	12	11	10	36	22	22	12	3	2	3	Fairly well graded, lacks binder
15	595	Gravel........	40	60	8	25	8	13	6	12	28	13	19	41	19	3	2	3	Lacks binder. Suitable for concrete.
16	615	Boulder clay..	60	40	0	0	17	23	24	14	22	21	16	15	15	15	10	8	Well graded aggregate.
17	620–623	Boulder clay..	55	45	0	15	19	24	11	12	19	17	12	14	18	19	13	7	Well graded aggregate.
18	640	Clayey gravel.	30	70	0	0	3	10	10	24	53	22	17	20	23	10	4	4	Good clayey fine gravel.
19	660	Boulder clay..	55	45	11	9	15	13	16	16	20	14	13	16	22	19	11	5	Well graded aggregate. Packs well.
20	707–714	Gravel........	70	30	0	12	23	29	8	12	16	23	16	18	23	12	5	3	Well graded but lacks binder.
21	714–717	Boulder clay..	43	57	0	0	4	13	9	18	56	30	18	14	12	12	9	5	Good surfacing material.
22	714–717	Gravel........	58	42	4	19	14	20	12	13	18	12	11	27	35	10	3	2	Can be used for concrete purposes
23	786	Gravel........	60	40	5	6	14	19	11	17	28	18	24	30	17	7	3	1	Well graded, lacks binder

24	800–805	Boulder clay..	35	65	0	0	15	11	13	23	38	17	13	15	17	15	10	13	Sample taken from road crust.
25	808–810	Gravel........	20	80	0	0	0	4	7	22	67	13	8	15	31	23	8	2	Suitable for concrete work.
26	815	Gravel........	55	45	11	4	12	16	9	13	35	23	22	15	13	14	10	3	Well graded. Carries enough binder to be used in surfacing work.
27	830	Gravel........	42	58	0	0	2	21	10	22	45	23	11	11	23	25	5	2	
28	830	Gravel........	70	30	0	12	32	35	13	6	2	2	1	4	35	41	11	6	Poorly graded. Too fine sand. Silty.
29	845–851	Gravel........	10	90	0	0	7	11	9	20	53	8	19	31	29	7	2	4	Too sandy for road surfacing. Could be used in concrete.
30	867	Gravel........	12	88	0	0	7	22	8	18	45	10	21	42	22	3	1	1	

TABLE VIII

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF-LAKE LOUISE ROAD (Eldon-Laggan Division)

Sample No.	Type of material	Character of material						Amount available	Remarks
		Composition of pebbles			Remarks	Shape of pebbles	Clay and silt		
		Durable	Intermediate	Soft					
		%	%	%			%		
1	Gravel	45	45	10	Largely quartzite	Subangular	10	Small	Loamy.
2	Boulder clay	....	....	....	Limestone and dolomite	....	55		
3	Gravel	0	75	25	Dolomite predominates. Some sandstone and shale.	Rounded	9	Small.	
4	Gravel	30	50	20	Largely metamorphosed limestone.	Subangular	29	Probably large	Loamy and clayey, loose. Ridge.
5	Gravel	35	50	15	Largely quartzite with limestone and dolomite, partly altered.	Partly round, partly angular	48	“	“ “ “
6	Gravel	45	45	10			58	“	“ “ “
7	Gravel	45	50	5	“ “	“	7	Small	Clean, in flat.
8	Gravel	40	30	30	“ “	Mostly angular.	4	Fairly large	Loose sandy to bouldery, in flat.
9	Boulder clay	10	80	10	Largely metamorphosed limestone or dolomite.	Rounded to angular.	26	Very large	Well compacted. Hillock at Baker creek.
10	Boulder clay	40	45	15	....	“	54	“	
11	Gravel	50	30	20	....	Angular	6	About 1,500 cu.yd.	In flat.
12	Gravel	30	60	10	....	Angular	31	Very small	Loamy. Packs well.
13	Gravel	30	55	15	Pebbles coated with $CaCO_3$.	“	9	Over 5,000 cu.yds.	Bouldery deposit.
14	Gravel	40	40	20	D.—Quartzite. I.—Marble and sandstone.	“	8	1,000 cu. yds	Bouldery. Deficient in binder.
15	Gravel	30	55	15	D.—Quartzite. I.—Limestone.	Rounded to subangular.	4	Small	Loose washed gravel in flat.
16	Boulder clay	35	50	15	“	“	23	....	Loose, loamy. Ridge.
17	Boulder clay	35	50	15	“	“	27	Small	In road cuts. Well compacted opposite Temple Sta.
18	Clayey gravel	20	70	10	I.—Largely marble	“	18	Probably exhausted.	Was used with success last summer in road surfacing work.

