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GRAVEL AND GRAVEL ROADS

by

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The purpose of this bulletin is to set forth a few important points in connection with gravel and its use in road construction and maintenance. The writer has had the opportunity of inspecting many gravel roads in Nova Scotia, New Brunswick, Quebec and Ontario, and the following remarks are the result of his observations and his study of roads in general.

Heavy motor traffic in recent years has resulted in greatly increased use of gravel for roads. Waterbound broken stone roads serve well for horse-drawn traffic, but they fail rapidly under motor traffic and are expensive to repair. Gravel roads are much cheaper to construct, and while they are not particularly resistant to the disrupting forces of motor traffic, they may be easily and cheaply repaired or kept in good condition by a suitable patrol system.

The use of gravel as a cheap surfacing material has been given much attention by road engineers, and old methods of building and surfacing gravel roads are being discarded in favour of more efficient methods, and the suitability of various types of gravel is better understood. In order to meet the new conditions of traffic, gravel must possess certain qualities, therefore it is essential that a judicious selection of material should be made. It was formerly the practice to use any easily accessible gravel, and in most cases it answered the purpose fairly well. Under the old methods of construction and traffic conditions, soft gravels very often gave better results than hard gravels, but now the latter are to be preferred, since good wearing quality is one of the prime requisites in a material for the surfacing of a modern trunk highway. A hard gravel, to be satisfactory, should be very uniformly graded as to size of particles and should contain enough binding material. In applying it to the road, it should be laid in thin courses so as to compact evenly and produce a smooth surface. Of course less stringent requirements would apply to the average county or township roads, but even then the wearing quality and uniformity of grading should be the two most important considerations.

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Since gravels vary widely in composition and relative size of particles, it is not considered advisable to draw specifications within too narrow limits. Nevertheless there are certain qualities necessary in all gravels in order to be considered suitable. A good gravel should contain no loam and not more than 15% of soft and friable particles. At least from 50 to 75% should be retained on a ¼ inch test screen. It should contain from 8 to 15% of cementing material, such as iron oxide, carbonate of lime (limestone) or clay.

When developing a gravel deposit, the loam and badly weathered surface material should be removed completely, as it is useless as road material and might later cause defects in the road.

Composition. A gravel with a large proportion of friable particles will compact readily and form a smooth, even surface shortly after being laid on the road, but will wear very rapidly under motor traffic. Where such material is plentiful and easy of access, it may be economical to use it on roads frequented principally by horse-drawn vehicles, since then a larger proportion than 15% of soft particles is permissible. Service tests will be the best guide to determine the ability of the material to withstand the wear in such cases.

Grading. For convenience of discussion, a gravel may be considered as consisting of sand, pebbles and boulders. The material which passes through a ¼ inch test screen is classed as sand. That which is retained on a ¼ inch screen but is less than 3 inches in diameter is classed as pebbles, and all over 3 inches is called boulders.

The maximum size of the pebbles and the proportion of pebbles to sand are factors to be considered in choosing gravel.

There should be no stone larger than 3 inches in gravel for lower courses and none larger than 1½ inches in surfacing gravels.

The proportion of pebbles to sand cannot be set definitely for all gravels since the hardness of the pebbles and their gradation of size must be considered.

In general the sand should be present in only sufficient quantity to fill the interstices between the pebbles. Such gravels when compacted, will afford the greatest density and present the greatest number of pebbles to withstand the wearing action of traffic.

In relatively soft gravels, at least 75% of the total should be retained on a ¼ inch test screen, and in harder gravels the minimum percentage of pebbles may vary from 75 to 65. In cases where the gradation of pebble sizes is irregular, the proportion of pebbles to sand may have to be further reduced in order to obtain an aggregate of maximum density.

When a gravel deposit contains more than 10% of stones over 3 inches in size, so-called boulders, it is recommended strongly that the latter be not discarded, but passed through the crusher. A supply of fresh and angular stone is thus made available, and when intermixed with the gravel, greatly helps in compacting the road and improves its wearing quality. The best method is to pass all such gravel through the crusher with the jaws set to the maximum desired

size since the crushed and uncrushed constituents are thus more intimately mixed.

Binder. The binder is very fine material the function of which is to cement together the larger particles making up a gravel road surface. When present in a gravel it is either as a loose powder, or as a coating on the gravel particles, or else it is derived from the crumbling of the softer pebbles under traffic.

When a gravel stands up firmly in the bank, it is usually a good indication that it will cement readily on the road, but this does not mean that all gravels which are loose in the bank will bind poorly on the road.

Most gravels in Eastern Canada contain some friable or partly disintegrated particles which on being ground up by the traffic yield a fairly good cementing material.

