ART. XI.—OUR COMMON ROADS—BY M. MURPHY, *C. E., Provincial Government Engineer, N. S.*

There is a very great amount of labour employed, not only in bringing the product into existence, but in making it when in existence accessible to those for whose use it is intended. Many important classes find employment in some function of this kind. The distribution of our products is just as important as their production. There is the whole class of carriers by land or water distributing the products of the sea, the farm, and the mine, and in doing so rendering just as important services as if they were the producers. It is enough if the producer and the carrier contribute sufficiently towards necessary consumption; they are all agencies of production, and all are essential, and influence the progress of society. No less important are the arteries of distribution or transport, such as railways, roads, water conveyance, etc. Roads are frequently, in our Colonies, made by the Government, and opened gratuitously to the public, and in this case each producer, in paying the quota of taxes levied, pays for the use of those roads which conduce to his convenience, and if they are made with any tolerable degree of judgment, they increase the returns of his industry by far more than an equivalent amount.

One of the problems of to-day—one that must largely affect the future of this country, and upon which a large proportion of public money is annually being expended — is that of road-making. We cannot say that the day of the ordinary highway is past or has become less important because we are introducing railways. Each means of communication has its own use, and the office of each is, not to displace the others, but to supplement them; and although the study of road-makiug for the past fifty years has been eclipsed by the great structural works resulting from scientific research and engineering skill, which have contributed so much to the advancement of civilization, it is not of so trivial and subordinate a nature as it may at first appear. It is to be hoped that it will be shewn this evening that the subject of this paper is one which, however it has been neglected in our Province, offers a wide and promising field for the skill of those who may be intrusted with the control and maintenance of the highways of this country, and that it is brought before you in such manner as may be acceptable to the President and members of this Society.

Now, the author holds that there is just as much science and engineering skill required in the practice of road-making as there is in any one of the branches of the engineering profession with which he is acquainted. He is not, however, to be understood to say that the practice of road-making is an exclusive one. On the contrary, there is room for all. There is too often a mutual distrust between scientific and practical men, and though it is year by year decreasing as progress and civilization increase, it still exists, and is largely to be ascribed to the misinterpretation of a term, which term is in this case "science." What, then, does the term science actually signify? Simply:

A knowledge of facts the result of observation; or

A knowledge of laws obtained by reasoning on combined facts.

If we add a power and a habit of reflection, that may help us in extending or developing the law itself beyond the limits of the observed facts, and enable us to advance into new regions of inquiry, we may be able to foretell facts which are at the time beyond the range of our practical experience.

We have the rules and laws that govern road-making in Great Britain, as practised by McAdam, Telford and Parnell, as well as those of more modern experience, to which we shall refer further on, and we doubt much if any of these systems would be judicious to adopt in our climate. We must, therefore, adapt ourselves to the science, the ordinary experience, of our daily life, and reduce them to rules of precision. We want a proper method of locating country roads with due regard to grades, tractive force and economy of construction. This is science, and may be made familiar to any intelligent non-professional reader. We want a better knowledge with respect to the selection of such materials as seem necessary and desirable, having regard to practical worth and greatest endurance; and thirdly, we require better systems of application. All these requirements can only be obtained by a knowledge first acquired by induction from facts observed, and to the mechanical skill applied in aid of it.

The formation of public roads and carriage ways, with their accessories, bridges and viaducts, was possibly the first manner in which the occupation of the engineer was developed. The author may therefore be pardoned for introducing the subject by reference to the road-making of the ancients, from which our systems have to a large extent been gradually evolved. The ancient capital of Mexico was approached from various directions by paved roads, from two to three miles in length, and thirty feet in width. Bernal Diaz, companion of Cortez in his conquest of Mexico, so describes it. When the Spaniards under Pizarro first invaded Peru, they found, among other indications of civilization, a net-work of highways superior to those in their own country. Roads traversed Quito, passing through Cuzco, into the empire of Chili. It is on historical record that there were over 1,700 miles of these roads, and that they were paved with large flags of freestone, and in many places set in asphaltic cement.

The earliest roads about which anything definite is known are those of ancient Rome, one of which, the most celebrated —the Appian Way—commenced 312 B. C. The Roman roads, preserved generally a straight course, which is said to be due to the convenience of laying them out. Others say they were principally constructed with the view of transporting the Roman legions, and, like those of Peru, were generally laid out in the direct line of route from one city to another, seldom avoiding any obstacle, and usually, for defensive purposes, keeping to the higher ground. In solidity of construction, they have never been excelled, and many of them still remain. Their construction is thus described by Mr. Thomas Codrington, C. E.: "Two parallel trenches were first cut to mark the breadth of the road; loose earth was removed until a solid foundation was reached, and it was replaced by proper material consolidated by ramming, or other means were taken to form a solid foundation for the body of the road. This appears to have been, as a rule, composed of four layers, generally of local materials, though sometimes, they were brought from considerable distances. The lowest layer consisted of two or three courses of flat stones, or, when these were not obtainable, of other stones, generally laid in mortar; the second layer was composed of rubble masonry of smaller stones or a coarse concrete; the third of a finer concrète, on which was laid a pavement of polygonal blocks of hard stone, jointed with the greatest nicety. The four layers are found to be three feet or more in thickness, but the two lowest were dispensed with on rock. The paved part of a great road appears to have been almost 16 feet wide, and on either side, and separated from it by raised causeways, were unpaved sideways, each of half the width of the paved road. Where, as on many roads, the surface was not paved, it was made of hard concrete, or pebbles or flint set in mortar. Sometimes clay and marl were used instead of mortar, and it would seem that where inferior materials were used, the road was made higher above the ground and rounder in cross-section."