19	Boulder clay..	40	50	10	"	....	31	" ..	" " "
20	Gravel........	60	35	5	D.—Largely quartzite......	Fairly angular	9	Large............	Loose, loamy and bouldery.
21	Boulder clay..	35	60	5	$CaCO_3$ coating............	Fairly angular	25	Fairly large......	Can be readily obtained from big cut along road.
22	Gravel........	25	65	10	....	Fairly angular	6	"	
23	Gravel........	35	20	45	High content of soft flat shales.	Many flat	4	About 1,000 cu.yd.	
24	Boulder clay..	20	35	45	" " ..	pebbles. ..	31	....	Sample taken from road crust.
25	Gravel........	30	35	35	" " ..	" ..	10	Small............	Very sandy.
26	Gravel........	30	45	25	I.—Mostly limestone and sandstone.	Largely angular.	13	700 cu. yds........	
27	Gravel........	60	35	5	D.—Quartzite.............. I.—Limestone and dolomite. S.—Shales.	Subangular...	5	Large............	Clean, loose sand and gravel.
28	Gravel........	50	40	10	"	Subangular....	12	Large............	Silty.
29	Gravel........	45	35	20	"	Rather angular.	6	Fairly large......	Turbidity in color test due to clay content. Mortar tested good.
30	Gravel........	40	40	20	"	" ..	2	Large............	Clean sand for concrete.

TABLE IX

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF-WINDERMERE ROAD (Vermilion River Division)

Sample No.	Location of deposit (chainage)	Type of material	Granulometric analysis: Proportion of gravel to sand		Gravel: Per cent retained on screens							Sand: Per cent retained on sieves						% passing 200	Remarks
			Per cent grav.	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
31	253	Boulder clay...	68	32	13	8	25	18	9	12	15	18	12	12	12	12	12	22	Fairly well graded for surfacing purposes. Opposite Tokkum creek.
32	....	Boulder clay..	50	50	12	10	13	16	11	16	22	18	8	7	8	14	17	28	North of gate.
33	290–295	Boulder clay..	50	50	0	6	5	25	14	20	30	23	16	15	13	7	9	17	In flat.
34	67	Boulder clay..	40	60	0	3	12	19	15	22	29	15	11	8	9	14	27	16	Packs well on road.
35	80–87	Boulder clay..	33	67	0	0	6	17	18	22	37	16	11	7	7	7	13	39	Very poor road material.
36	116–118	Gravel........	45	55	4	8	14	15	10	14	35	30	23	18	10	4	2	13	Suitable for road surfacing purposes.
37	145	Sand..........	......	100	....	....	....	....	....	....	....	....	0	2	19	36	20	23	Too fine for concrete.
38	156	Boulder clay..	68	32	35	3	15	10	9	11	17	24	18	15	12	8	8	15	Well graded. Suitable for surfacing purposes.
39	220–225	Boulder clay..	50	50	0	13	18	15	10	17	27	19	17	12	10	7	8	27	Packs well on road. Well graded. Good surfacing material.
40	230	Boulder clay..	45	55	0	8	13	16	13	18	32	19	14	15	13	8	7	24	" "
41	243	Clayey gravel.	80	20	11	6	21	18	10	14	20	24	13	11	14	13	8	17	" "
42	268	Gravel........	69	31	0	0	2	12	19	25	42	59	16	4	2	2	4	13	Packs and cements well on the road.
43	277	Gravel........	46	54	0	4	10	20	17	19	30	19	13	10	10	7	7	34	High content of clay and loam.
44	282	Gravel........	44	56	6	0	22	14	14	19	25	15	11	8	8	9	10	39	High clay content, compacted hard.
45	295–298	Gravel........	36	64	0	0	17	31	10	17	25	16	17	19	14	10	6	18	Too large proportion of sand. However actual road surface firm and smooth.
46	323–325	Boulder clay..	57	43	4	23	27	15	8	9	14	13	10	9	10	12	20	26	Fairly well graded. High clay content.

47	327–328	Boulder clay...	55	45	19	6	9	24	10	12	20	21	16	13	10	6	6	28	Better material than above.
48	333	Boulder clay..	44	56	0	0	15	19	12	21	33	20	14	12	12	11	7	24	Fairly good material.
49	345	Boulder clay..	45	55	0	21	14	11	12	16	26	20	12	11	12	10	20	15	“ “
50	432	Gravel........	70	30	12	7	12	20	15	15	19	28	17	15	12	8	5	15	Well graded loamy gravel.
51	442	Gravel........	62	38	0	8	22	18	15	16	21	23	25	29	13	14	2	4	Lacks binder to be used as surfacing material. Clean enough for concrete.

TABLE X

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF-WINDERMERE ROAD (Vermilion River Division)