It is not uncommon to find in hilly tracts of land, gravel composed of very hard granite, or quartzose pebbles, and totally devoid of binder. It will then be necessary to use some cementing material from nearby sources, and if clay is the only material available, care should be taken to add just the amount necessary to effectively act as binder - at most 10%. In such cases it is essential that the gravel contain enough sand, since once the gravel and clay mix is incorporated into the road surface, sand will lessen the weakening action of the clay during wet weather, and to a degree prevent the formation of mud. Owing to climatic conditions in Eastern Canada, the use of clay should be avoided as much as possible. Loam should never be used as a cementing medium.

Iron oxide is one of the best binders found in gravels, and its cementing quality is not affected by weather conditions. The cementing quality of limestone is in proportion to its calcium carbonate content.

Beach or stream gravels are not so desirable as bank gravels for road purposes on account of being deficient in binding material and holding a large proportion of hard, rounded, smooth pebbles. Another objectionable feature of such gravels is that the range of pebble sizes is more limited than in the bank gravels, with consequent higher proportion of voids. Nevertheless, beach gravels have been satisfactorily used on highways bordering the seacoast in the Maritime provinces. To give best results such material should be rather fine, well-graded, composed of not too rounded pebbles, and applied on the road in thin layers. It will not compact so readily and form so smooth a surface as does the average bank gravel, but with proper maintenance will be quite durable. The addition of fine bank material will materially help the compacting of beach gravel road surfaces.

Testing. A careful inspection of any roads built and surfaced with a gravel should reveal the suitability or unsuitability of it for road work. If there is no opportunity to observe its behaviour in roads under traffic conditions, a field examination of the gravel deposit will furnish a certain amount of information as to its probable suitability, but this cannot be regarded as conclusive.

Where heavy traffic is to be expected, or where there is doubt as to which of several gravels will give best results, field observations should be supplemented by laboratory tests to determine the compactibility, the binding quality and the durability which may be expected under service. The samples for this purpose should be collected so as to fairly represent the material which it is proposed to use. No sample should weigh less than twenty-five pounds. It is sometimes desirable to include tests to determine the suitability of the gravel as aggregate for concrete structures. The Road Materials Laboratory, Mines Branch, Department of Mines, Sussex Street, Ottawa, is fully equipped to conduct the above tests, also all the standard tests on broken stone and paving blocks, and is prepared to undertake such tests as time permits, arrangements for which should be made through the Director of the Mines Branch.

Construction. It is not the purpose of this article to enter into the details of gravel road construction, since the Provincial Highway Departments have their own specifications covering these. All the methods in use can be referred to two main types, the surface method and the trench method. In the former, the gravel, laid on a flat or cambered subgrade, is spread so as to cover the travelled way and the shoulders; in the trench method earth shoulders are first constructed on a cambered subgrade and gravel laid between the shoulders and retained in place by them.

The trench method is principally used where the cost of gravel is high because of its scarcity. This method is less wasteful of material but is more costly on account of the road having to be built in two or preferably three layers, and each layer rolled.

The surface method is the one more commonly used on our country highways. On narrow roadways the gravel is laid in a single layer on a flat subgrade, the thickness of the material decreasing gradually both sides of the centre line so as to produce a crown. On wide roadways, the gravel is laid in one or several layers on a cambered subgrade, the thickness being the same over the full width of the travelled way and coming to nothing on the outer edge of the shoulders. This is called the feather-edge method.

Maintenance. A gravel road is far from being a permanent structure, and will need constant attention in order to be really serviceable. The saying - "A stitch in time saves nine" - applies with particular emphasis to a gravel surface. One of the most efficient devices for maintaining untreated gravel roads is the road drag. The dragging should be started in the spring when the road surface is still moist and soft from the effect of thawing, and should be repeated after every heavy rain, and before freezing in the fall. Ruts, pot-holes or other depressions which cannot be filled by dragging, should be patched with new gravel of the same coarseness as the one already on the surface.

Where wave-like depressions have developed due to fast motor traffic, dragging alone will not suffice, and some Highway Departments obtain very good results by having the road surface scarified to a depth of 1½ to 2 inches and reshaped by a grader or planer with the blade set at nearly right angles with the direction of travel, the grading being repeated and new material applied where depressions

or weak points develop. This operation is best carried on in the spring when the surface has thawed to a sufficient depth, and repeated in the fall, after the first heavy wet spell.

When the traffic reaches an average of 300 or more vehicles per day, best results without undue maintenance costs will only be obtained through the superficial treatment of the road with so-called dust palliatives and road binders. There are many substances suitable for use in surface treatment, but only one, calcium chloride, has been commonly used on country highways in Eastern Canada. Calcium chloride is a hygroscopic salt, that is, a salt that possesses the property of absorbing moisture from the atmosphere or any nearby source. When applied to a gravel road, it will soon penetrate the gravel, forming a moist mat at the surface. It thus keeps the fine material from being blown away, and prevents the too rapid wear and deterioration of the road surface. Its action is only temporary, and it will be necessary to renew its application. In our climate two applications in the first year, and one in the second year, are usually sufficient. Calcium chloride will work best in moderately moist climates. It has been used in parts of Ontario and Quebec with very good results. During prolonged dry weather, it may not absorb enough moisture and it will be necessary to feed it by occasionally sprinkling the road surface with water. In very moist climates, calcium chloride cannot be of much use, and may even be detrimental.