With the disruption of the Roman empire came a period at which road-making and maintenance became neglected, and seems to have fallen into general disuse, until about the twelfth or thirteenth century. About the middle of the 12th century the principal streets of large towns were protected by stone. The streets were prepared with a gravel or concrete bed, and on this a pavement was laid, consisting of deep rectangular blocks of such rock as granite, trap, or quartzites, of 10 to 12 inches in depth, and of irregular widths, and of from 1 to 2 feet in length, bedded and jointed in strong mortar. In many continental cities this method of street paving is yet adhered to.

The bad state of the roads in England in 1685 is given by Macaulay's History, pp. 339, 340, vol. 1: "It was by the highways that both travellers and goods generally passed from place to place, and these highways appear to have been far worse than might have been expected from the degree of wealth and civilization which the nation had even then attained. On the lines of best communication the ruts were deep, the descents precipitous, and the way often such as it was hardly possible to distinguish, in the dusk, from the unenclosed heath and fen which lay on both sides. Ralph Thurseby, the antiquarian, was in danger of losing his way on the great North road, between Barnaby Moore and Tuxford, and actually lost his way between Doncaster and York. * * * It happened almost every day that coaches stuck fast until a team of cattle could be procured from some neighbouring farm to tug them out of the slough. But in bad seasons the traveller had to encounter inconveniences more serious. * * * The great route through Wales to Holyhead in 1685 was in such a state that the Viceroy going to Ireland was five hours in going 14 miles from St. Asaph to Conway."

The roads in England were at that period in a much worse condition than those of most European countries, and they were sometimes almost impassable, even in the heart of the great cities. Long after this, so late as 1736, the roads in London were so bad that in wet weather it sometimes took no less than two hours to drive from Kensington to St. James' Palace. About the middle of the last century, some decisive steps were taken for improvement in both construction and maintenance, and shortly afterwards much improvement was effected by the introduction of the systems of Telford, McAdam and Parnell, and some other roadmakers well known as equally efficient, but not so fortunate as to be brought, through their work, into such prominent notice. During the present century a great deal has been done to improve the highways of Europe, more especially in France and Great Britain.

It is not proposed to touch upon any of the engineering operations connected with the successive improvements that have been effected, and that have now become so numerous within city or town limits, in the construction and maintenance of public streets and footways, such as pavements, pitched or stone block pavement, asphalt, wood, iron, and other pavements, or to enter into their merits or demerits. The object of this paper is to assist in enquiring into and formulating a system that may in some measure tend towards the improvement of our common roads in Nova Scotia.

MACADAMIZED ROADS.

All roadways having a surface of hard, roughly-broken stone are generally classed under the above general head. The most important of these are the two separate and distinct systems introduced by McAdam and Telford. The pavement of the latter is well described thus: "The cross-section of the surface should be that of a flat elipse, as this shape assists the water to pass from the centre towards the sides, without making the sides too round and greatly contributes to drying the road, by allowing the the action of the sun and air to produce a great degree of evaporation. When the materials are quarry or field stones, the hardest part of them should be used, each stone so broken that it may in its largest dimensions pass through a ring 2½ inches in diameter. When the materials consist of gravel, the stones only which exceed 1½ inches in size should be taken from the pits for the use of the middle part of the road, and every gravel stone exceeding 2 inches in diameter should be broken."

In constructing a new road (Fig. 1) he directs that a gravel foundation should be carefully laid by hand 7 inches deep in the middle, and reduced to 3 inches on the sides; the stones, none of which should exceed 5 inches in breadth on its face, to be set on their broadest ends, and the cavities filled with stone chips. For a width of 18 feet over the centre of the pavement, six inches of broken stone or hard pebbles, not exceeding 2½ inches in diameter, should be laid. The six-feet roadway on each side may be made with good clean gravel or small stones, the whole to be covered with a coating of small gravel 1 inch in thickness. He directed that all such roads should have a total depth of 14 inches of firm material in the centre, and 5 inches at the outer edges.

That all layers of stone should be placed only in wet weather and during the winter months.

Telford subsequently modified his practice, and in the first instance spread four inches of stone, broken to 2½ inch gauge, which was to be worked in by the traffic, all ruts to be raked in as formed, till the surface was firm; after which he laid 2 inches more of similar material, treated in a like manner, and the whole was covered with 1½ inches of good clean gravel. At Coventry he covered the pitching with a six-inch layer of Nuneaton stone, broken to a gauge of 2½ inches, and well raked into the surface of these a covering of good gravel blinding 1½ inches in thickness.