Sample No.	Type of material	Character of material						Amount available	Remarks
		Composition of pebbles				Shape of pebbles	% clay and silt		
		Durable %	Intermediate %	Soft %	Remarks				
31	Boulder clay....	5	55	40	Marble, limestone and shaly limestone.	Subangular and flat	40	Small	
32	Boulder clay....	0	95	5	Largely marble............	Angular	45	Small	
33	Boulder clay....	5	50	45	Largely marble............	Subangular	34	Very small	
34	Boulder clay....	....	20	80	Very high % soft calcareous shales and weathered stone.	Flat	55	Fairly large	High in clay content.
35	Boulder clay....	5	15	80	" "	Flat	64	....	Too high clay content.
36	Gravel.........	5	30	65	" "	Flat	15	Small	Fairly clean concrete aggregate, but high clay content.
37	Sand...........	....	....	....	....	....	33	Small	Too silty.
38	Boulder clay....	5	25	70	" "	Flat	26	900 cu. yds.	About proper clay content.
39	Boulder clay....	0	35	65	" "	Flat	38	A few hundred cu. yds.	Loose, loamy material.
40	Boulder clay....	10	65	25	Largely marble and limestone.	Subangular	36	Large	Well compacted material in bank and on road surface.
41	Clayey gravel..	5	60	35	" "	Subangular	28	800 cu. yds.	Road surface a little loose.
42	Gravel.........	5	70	25	" "	Subangular	17	A few hundred cu. yds.	Proper amount of binder.
43	Gravel.........	5	40	55	Largely limestone, shaly limestone and weathered shales.	Angular and flat	50	Small	Very loamy and clayey gravel.
44	Gravel.........	0	35	65	" "	" "	57	Small	" "
45	Gravel.........	5	65	30	" "	" "	21	Small	Too high clay content to be used for concrete.
46	Boulder clay....	0	30	70	" "	Subangular and flat	66	....	High clay content. Boulders.
47	Boulder clay....	0	35	65	" "	" "	42	Over 1,000 cu. yds.	Well compacted on road.
48	Boulder clay....	0	45	55	" "	" "	48	Fairly large	Very few boulders.
49	Boulder clay....	0	50	50	" "	" "	57	Rather small	Loamy.
50	Gravel.........	5	35	60	" "	" "	20	Probably large	Contains just enough binder.
51	Gravel.........	0	55	45	" "	" "	28	Fairly large	Rather clean concrete aggregate

TABLE XI

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF-WINDERMERE ROAD (Sinclair Pass—Kootenay Valley Division)

Sample No.	Location of deposit (chainage)	Type of material	Granulometric Analysis: Proportion of gravel to sand		Gravel: Per cent retained on screens							Sand: Per cent retained on sieves						% passing 200	Remarks
			Per cent grav.	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
	Mileage from Columbia Valley road																		
52......	½ mile......	Boulder clay..	53	47	7	5	6	13	14	22	33	21	13	11	13	14	13	15	Well graded, suitable for surfacing purposes.
53......	½ "	Gravel........	50	50	0	0	0	13	18	23	46	32	21	16	13	10	6	2	Good concrete aggregate.
54......	¾ "	Boulder clay..	50	50	0	0	10	12	14	30	34	16	15	18	17	17	11	6	
55......	Just S. of Radium Hot Spring	Boulder clay..	65	35	0	15	16	29	10	11	19	29	20	18	12	6	8	7	Material in bank partly coarser than sample.
56......	N. of Radium Hot Springs.	Disintegrated rock (talus).	90	10	16	7	25	23	8	11	10	38	14	10	9	8	9	12	Fairly well graded talus material.
57......	2½ miles....	" "	67	33	19	12	8	12	11	12	26	37	15	9	7	6	8	18	Talus runs coarser than sample.
58......	3¼ "	Gravel........	47	53	0	8	4	14	15	24	36	26	14	12	13	12	11	12	Sandy fine gravel. Contains enough binder to be used in surfacing work.
59......	4 "	Boulder clay..	65	35	15	7	10	15	12	17	24	32	15	9	8	9	15	12	Fairly well graded, compacts well on road.
60......	4¼ "	" "	38	62	0	0	15	14	10	20	41	23	17	13	11	10	12	14	Per cent over ¼-inch a little low.
61......	4¾ to 5 "	" "	48	52	0	0	33	10	11	25	51	33	18	13	9	8	9	10	Good surfacing material.
62......	5½ "	Gravel........	70	30	13	3	12	20	12	17	23	30	11	8	11	13	16	11	Loamy fine to medium gravel. Good grading.
63......	6¼–6½ "....	"	70	30	4	0	8	16	12	23	37	47	16	9	6	5	7	10	" " "

TABLE XI—*Con.*

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountain Park

ALONG BANFF-WINDERMERE ROAD (Sinclair Pass—Kootenay Valley Division)