Drainage. The object of drainage is to keep water from penetrating the road structure, since water is the most serious destructive agent of roads. This is accomplished by the road camber or crown, side ditches and underground drains. The road crown keeps the water from penetrating the road surface, by allowing it to run off to the sides. The ditches collect the surface water and carry it away rapidly from the roadside. The sub-drains, by lowering the level of the underground water, keep the latter from reaching the road surface through capillary action. On a side hill, the ditch will also intercept part of the underground water which, under the action of gravity, tends to reach the road bed. Under-drains, if covered with porous material, will collect and carry off an important part of the surface water, thus necessitating only very shallow ditches.

Most defects in gravel roads can generally be traced to faulty or insufficient drainage, and too much emphasis cannot be placed on this important point. Adequate drainage facilities should be provided when building the road, and it should thereafter be made a point of the maintenance programme to see that the drainage system functions properly at all times. This will decrease the heaving resulting from spring thawing, which is so disastrous to our roads.

Corrugations. Corrugation, or so-called "wash-boarding" of gravel roads, is one of the effects of fast-moving motor vehicles. In the past few years many investigators have tried to discover all the factors contributing to cause corrugation, and the measures necessary to eliminate such a serious defect and prevent its recurrence. It is now known that corrugation will form on untreated surfaces, irrespective of the methods of construction, the kind of gravel used, and the nature of the road subsoil, but will be most pronounced on roads surfaced with fine sandy gravel containing but little binding material. Treatment with calcium chloride or light oil will materially reduce corrugation, but not eliminate it

oil will materially reduce corrugation, but not eliminate it completely. Bituminous surface treatment, forming a strongly bound coating of bitumen and stone, will effectively prevent the formation of corrugations.

Publications on Road Materials, issued by the Department of Mines, Ottawa.

Geological Survey, Memoir 85, Road Material Surveys in 1914, by L. Reinecke: (Types of country roads and materials used in their construction; deposits of diabase along the north shore of lake Huron; road materials in Essex and Kent counties, and along the north shore of lake Ontario between Port Hope and Hamilton, Ontario).

Geological Survey, Memoir 99, Road Material Surveys in 1915, by L. Reinecke: (Stone and gravel along the Ottawa-Prescott highway, Ontario, and along the Hull-Grenville portion of the Hull-Montreal highway, Quebec).

Geological Survey, Summary Report, 1916, pp. 192-206: (Road materials between Kingston and Smiths Falls, and between Napanee and Port Hope, Ontario; in Vaudreuil and Soulanges counties, and part of Two Mountains and Argenteuil counties, Quebec).

Geological Survey, Memoir 107, Road Materials in the Vicinity of Regina, Saskatchewan, by L. Reinecke (1917).

Geological Survey, Memoir 114, Road Material Surveys in the City and District of Montreal, Quebec, by Henri Gauthier (1917).

Mines Branch, Bulletin 32, Road Materials along the St. Lawrence River, from the Quebec Boundary to Cardinal, Ontario, by R. H. Picher (1917).

Mines Branch, Summary Report, 1918, pp. 169-200: (Road materials along the Winnipeg-Brandon highway, Manitoba; parts of Alberta and southern British Columbia).

Mines Branch, Summary Report, 1919, pp. 135-155: (Road materials along the Banff-Vermilion Pass highway, Rocky Mountain Park, Alberta; in the Winnipeg-Brandon district, Manitoba; around the town of Renfrew and along the Prescott-Gananoque highway, Ontario; part of Chateauguay and Beauharnois counties, Quebec).

Mines Branch, Summary Report, 1920, pp. 72-75: (Road materials along the Gananoque-Napanee highway, Ontario).

Mines Branch, Investigations in Ceramics and Road Materials, 1921, pp. 271-318: (Road materials along the Castle-Laggan and parts of the Vermilion Pass-Windermere highway, Canadian National Parks, Alberta and British Columbia; along the Ottawa-Pointe Fortune highway, Ontario; and around Halifax, Truro, New Glasgow, Windsor and Kentville, Nova Scotia).

Mines Branch, Summary Report, 1922. pp. 227-261: (Road materials along parts of the Banff-Laggan and Banff-Windermere highways, Canadian National Parks, Alberta and British Columbia; along the main highways of Nova Scotia).

Mines Branch, Investigations in Ceramics and Road Materials, 1923. pp. 8-71: (Inspection of gravel roads in Ontario and Quebec and investigation on the qualities of the materials used in their construction; road materials along the main highways of Nova Scotia).

Mines Branch, Investigations in Ceramics and Road Materials, 1924, pp. 18-45: (Road materials along the main highways of New Brunswick).