The method introduced by Mr. McAdam was as follows (see Fig. 2): He dispensed with the foundation of large stones, and if anything preferred a soft substratum to a hard artificial one, and selected angular fragments of granite, basalt, or whinstone, broken sufficiently small to pass through a ring 2½ inches in diameter, preference being given to stones from 1 to 2 ounces in weight, and he in no case allowed the use of stone exceeding 6 ounces, the larger ones being broken to the regulation size, which after much experience and many carefully experiments, was still further reduced to cubes of 1 inch to 1½ inches in every direction.

If we compare Telford's mode of pavement with Tresaguet's method of constructing roads as described by the latter and generally adopted in France sixty years before Telford's time, we cannot help but surmise that he borrowed his system, or that it was evolved largely from the French. Tresaguet says, so early as 1775; "The bottom of the foundation is to be parallel to the surface of the road. The first bed on the foundation is to be placed on edge and not on the flat, in the form of a rough pavement, and consolidated by beating with a large hammer, but it is unnecessary that the stones should be even one with another. The second bed is to be equally arranged by hand, layer by layer and beaten and broken coarsely with a large hammer, so that the stones may wedge together and no empty spaces remain. The last bed 3 inches in thickness, is to be broken to about the the size of a nut with a small hammer on a sort of anvil, and thrown upon the road with a shovel to form the curved surface. Great attention must be given to choose the hardest stone for the last bed even if one is obliged to go to more distant quarries than those which furnish stone for the body of the road; the solidity of the road depending on this latter bed, one cannot be too scrupulous as to the quality of materials which are used in it."

Telford held that when the bottom is soft and wet, and the sub-soil cannot be properly drained, a bottoming of some sort was desirable, and where stone can be easily got for a pitched foundation, it will be found a most economical as well as most convenient way of making a road if it is required to be of considerable strength.

McAdam considered a bottoming of large stones useless, and even went so far as to condemn it as mischievous, on the ground that the large stone at the bottom caused motion of the materials and kept open passages for water to the sub-soil beneath. He contended that the thickness of the road should only be regulated by the quantity of materials necessary to form a stable and impervious covering, and never with any reference to its power of carrying weight, and that if water passed through a road it would go to pieces whatever was its thickness. (Remarks on Road-making, by J. L. McAdam, p. 40.)

McAdam's doctrines are generally condemned as contrary to the first principles of science. (Parnell's Treatise on Roads, p. 78.) He also said that he preferred a soft substratum to a hard one, provided it were "not such a bog as would not allow a man to walk over it." (Evidence of Select Committee on Highways, 1819, p. 23.)

To McAdam, nevertheless, is due the credit of having been the first to introduce the proper method of breaking and preparing road materials, and to the possibility of forming them into a compact road surface. To him also is due the establishment of a regular system of road maintenance under properly qualified surveyors.

Various forms and modifications of McAdam's and Telford's systems have been since adopted with varying success. Mr. Baylis, in his suburban practice (see Fig 3), laid a 3-inch coat of 2-inch cubes, which were allowed to become consolidated by the traffic, when he spread a second coat of the same thickness, and covered it with a thin gravel blinding. Others have tried slag or hard foundry refuse from 6 to 8 inches in depth, and the result justifies its continuance in certain localities. Mr. Joseph Mitchell, of Inverness, has introduced in the summer of 1865, one of the best modifications of macadamized roads. This consists of granite cubes, broken to the usual size, and spread over the road to the required thickness, a strong grout of Portland cement and sharp sand well rolled to an uniform surface. Such roads are said to possess great solidity, and are less productive of dust than ordinary Macadams. The wear under the ordinary traffic was about half an inch in three years, but after nine years the surface had worn very irregularly, owing principally to its rigidity and the difficulty of spreading the material in uniform proportions. (Transactions Society of Engineers, 1878, p. 66.)

The covering of most of the common roads in the United States is pretty much the same as our own. In mostly all new countries the same practice, being the cheapest and readiest, is adopted. The natural soil is excavated from the side ditches and plastered or thrown on the middle of the roadway. General Gilmore, in his treatise on roads, streets and pavements, says: "In many cases, especially in sandy or gravelly soils, even the side ditches are omitted, and the road is simply a wagon track upon the natural surface, which soon becomes a broad. shallow ditch, collecting and retaining the surface water from both sides of the track.' (pp. 66 and 67.)

The management of public highways is, at the present time, receiving much attention both in Europe and America. Improved systems of road construction and repairs is one of the problems of the day. The amalgamation of districts in central boards has been advocated and is attended with many advantages. Uniformity of system and maintenance on correct principles, under the supervision of persons of wider experience than the ordinary road maker, tend to economy and not only generalize the system but improve it. The Administration des Pouts et Chausses in France is a good instance. The opportunities which an organization offers for investigation and for generalizing information are shewn by the documents issued by it and many valuable memoirs on subjects connected with road maintenance are translated and largely circulated over the world.