Sample No.	Location of deposit (chainage)	Type of material	Granulometric analysis: Proportion of gravel to sand: Per cent grav.	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	% passing 200	Remarks
64......	6½ miles....	Gravel........	54	46	0	16	3	7	11	20	43	44	24	13	8	4	3	4	Contains enough binder to be used in surfacing work.
65......	7½ "	Boulder clay..	70	30	0	0	10	23	18	26	23	26	16	13	12	11	11	11	
66......	7·8 "	"	52	48	0	2	4	16	15	23	40	21	11	12	12	10	10	24	Fairly well graded stone aggregate. Contains high clay content.
67......	8½ "	Drift..........	47	53	0	2	10	14	18	27	29	37	19	8	4	4	7	21	Loamy material, loose.
68......	Summit Lake.	Gravel........	75	25	3	4	11	22	16	23	21	29	14	12	12	11	9	13	Loose loamy gravel in flat.
69......	9½ miles....	"	40	60	0	2	7	21	13	21	36	16	15	18	18	13	11	9	High per cent passing ¼-inch screen. Loamy.
70......	10 "	Boulder clay..	67	33	0	0	8	17	14	25	36	37	21	12	8	8	8	6	Well graded.
71......	10-10¾ "	Gravel........	78	22	0	0	2	8	14	30	46	45	11	8	7	7	12	10	
72......	10-10¾ "	Boulder clay..	60	40	0	5	8	16	16	23	32	27	18	16	13	11	12	3	
	Chainage																		
73......	879–867.....	Clayey gravel	35	65	0	0	2	11	14	25	48	23	19	17	14	9	9	9	Contains high clay content.
74......	776..........	Gravel........	52	48	0	0	14	17	12	23	34	25	13	12	12	11	12	15	Contains clayey loam binder. Well graded fine gravel.
75......	753.........	"	55	45	14	4	7	19	16	16	24	23	18	20	15	9	11	4	Well compacted in bank and on road. Good grading.
76......	720.........	"	67	33	0	2	5	18	13	24	38	37	15	8	7	10	11	12	Very good gravel.
77......	697–415.....	"	83	17	5	14	21	24	12	11	13	38	15	12	15	7	4	9	Clean concrete aggregate. Lacks binder for use in road surfacing.

TABLE XII

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF-WINDERMERE ROAD (Sinclair Pass—Kootenay Valley Division)

Sample No.	Type of material	Character of material						Amount available	Remarks
		Composition of pebbles				Shape of pebbles	% clay and silt		
		Durable %	Intermediate %	Soft %	Remarks				
52	Boulder clay	5	65	30	Mostly fresh limestone coated with calcium carbonate.	Rounded	24	Large	Looks almost like gravel carrying clay.
53	Gravel	5	80	15	" "	"	10	Fairly large.	
54	Boulder clay	0	70	30	" "	"	45	Large.	
55	"	0	75	25	....	"	28	Small.	
56	Disintegrated rock (talus).	0	20	80	Brick red altered dolomite	Angular	29	Very large	Compacts well but yields a dusty road surface. Will wear fast.
57	"	0	70	30	Largely limestone	"	27		
58	Gravel	0	85	15	" "	Rounded	23	Small.	Too high clay and silt content for concrete.
59	Boulder clay	5	85	10	" with $CaCO_3$	Subangular	36	At least 2,500 cu. yds.	
60	"	0	75	25	Largely limestone	"	36	1,000 cu. yds.	
61	"	0	90	10	" "	"	26	Large	Good surfacing material.
62	Gravel	0	90	10	" "	"	31	Very small	Loamy.
63	Gravel	0	80	20	....	....	26	Rather small	Loamy loose gravel.
64	"	0	90	10	....	....	16	Large	Packed hard in bank. Clay and silt content high for concrete.
65	Boulder clay	0	60	40	Limestone and weathered shales.	Angular	47	Small	Rather poor material.
66	"	0	90	10	....	....	55	Fairly large	Very high clay content.
67	Drift	0	60	40	Limestone and shales	"	28	Very small	Loam.
68	Gravel	5	20	75	Weathered shale	Rounded to flat.	27	Small	Loam. Ought to bind well.
69	"	0	40	60	" "	"	34	Small	Loamy.
70	Boulder clay	5	60	35	Largely limestones and shales.	Subangular	32	A few hundred cu. yds.	

TABLE XII—*Con.*

Results of Physical Tests on Gravel and Boulder Clay Samples, Rocky Mountains Park

ALONG BANFF-WINDERMERE ROAD (Sinclair Pass—Kootenay Valley Division)

Sample No.	Type of material	Character of material						Amount available	Remarks
		Composition of pebbles				Shape of pebbles	% Clay and silt		
		Durable %	Intermediate %	Soft %	Remarks				
71......	Gravel........	0	70	30	Largely limestone and shales	Subangular...	25	Very small.	
72......	Boulder clay..	0	90	10	" "	" ...	35	Fairly large.	
73......	Clayey gravel	5	85	10	" "	" ...	25	"	
74......	Gravel........	5	70	25	" "	Rounded.....	33	"	Clayey loam.
75......	"	5	65	30	Fresh blue limestone pebbles.	"	20	Large.............	Sufficient clay content for surfacing purposes.
76......	"	5	85	10	" "	"	26	2,000 cu. yds......	Still better material than above.
77......	"	10	75	15	" "	"	17	Large.............	Silt.

TABLE XIII

Results of Physical Tests on Gravel samples, Rocky Mountains Park. Sand mortar 1:3 mix

BANFF-LAKE LOUISE ROAD (Eldon-Laggan Division)

Sample No.	Fineness modulus	Per cent clay and silt	Colour test	Per cent water used	Per cent of strength relative to that of Standard Ottawa sand[1]				Remarks
					Tensile strength		Compressive strength		
					7 days	28 days	7 days	28 days	
7	2·56	7	Almost clear	13	128	114	161	129	Good concrete aggregate
8	3·24	4	100	12	96	92	155	144	" " "
11	2·82	6	Almost clear	12	125	117	171	139	" " "
13	2·70	9	Turbid	13	97	90	139	108	" " "
22	2·65	6	Clear	12	121	132	152	149	" " "
23	3·17	4	Almost clear	11	152	135	165	149	" " "
25	2·27	10	100	13	103	91	140	112	" " "
27	2·63	5	Almost clear	15	123	119	164	136	" " "
29	2·74	6	Turbid	14	115	114	106	108	" " "
30	3·07	2	Clear	12	131	118	115	121	" " "

ALONG BANFF-WINDERMERE ROAD (Vermilion River Division)

Sample No.	Fineness modulus	Per cent clay and silt	Colour test	Per cent water used	Tensile 7 days	Tensile 28 days	Compressive 7 days	Compressive 28 days	Remarks
36	3·20	15	Almost clear	15	127	114	171	124	
37	0·80	33	Slightly coloured	20	84	85	79	87	Too fine sand. Silty. Unsuitable.
45	2·43	21	" "	17	115	97	112	104	
51	3·32	8	Almost clear	13	143	126	163	105	

TABLE XIII—*Con.*

Results of Physical Tests on Oravel Samples, Rocky Mountains Park. Sand mortar 1:3 mix

ALONG BANFF-WINDERMERE ROAD (Sinclair Pass—Kootenay Valley Division)

Sample No.	Fineness modulus	Per cent clay and silt	Colour test	Per cent water used	Per cent of strength relative to that of Standard Ottawa sand[1]				Remarks
					Tensile strength		Compressive strength		
					7 days	28 days	7 days	28 days	
53.......	3·28	10	Slightly coloured...	14	149	154	197	160	Fairly high. Good concrete aggregate.
58.......	2·60	23	100.................	15	133	116	182	160	" " "
64.......	3·75	16	Clear...............	13	160	142	167	106	" " "
69.......	2·43	34	Turbid.............	22	72	66	62	57	Low on account of fineness of sand and clay coating on pebbles.
74.......	2·48	33	200.................	19	93	85	95	61	" " "
76.......	2·93	26	Turbid.............	18	93	80	111	85	" " "

[1]Ottawa Standard sand, strength of 1 : 3 mortar :
- tensile, 7 days— 248 lbs. per sq. in.
- " 28 days— 370 lbs. per sq.i
- compressive, 7 days—2,065 lbs. per c
- " 28 days—3,525 lbs. per cu.i

Amount of water used—11 per cent.

IV

EXPERIMENTAL ABRASION TEST ON CONCRETE

Samples of concrete for pavements were received on November 7, from Mr. E. Viens, chief of the Laboratory for Testing Materials, Department of Public Works, Ottawa.

The samples consisted of two sets of 15 concrete cylinders 2 inches in diameter and approximately 2 inches high, respectively made of limestone and trap rock aggregate graded up to $\frac{3}{4}$ inch.

The object of the test was to find out if the type of rock used as stone aggregate in the mixture would have any influence, and if so, to what extent, on the ability of the concrete to resist wear.

Description of the Test Performed

There is no standard test to measure the wear of concrete. However, wear tests are performed on concrete blocks in the Structural Materials Research Laboratories of the Lewis Institute at Chicago. The machine used is the Talbot-Jones rattler, which is built on the plan of a brick rattler.

The test performed on the submitted samples was carried on along the lines of the standard abrasion test for road stone, as an experiment. The modified Deval abrasion machine, with slotted cylinders, was used. In this modified machine all dust (material passing $\frac{1}{16}$ inch) is removed as fast as it forms; thus the possibility of a dust cushion, which in the case of soft material is responsible for erroneous results, is eliminated.

In the standard abrasion test for road stone a charge consists of about 50 pieces of stone weighing within 10 grams of 5 kilograms. The weight of material passing $\frac{1}{16}$ inch mesh that is worn off in 10,000 revolutions expressed as the percentage of the weight of the charge, constitutes the measure of the abrasion of the stone. It is known as the per cent of wear.

The samples handed us did not comply with the requirements of the standard test as to number and shape of pieces, weight, etc., consequently only comparative results could be expected.

Results of Abrasion Test

Per cent of wear at end of—

	1,000	2,000	3,000	5,000	10,000 revolutions
Limestone agg...	6·27 p.c.	10·74 p.c.	14·30 p.c.	20·20 p.c.	32·75 p.c.
Trap aggregate...	5·80	8·62	11·04	15·20	23·00

The average per cent of wear obtained in the abrasion test for the two types of stone considered is as follows:—

	Limestone	Trap
Slotted cylinders method..............................	8·25 p.c.	5·0 p.c.
(Closed " "	4·0 "	2·2 ")

In a general manner the tested concrete cylinders behaved like stone does in the usual test. A higher scale of figures was reached but the results are parallel with those generally obtained in the case of limestone and trap rock. In this test for wear the softer rock always shows larger increments in the per cent of wear as the number of revolutions of the cylinders increases. The figures given above indicate that in this respect the concrete cylinders have followed the rule. The differences in the per cent of wear at various stages of the test are in accordance with the usual results for limestone and trap rock.