The excellence of road making in Ireland is due to management by county areas. In Scotland many of the counties managed both turn-pike and statute labor for many years, and by the Roads and Bridges Act of 1878 the system of County management was extended to all parts of Scotland. The Highways and Locomotive Amendment Act of the same year enlarged the areas of road management in England in several important respects.

I have so far touched upon the evolution and history of road making abroad. Let us now examine the cost, and see if we could judiciously apply the practice being adopted in Europe or how much of it, to our own Province.

The following table gives some of the results obtained on the roads in the Department of the Loire, France, and the daily traffic over them, as reported by M. Graeff, engineer in chief, des Points et Chausees. The road covering was schist and 21 feet wide.

Length of Road.	Mode of Maintenance.	Daily Tonnage.	Annual Wear in Cubic Yards.
1 mile....	Periodical reconstruction	1400	579
1 "	Minute and constant repairs..	1400	727
1 "	Periodical reconstruction	1800	1866
1 "	Minute and constant repairs..	1800	2104
1 "	Periodical reconstruction	2300	2794
1 "	Minute and constant repairs..	3200	4635
1 "	" " ..	5400	9934

Some of the roads in the arrondisement of St. Etienne, built with basalts, furnished the following data :

Length of Road.	Mode of Maintenance.	Daily Tonnage.	Annual Wear in Cubic Yards.
1 mile....	Periodical reconstruction.....	1200	175
1 "	" "	2000	372
1 "	Minute and constant repairs..	2000	480

The foregoing tables shew, (1) that the destruction of the road material increases more rapidly than the tonnage; (2) that the tough basalts are much more valuable for road covering than soft schist; and (3) that for roads of large traffic, the system of maintenance by periodical reconstruction, accompanied by such intermediate repairs, more or less constantly, as will secure hardness, and smoothness of surface and uniformly diminishing thickness, is superior to the one on minute and constant repair exclusively. It is now generally admitted in France that this last-named system is not advantageously applicable to roads on which the daily tonnage exceeds 600 tons. The same principles will apply to the repairs and maintenance of road coverings composed of gravel or a mixture of gravel and broken stone (Gilmore.)

COST OF ROAD MAINTENANCE.

The whole cost of the macadamized national roads of France taking an average year, was:

Materials	$ 89 06	per mile.
Manual labor.........	71 54	"
	$160 60	per mile.

The average quantity of materials was 78 cubic yards per mile, the mean rate of wages was $0. 45 per day. and the labor per cubic yard of material $0.91, of which ⅓ day's work per cubic yard was for the maintenance of the surface of the road.

The cost of maintenance of course varied a good deal in different departments, the average in some being as low as $73.00 or $77.86 per mile, but in the majority the cost was not very far removed from the average.

The cost of repairs for four roads in the county of Edinburgh is given as follows, and may be taken as a fair average of the annual expenditure:

Lasswade and Wright's Houses, 186½ miles	$109 98
Dalkeith and Post Road, 85¾ miles	237 74
Cramond, 29½ miles	315 85
Calder Slateford and Costerphine, 139 miles	137 96

In each district the roads extend from Edinburgh to the boundaries of the county, so that the cost per mile are the average of rates, which widely differ with the traffic and the situation of the roads. The wages are about $4.38 per week, and the materials cost from $1.07 to $1.72 per cubic yard on the average.

The average cost of the parish roads included in highway districts in England and Wales ranged from $16.55 to $183.22 per mile in different counties, the mean of the whole length of roads being $65.94 per mile.

It will be observed that comparing whole districts, the average cost of maintenance varies considerably, and if single roads or parts of roads were to be taken, the difference of cost would be greater, some being as little as $24.33 per mile, while others with heavy traffic cost upwards of $1703.33 per mile for short lengths. The wages from $3.65 per week in the cheapest counties to $4.38 or more in Glamorgan, aud the cost of material per cubic yard ranged from $0.61 in some parts of the cheapest counties to $1.25 near Swansea. (Codrington.)

General Gilmore, U. S. Army, in his treatise on Roads and Street pavements, 1888, classifies American country roads as follows:

1. Earth roads.
2. Corduroy roads.
3. Plank Roads.
4. Gravel Roads.
5. All broken stone (or Macadam) roads.
6. Stone sub-pavement with top layers of broken stone. (Telford.)
7. Stone sub-pavement with top layers of broken stone and gravel.
8. Stone sub-pavements with top layers of gravel.
9. Rubble stone bottom with top layers of broken stone, gravel, or both.
10. Concrete sub-pavement with top layers of broken stone, gravel or both.

He proceeds to say:

EARTH ROADS.