It is important to note that at the conclusion of the test the concrete cylinders made of limestone aggregate were well rounded, with a perfectly smooth surface, while the trap rock concrete cylinders had kept more of their cylindrical shape and showed a rough surface.

It seems obvious from these results that the nature of the stone aggregate used in a concrete mixture has some influence on its resistance to wear, especially if the concrete is subjected to continuous and severe abrasive action. Moreover, if a slippery surface is to be avoided, a stone aggregate of good wearing qualities will likely yield a concrete pavement with a rough surface as it is worn under traffic.

TABLE XIV

Results of Physical Tests upon Bed-rock—Nova Scotia

Sample No.	Location	Type of rock	Specific gravity	Weight per cu. ft.	Water absorbed pounds per cu. ft.	Per cent wear	French coefficient of wear	Hardness	Toughness	Cementing value	Remarks
354	Nine-mile river, N.W. of Elmsdale.	Quartzite (Whin rock).	2·70	169	0·37	2·2	18·2	18·6	25	....	Very durable road-stone.
355	S. of Oakfield sta., Truro rd.	“ ..	2·68	167	0·75	2·9	13·8	18·6	12	....	“
363	Hilden..................	Siliceous shale......	....	....	....	2·5	16	....	....	46	
356	2½ miles W. of Shubenacadie on Robertson rd.	Limestone..........	2·38	148	3·10	13·4	3·0	8·7	4	....	Weathered and soft, unsuitable for road work.
365	2 miles W. of Shubenacadie on Robertson rd	“	2·49	155	3·38	4·7	8·5	....	....	....	Rather soft material fresher than above.
364	S.E. of Kentville.......	Diabase...........	2·87	179	0·65	2·1	19	17	16	....	Very durable.
357	N. of Centreville.......	Gabbro............	2·90	182	1·18	3·1	13	17·1	20	....	“
366	Along escarpment N. of Centreville.	Trap............... (Amygdaloid).	2·68	168	8·04	7·7	5·2	....	....	....	Much weathered, unsuitable for automobile traffic.
358	Rock types entering into the composition of gravel samples collected.	Fine grained sandstone.	....	....	....	3·2	12·5	....	....	low	
359	“ “ ..	Coarse grained sandstone.	....	....	....	8·7	4·6	....	....	....	Friable.
360	“ “ ..	Granitic rocks......	....	....	....	2·6	15·4	....	....	....	Very durable aggregate.
361	“ “ ..	Quartzites..........	....	....	....	2·4	16·7	....	....	....	“ “
362	“ “ ..	Trap (Amygdaloid)	....	....	....	5·4	7·4	....	....	185	Soft, but cementing well.
	Ohio Road Quarry, 2 miles N. of Shelburne	Diabase...........	2·88	....	0·2	2·4	16·7	18·5	14	....	Very durable material
	Reid's quarry, Jordan Falls.	“	2·89	....	0·5	2·5	16·0	17·8	16	....	“ “
	Black Point, below Liverpool.	“	3·12	....	0·3	2·2	18·2	16·8	10	....	“ “
	Cherry cove, Lunenburg co.	“	2·87	....	0·9	2·5	16·0	17·9	15	....	Very durable material
	Sable river, Shelburne co.	Schistose, micaceous quartzite.	2·71	....	0·4	2·1	19·0	16·7	14	....	“ “
	Sable river, Shelburne co.	Mica schist.........	2·78	....	0·9	6·8	5·9	....	....	....	Very soft.

TABLE XV

Results of Tests on Gravel Samples—Nova Scotia

Sample No.	Location of deposit	Granulometric analysis: Proportion of gravel to sand		Gravel: Per cent retained on screen							Sand: Per cent retained on sieves						% passing 200	Remarks
		Gravel per cent	Sand per cent	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
458	Near Waverly, along lake Thomas.	65	35	16	11	25	16	8	10	14	18	12	10	9	16	13	22	Hard quartzite gravel in clay matrix. Packs well on road.
486	Near Wellington...........	55	45	....	....	....	....	....	....	....	15	12	10	10	10	8	35	Contains clay. Used on roads with good results.
480	John Jordon's pit, 1 m. N. of Enfield.	50	50	....	5	16	29	10	13	27	20	13	14	21	20	8	4	Dark coloured, well packed gravel.
484	Nine-mile river, near Elmsdale.	70	30	26	13	14	16	9	9	13	23	17	24	28	6	1	1	
481	Dewis' siding, Shubenacadie.	30	60	16	18	9	9	6	16	26	27	20	20	15	10	4	4	Reddish brown, clayey.
478	Robertson's pit, 3 m. W. of Shubenacadie.	50	50	....	18	10	13	8	16	35	23	28	25	14	6	2	2	Dark coloured.
454	Upper Nine-mile river, pit at forks near cemetery.	15	85	....	....	....	48	7	13	32	5	8	40	38	5	2	2	Reddish brown iron oxide and organic matter.
457	N.W. of upper Nine-mile river, Ridge N. of road.	35	65	20	35	6	20	6	4	9	3	2	3	13	40	26	13	Sand, iron oxide stained.
466	Near Broadfield station....	35	65	....	16	22	24	11	10	17	10	20	45	20	3	1	1	
472	Robert Harvey's pit, Hilden.	65	35	17	12	7	19	11	24	10	38	19	19	12	6	2	4	Dark red coloured.
465	N.W. of Truro, along Amherst road.	80	20	28	12	12	13	10	11	14	39	19	15	11	8	4	4	Well cemented.
455	Along Amherst road W. of Masstown.	......	100	....	....	....	....	....	....	....	....	....	6	42	25	20	7	Brick red sand, weathered. Little mica content. Too fine.
473	Gravel used on Amherst road near G enholme.	80	20	....	18	19	21	11	13	18	28	22	25	16	5	2	2	Reddish coloured. Well graded.
470	Mackenzie's pit, North river	75	25	25	10	15	24	7	7	12	34	20	20	15	6	3	2	Red coloured, well packed. Well graded.
453	North river...............	55	45	....	....	20	20	10	15	35	25	30	30	10	2	1	2	Well graded but lacks binder.
463	Alma, W. of New Glasgow.	75	25	....	11	22	32	13	12	10	18	24	29	12	4	4	9	Dark red coloured. Coated with $CaCO_3$