Earth Roads necessarily possess so many defects of surface that whatever amelioration their condition is susceptible of by careful attention to grade, surface, drainage and sub-drainage, should be secured. The grades should be easy, not exceeding 1 in 30; the road surface should slope not less than 1 in 20 from centre towards the sides; the ditches should be deep and capacious, with a fall of not less than 1 in 120, and trees should be removed from the borders to admit the wind and sun. In soils composed of a mixture of sand, gravel and clay, the road is formed of this material, and requires only that the ditches be kept open and free, and that the ruts and hollows be filled up as fast as they form in the surface, in order to render the road a good one of its kind.

In loose, sandy soils, a top layer of 6" thick, of tough clay, will be an effective method of improvement, which to save expense may be restricted to one half the width of the roadway. Sand may be added to adhesive clay soils, with equal benefit, the object in either case being to produce an inexpensive road covering that will pack under the action of the traffic during the dry season, and will not work up into adhesive mud during rainy weather.

" A pernicious custom prevails throughout a large portion of the United States of repairing country roads only at certain seasons of the year, The cost of maintenance would be greatly reduced by frequent repairs, and especially by keeping the side ditches clear and open to their full width and depth, but promptly filling in the ruts, and by maintaining the required slopes from the centres towards the sides. It will seldom be found that the material obtained by cleaning out the side ditches is fit to put upon the roadway." These remarks so largely apply to the clay roads of our own province, to the methods of repairing them and the material being used that I quote them fully.

Corduroy Roads.—So called from their ribbed character scarcely deserve the name of road, but are, nevertheless, useful to the settler. They are generally made over marsh and swamp, which in wet seasons would be otherwise absolutely impassable for wheeled vehicles. Nearly all the logs for such construction are usually procured in clearing a width of four rods or 66 feet prescribed for most country roads, the width of the corduroy or covering being restricted to 15 or 16 feet so that two vehicles can pass without interference. The logs are cut to the same length, which should be that of required width of road; and if proper selection is exercised so that their size or diameter is uniform, and if they are properly laid on sleepers placed lengthwise so that their top surfaces will be even, then covered with a layer of brush, and finished off with a coat of soil or turf, they will answer their purpose until the settlement becomes more populous and warrants the construction of a better and more desirable roadway.

"*Plank Roads*," says Gilmore, " were much in vogue 25 or 30 years ago, and are still used in localities, where lumber is cheap and stone and gravel scarce and expensive. They are usually about 8 feet wide and occupy one side of an ordinary, well drained and properly graded earth road, the other side being to turn out upon and for travel during dry season. The method of construction most commonly followed, is to lay down lengthwise of the road, two parallel rows of planks called *Sleepers* or *Stringers*, about 5 feet apart between centres, and upon these to lay cross-planks of 3 to 4 inches in thickness and 8 feet long, so adjusted that their ends will not be in a line but form short offsets at intervals of two to three feet, to prevent the formation of long ruts at the edges of the road, and aid vehicles in regaining the plank covering from the earth turnout. New plank roads possess many advantages for heavy haulage, as well as for light travel, when the earth road is muddy and soft, but in a short time the planks become so worn and warped, and so many of them get displaced, that they are very disagreeable roads to travel upon. They are so deficient in durability that a common gravel road as hereinafter described, will in the end be found more profitable in most localities. The ease and rapidity with which they can be constructed renders them a popular and even a desirable make-shift in newly settled districts and towns where lumber can be procured at low cost, but they lack the essential features of permanence and durability, which all important highways should possess. The sleepers ought always to be treated by some effective wood preserving process to prevent decay. In the planks ordinary rot will be anticipated by their destruction from wear and tear."

Gravel Roads.—The American as well as the European practice, is to screen pit gravel before applying it to the surface layer. Two wire screens, one with wire 1 to 2 inches apart, the other ½ to ¾-inch apart, are necessary. The pebbles that will not pass the larger screen are rejected, and are afterwards broken up into smaller fragments, while the earth, gravel and sand that pass through the smaller one, although unsuitable for the road surface, will answer for blinding or for a sub-layer or side walk covering.

A layer from 4 to 6 inches thick of good unscreened pit gravel in its natural state is first spread upon the road bed, which is then thrown open to travel, until it becomes tolerably well consolidated, after which a second layer of screened gravel is added of sufficient depth to suit the requirements of traffic. The whole is generally consolidated by a roller. The aggregate thickness of the layers does not exceed 8 to 10 inches.

The sides of the road should be rolled first to such a degree of firmness that when the roller is placed upon the highest portion along the middle, the tendency of the gravel to spread and work off towards the side gutters will be resisted. A gravel road, carefully constructed in the manner above described, will possess all the essential requisites of a good road.

McAdam and *Telford* roads have been already described. A few remarks on rolling of McAdam roads, by Mr. William H. Grant, Superintending Engineer of the New York Central Park, in his report on the park roads, are so interesting that I quote them: "At the commencement of the McAdam roads, the experiment was tried of rolling and compacting the stones by a strict adherence to McAdam's theory—that of carefully excluding all dirt and foreign materials from the stones, and trusting to the action of the roller and the travel of teams to accomplish the work of consolidation. The bottom layer of stone was sufficiently compacted in this way to form and retain, under the action of the rollers (after the compression had reached its practical limit), an even and regular surface, but the top layer, with the use of the heavy roller loaded to its utmost capacity, it was found impracticable to solidify and reduce to such a surface, as would prevent the stones from loosening and being displaced by the action of wagon wheels and horses' feet. * * * The rolling was persisted in, with the roller adjusted to different weights up to the maximum load" (12 tons) "until it was apparent that the opposite effect from that intended was being produced. The stones became rounded by the excessive attrition they were subjected to, their more regular parts wearing away, and the weaker and more smaller ones being crushed. The experiment was not pushed beyond this point. It was shown that broken stone of the ordinary sizes and of the best quality for wear and durability would not consolidate in the effectual manner required for the surface of a road *while entirely isolated from, and independent of, other substances.*"

Shell Roads.—Along the Atlantic and Gulf coasts of the United States, stone suitable for road-making does not in many districts exist. Oyster shells are used, and when applied upon sandy soil, it is said, form an excellent road for pleasure driving or light traffic, and when properly maintained possess most of the essentials of a good road.

Charcoal Roads.—A good road is said to have been made through a swampy forest in Michigan in the following manner: "Timber from 6 to 18 inches through was cut 24 feet long, and piled up lengthwise in the centre of the road, about five feet high, being nine feet wide at the bottom and two at the top, and then covered with straw and earth in the manner of coal pits. The earth required to cover the pile taken from either side leaves two good-sized ditches, and the timber, though not split, is easily charred; and when charred the earth is removed to the side of the ditches, the coal raked down to a width of 15 feet, leaving it two feet thick at the centre and one at the sides, and the road is completed." Its cost was $600 per mile, and contracts for two such roads were given out in Wisconsin at $499 and $500 per mile respectively. (Gillespie on roads)

Such, then, is the history, evolution and practice of road-making around us. Let us see if we carry on such a combination of facts as present themselves, reason and reflect and adapt ourselves to the best methods for the construction and maintenance of the highways of our Province. We must be guided by the particular materials or mode of construction, by the locality, the facility for obtaining suitable material, and the necessity and purpose which the traffic may be intended to serve. The surface of Nova Scotia is so varied that it presents nearly all the steps of geological sequence. Our road-making material is accordingly diversified, and may require different modes of application in different districts. Laws of a local nature interfere and operate many modifications, even in limited areas. Along the Atlantic shore we have the Lower Cambrian rocks, with occasional depositions of moraines, boulder clays and quartzites, out of which may be also selected, here and there, a gravelly road covering. Along our northern boundary we have trap rock, which is excellent for road-making, but in the carboniferous districts, such as Cumberland, Pictou, and along the Northumberland Strait, the common clays of the country yield but a poor covering for our highways.

There are many matters connected with road-making which should be considered, as the modern modes of road construction could not be adopted in many districts. In fact, the country is not fully ripe at the present moment for adopting the most improved methods. Therefore engineers and road-makers must, as far as possible, deal with the materials they have at command, and inculcate correct principles in the use of such materials. One great point upon which stress should be laid was the formation of the cross-section of a road. No road could long remain perfect in this country unless the drainage from it was good, considering the ordinary materials with which the engineer had to deal, and which to a greater or less extent are pervious to moisture. The great question seemed to be that of price. Engineers cannot impress governments or municipal bodies with all the advantages which accrue from any particular form of road or method of construction, unless they could first of all, demonstrate that it would be the cheapest, either as the first cost or ultimately. The cost and durability of the various systems depend so much upon the nature of the traffic, gradients, care in original construction, and material available, that no rigid rule can be adopted; it is only by careful study and judicious application that we can arrive at the best and most economical system.

The systems of McAdam and Telford, being those which will doubtless continue to be most generally adopted for country roads and those of small towns and suburban districts, and as there is a growing feeling throughout the Province that McAdam's system should be adopted, it may be opportune to discuss its desirability here.

We must begin by grading the road to some degree of uniformity, and draining it thoroughly. The latter is absolutely necessary, otherwise the coating of broken stones forming a compact road surface would be frequently hove by the frost in this fitful climate. Next we would require steam stone-crushers. Generally speaking, stone-breaking machines can be used to the greatest advantage when the material is difficult to break, and where there are facilities for distributing large quantities from one, or a small number of sources of supply. The economy of substituting machinery for hand labor will generally be almost entirely a question of transport of the broken stones to the road. In many parts of the Province good stones for road material, whin or quartzite, encumber the ground. We can in this case save the cost of quarrying.