496	Near Telford, along Antigonish road.	70	30	6	2	16	21	13	16	26	31	22	19	12	7	3	6	Dark red coloured. Well graded.
467	Along Windsor-Chester rd. 1 m. S. of Windsor Forks.	45	55	....	10	25	20	10	15	20	20	22	26	18	8	3	3	Lacks binding power.
456	Church's pit No. 2, Falmouth.	......	100	....	....	....	....	....	....	....	....	....	....	6	67	21	6	Dark reddish brown quartz sand Too fine.
479	Same as above............	55	45	....	23	5	19	12	20	21	22	18	23	20	10	4	3	Well graded for road work.
485	Same as above............	60	40	40	5	10	13	8	9	15	20	30	30	12	4	2	2	Pebbles coated with dark red clay.
468	Church's pit No. 1, Falmouth.	65	35	5	5	20	25	11	17	17	18	23	33	18	4	2	2	
459	Forks of Mt. Denison and Bog roads, W. of Falmouth	10	90	....	....	....	....	....	....	....	5	5	12	40	28	6	4	Sand with rounded quartz grains coated with red clay.
477	Ellis' pit, between Windsor and Hantsport.	15	85	....	....	15	15	10	10	50	25	28	24	13	6	2	2	Brownish coloured. Carries impurities. Good grading, but sandy gravel.
461	Along Bog road; near iron bridge, between Hantsport and Mt. Denison.	20	80	....	27	17	15	9	14	18	8	8	12	21	24	20	7	Pebbles clay coated. Reddish buff coloured. Organic matter Sand is fine.
460	Aberdeen beach, Mt. Denison.	......	100	....	....	....	....	....	....	....	1	2	7	66	20	3	1	Yellow beach sand.
475	Oak Hill, Hantsport.......	60	40	....	15	8	15	12	20	30	20	13	23	30	8	4	2	Loam and organic matter.
471	W. of Wolfville, along main road.	60	40	6	18	12	13	9	13	29	35	35	20	6	2	1	1	Pebbles coated with $CaCO_3$. Although containing little fine, binds well on road.
483	W. of Wolfville............	50	50	....	17	18	17	7	12	29	26	33	25	11	3	1	1	" "
464	Aldershot pit near cross road.	40	60	....	3	10	17	18	23	29	16	13	25	29	14	2	1	
474	S. of North Alton.........	50	50	....	10	11	16	13	20	30	25	18	17	16	9	6	9	Well graded, contains binder.
482	E. of Coldbrook...........	75	25	22	15	7	16	9	12	19	33	35	25	4	1	1	1	
462	Between Cambridge and Coldbrook.	45	55	....	30	19	16	10	10	15	17	18	27	24	7	3	4	
476	Centreville................	10	90	....	....	....	17	18	17	48	10	20	40	20	6	2	2	Brick red gravelly soil.
498	N. of Centreville..........	......	100	....	....	....	....	....	....	....	1	2	12	20	30	20	15	Weathered trap rock disintegrated into sand. Binds well.