The stone-breaking machines of Blake's, Hope's, and Archer's have been thoroughly tried. The quantity of whinstone broken by a 16" x 9" Hope machine is about 40 tons per day, supposing that the machine was kept in regular work, which can very rarely be realized in practice. Gilmore says the American breakers yield from 3 to 7 cubic yards per hour. From all the information I can gather, I doubt if one can get 40 tons per day one day with another. The cost is as follows :

Engineer or driver	$2 50
4 men and 1 boy	5 50
Coal, $\frac{3}{4}$ ton	3 00
Oil cotton waste	0 85
	$11 85

To use stone-breaking machines to advantage they must be kept steadily at work. It may be moved from place to place by the engine. The former when mounted on wheels, weighs 5 or

7 tons, and the engine which draws it must be capable of removing it from one place to another. The cost of the broken material will be approximately, where boulders are available, without the expense of quarrying,—

Collecting, sledging and supplying to machine	$0 35
Breaking by machine	0 30
Carting from depot to road	0 20
Wear and tear of machinery, removing machine, screens, etc.	0 05
Per ton of broken stone	$0 90

Owing to the large quantities of whin stone, iron stone, trap and other metamorphic and igneous rock available with quarrying in Nova Scotia, it may be possible to get the broken material for the price given above. Ninety cents per ton will, however, be considered a minimum price by parties who have used the stone-breaking machine now in common use.

From these data we may be able to estimate what a mile of road would cost treated according to the system of McAdam, but with proper drainage to suit our climate.

M. Ducreux, M. Gasparin, and Mr. Leahy give about 55 per cent, as the amount of solid stone contained in broken stone metalling of 2 to 2½ inch diameter or gauge, the other 45 per cent, being void. A simple proportion will show that in this case a ton of stone will produce rather less than $\frac{9}{10}$ of a cubic yard.

Now if we assume our typical road to be well drained, properly formed, eight feet of the centre to be coated with 6 inches in thickness of McAdam, the remainder, or wings, to make 21 feet, to be of clay or gravel, a blinding of 1 or 1½ inches of the fine material (run through the screens at the crusher), to be spread over the broken stones and the whole consolidated by a roller, we may approximately estimate the cost of a mile thus:

For drawing, forming and spreading material, 320 rods at $1.00 per rod .... $ 320 00

Broken stone, 5280 $\times$ 8' $\times$ 7" $= \frac{913}{9}$ cubic yards = 1041 at 90c 912 60

Rolling 1500 sq. yards per day, according to Codrington, about 3 days to a mile, say 12 horses at $1.50 .... 18 00

Per mile $1250 60

The estimate is a minimum one compared with prices in other places. The materials being so convenient a large saving, comparatively considered, might be effected. It should, however, be understood that in districts where there are no such materials at hand and where long carriage would be necessary, the cost would be accordingly much larger. The progress would be for one steam crusher $\frac{1014}{40} = 25$ days, or roundly speaking one mile per month, which would give a day or two for repairs and removal.

Even with this expenditure we must not consider we would have perfect roads without much attention to repairs. The weather in Nova Scotia will act to some degree on the materials. Frost expands the moisture in the crust, and when the thaw comes a general disintegration will take place. Rain following frost and thaw is very damaging, and alternations of these without repairs and attention would soon destroy the best Macadam road coverings. The extent to which these various effects may be injurious will depend on the nature of the road materials, on the drainage, subsoil, situation, and many other accidental circumstances.

There is a general wish for steam stone crushers and for Macadam roads throughout the Province. The author would recommend that the Government introduce them into such municipalities as would be most likely to ensure their successful operation, where the material is plentiful and possibilities of success most promising.

THE TELFORD SYSTEM.

We have already described this system. In some localities there may be an abundance of stone, such as sandstone and the softer varieties of slate and limestone, which would be suitable for the Telford bottoming but would not possess the requisite hardness and toughness for the top covering of broken stone. In some cases, after the bottoming is set, the road may be finished with three to four inches of good gravel in the manner described for gravel roads. We would prefer having all the pavement stones of equal depth, and obtaining the requisite transverse convexity by forming the sub-strata to the desirable degree of curvature to receive them. A better drainage of the road-bed would doubtless be secured by forming the bed of the road parallel to the finished road surface.

The advantages and disadvantages of the sub-pavement or "bottoming" which forms the characteristic difference between the Telford and McAdam roads, have been the subject of lengthy discussion; both systems have their respective advocates, and both can claim respective merits; the materials at hand, the facilities for thorough drainage, and the extent and nature of the traffic, as well as the liability of displacement by freezing must all be considered. From the experience of the writer in Nova Scotia, now extending over a period of 20 years, if either is adopted he would prefer the Telford system of road-making, for the following reasons:

1. A foundation of this kind is believed to be as firm and durable as one of the same thickness composed entirely of broken stone, while it consists of considerably less.

2. A carefully-laid Telford pavement, covered with screened gravel, may answer all the purposes of our present country traffic, and can be constructed without the aid of expensive machinery.

3. It adapts itself more generally to the materials at hand, comes more within the scope of our resources, whilst the possibilities of success are more promising.