TABLE XVI

Results of Tests on Gravel Samples—Nova Scotia

Sample No.	Character of Gravel							Tensile and Compressive Strength of 1 : 3 Mortars					
	Composition of pebbles				Shape of pebbles	Colour test	Fineness modulus	Water used %	Per cent of strength relative to that of Standard Ottawa sand [1]				Remarks
	Durable %	Intermediate %	Soft %	Remarks					Tensile strength 7 days	Tensile strength 28 days	Compressive strength 7 days	Compressive strength 28 days	
458	100	....	......	All qtz..................	Angular.......	Clear	2·02						
486	....	....	100	Black sl................	Flat, ang......	....	1·83						
480	40	60	......	D.—Gr. qtz. dark volcanic rocks.......... I.—Ss.	Subang.......	Clear	2·56	15	49	91	83	132	Low at 7 days.
484	25	25	50	D.—Largely qtz....... I.—Gr. S.—Weath-ign-ss.	Rounded to subang.	Clear	3·17						
481	60	35	5	D.—Gr. qtz. trap...... I.—Lst, coarse gr.	Rounded......	Clear	3·15						
478	50	15	35	D.—Qtz. gr. volcanic rocks. I.—Ss. S.—Weath. ss. sh.	Subang.......	600	3·36	13	121	135	192	216	High.
454	65	15	20	D.—Ign. rocks, gr. qtz.	Rounded......	1,000	2·58	14	28	78	39	103	Very poor, due to fineness and impurities.
457	....	25	75	Partly weath., reddish ss.	Subang.......	....	1·80						
466	5	35	60	I.—Ss.................. S.—Ss., sh.	Rounded......	100	3·08	15	118	157	118	133	Very good.
472	15	60	25	D.—Qtz................ I.—Ss., ign. S.—Sh.	Rounded......	800	3·53	14	94	122	150	184	Good.
465	50	35	15	D.—Gr., sy., dia., qtz. I.—Ss. S.—Soft trap.	Rounded......	Clear	3·46	16	63	90	86	135	Low for grading, due to clay content.

455	......	......	......	......	......	Clear	1·27						
473	90	10	......	Mostly gr.	Subang.	400	3·40						
470	40	25	35	D.—Qtz. I.—Ss. S.—Weath. trap and sh.	Subang.	......	3·46	13	86	93	121	147	Fair.
453	5	5	90	80 per cent sh.	Thin, flat.	......	3·57						
463	30	20	50	D.—Qtz. I.—Ss. S.—Sh., weath. ss.	Rounded to subang.	......	3·01						
496	......	......	100	Weath. volcanic rocks.	Angular.	......	3·31						
467	40	30	30	D.—Gr. I.—Lst., ss. S.—Sch. weath. ign.	Rounded.	600	3·10						
456	......	......	......	......	......	Clear	0·79						
479	30	45	25	D.—Largely qtz. I.—Ss., lst. S.—Sh.	Rounded.	......	3·01						
485	25	40	35	D.—Qtz. I.—Ss., ign. S.—shaly lst.	Rounded.	......	3·38	12	136	145	228	236	Very high.
468	20	65	15	D.—Qtz. I.—Lst. ss. S.—Weath. trap.	Subang.	......	3·21						
459	......	......	......	......	Rounded.	800	1·89						
477	......	20	80	I.—Ss. S.—Weath. sh., sl. ss.	Rounded and flat.	1,200	3·41						
461	......	40	60	I.—Ss. S.—Sh. sl. weath. trap.	Rounded to subangular.	1,500	1·74						
460	......	......	......	......	......	Clear	1·86						
475	5	30	65	I.—Ss. S.—Weath. black sh. and sl.	Ang. flat and rounded.	2,000	2·89						
471	25	30	45	D.—Qtz. I.—Ss. S.—Sh., weath. volcanic	Rounded and flat.	Clean	3·89	11	127	144	211	213	Very high.
483	10	60	30	D.—Ign. qtz. I.—Ss, sl. S.—Weath. volcanic.	Rounded and flat.	500	3·62	11	137	151	207	216	Very high.
464	25	25	50	D.—Qtz. I.—Sch. S.—Sh. weath. trap.	Flat.	......	2·79	13	10	60	29	77	Unsuitable. Contains too much clay.
474	......	85	15	I.—Sch. sl. S.—Weath. trap.	Angular and flat.	100	2·89	14	115	125	168	155	High.
482	5	70	25	I.—Sl. S.—Weath. trap.	Flat.	Clean	3·89	13	79	93	119	134	Fair.

TABLE XVI—*Con.*

Sample No.	Character of Gravel: Composition of pebbles: Durable %	Intermediate %	Soft %	Remarks	Shape of pebbles	Colour test	Fineness modulus	Tensile and Compressive Strength of 1: 3 Mortars: Water used %	Per cent of strength relative to that of Standard Ottawa sand[1]: Tensile strength 7 days	Tensile strength 28 days	Compressive strength 7 days	Compressive strength 28 days	Remarks
462	35	35	30	D.—Largely qtz. gr.... I.—Ss. S.—Soft ss. and weath. trap.	Rounded to subang.	500	2·93	12	72	88	114	110	Fair.
476	30	10	60	D.—Quartz, qtz........ I.—Ss. S.—Sh. ss.	....	400	2·96						
498	....	....	......	....	....	Clean	1·19						

[1]Ottawa standard sand, strength of 1 : 3 mortars: tensile, 7 days— 261 lbs. per sq. in.; " 28 days— 292 lbs. per sq. in.; compressive, 7 days—1,550 lbs. per sq. in.; " 28 days—2,260 lbs. per sq. in.

Amount of water used—10 per cent.

Abreviations used in column for remarks:—dia., diabase; gr., granite; ign., igneous; lst., limestone; qtz., quartzite; sch., schist; sh., shale; sl., slate; ss., sandstone; sy., syenite; weath., weathered.