We might fairly assume that the cost of drainage and forming of road will be necessarily the same to receive a covering of either system. The cost of the Telford sub-pavement of 8 feet wide (same as the McAdam) 7 inches in depth, with a covering of 2 inches of screened gravel and a blinding of 1 inch of finer material, the whole to be consolidated by a roller, and all else being equal with the McAdam road, might be estimated approximately as follows:

Cost of draining, forming, etc..........	$ 320 00
Stone pavements 7″ deep, 5,280 × 8′ × 7″ = c. yds. 913 at 45c.......	410 85
Paving 320 rods at 50c..................	160 00
Gravel and blinding 5,280′ × 8′ × 4″ = 511 c. yds. at 50c................	260 50
Rolling.............................	18 00
Per mile..............................	$1169 35

The same remarks will apply to this estimate as to the McAdam, viz., it is a minimum one, and could only be applied where suitable stone encumbers the surface, where the haul would be short, and where no quarrying would be necessary. The voids in stone are not in this case deducted, as the gravel and blinding will under the weight of a roller fill up all or nearly all the interstices.

It will be seen that both the Telford and McAdam systems of road-making, to be adopted as fixed principles, are entirely beyond our means. There are, however, situations where their employment might be judiciously adopted in Nova Scotia. We know that the animal power or force necessary to move a load over our highways is to often restricted by bad or defective sections, and that the measure of the load is that which can be moved over them. In yielding muddy or loamy situations that so frequently intervene and retard travel, either the Telford or McAdam systems might be employed, whilst on higher and drier ground, where the bottom is solid and good, gravel alone might be used with much advantage. If we carefully examine any one of our principal highways in the western districts of the Province, we will find alternating stretches of good and bad road, and if we again select some of these—the worst—stretches that more frequently require attention for treatment under either of these systems, we may find that the construction of a few miles, perhaps very few, in a more permanent manner, will make the whole more uniform and equalize the necessary tractive force over the whole distance. If we can effect such improvement by such treatment, we may fairly conclude that the necessary expenditure would be a judicious one, and that its adoption might be well worth consideration.

GRAVEL ROADS.

Penfold (Practical Treatise on Roads) recommends "that pebble gravel should be first cleansed from dirt and useless matter by sifting and screening, and then the stones above one inch in diameter should be separated by another sifting and then broken." The general practice in both Europe and the United States, is to screen pit gravel and remove the earthy material from it, before spreading on the road. In Nova Scotia the custom is to apply it as road covering just as it comes from the pit. Our roads are therefore classed, according to our idea, good or bad roads, as the pit may turn out good or bad gravel. Gravel roads will have to serve our purpose in this country for some years longer, and as the mode of construction and maintenance now in vogue are susceptible of many improvements, it may be acceptable to shew how this material is being dealt with in its employment abroad, hoping that such suggestions and the discussion that may arise thereon, may tend towards developing greater practical worth and realizing a greater degree of endurance.

"A capital distinction," says General Gilmore, "must be made between gravel that will pack under travel and clean rounded gravel which will *not*, due to a small proportion of clayey or earthy matter contained in the former which unites and binds the material together. Sea-side or river-side gravel, consisting almost entirely of water-worn and rounded pebbles of sizes which easily move and slide upon each other, is unsuitable for a road covering unless some other materials be mixed with it, while pit gravel contains too much earthy matter." We have, however, seen very little gravel, even from our sea beaches, that will not, with a little blinding, pack under the traffic. Our roads are mostly gravel roads, yet it is doubtful if there is one continuous mile of a gravel road in Nova Scotia, outside of town limits, treated as the same class of roads in Europe and in the United States are treated. The gravel, if at all mixed with earthy material, should be screened; it should be spread to a depth of from 4 to 6 inches, or to such depth and width as may be considered necessary according to the volume of traffic to run over it, blinded with fine material and rolled.

If the bed of the road is rock, a layer of earth is frequently interposed between it and the gravel to prevent the too rapid wear of the latter, and assist in forming the crust. Where the road has already attained the desirable shape or form, and where the drainage is good, different treatment may be necessary for economy, and in many cases more judicious, especially for traffic not very heavy.

The relative strength and durability of different road material is a difficult matter to determine. No test but actual wear on the road can be fully relied on, and though it is easy to see that some pebbles or stones wear three or four times as long as others, it is almost impossible to take into account all the circumstances under which they are exposed to wear. The nature of the traffic, the moisture or dryness of the crust, and susceptibility to disintegrate from freezing and thawing, has often a great effect on the wear of the same material. It is only by studying such effects and by practical application we can find the most suitable materials and discover the best methods to employ them, for their necessary treatment and behaviour, may vary as the nature of surface and the conditions under which they are placed, may vary.

PLANK ROADS.

Eight years ago a planked road was laid over a swamp or bog near Liverpool, Queens County, on the leading highway from Milton to Caledonia, with some degree of success. It is claimed by the members representing the County of Queens that the result justifies the practice, and that in certain situations their adoption might be judiciously extended. The planks were laid on sleepers or stringers, in the same manner as General Gilmore describes the method generally used in the United states, and it is claimed that they answered their purpose admirably, and that the roadway over them is in good condition to-day. The writer considers their preservation from decay is largely due to their partial submersion in the bog and the tannic acid which it contains. Vehicles seem to pass easily over it, the bending and cross-breaking tendency of the road produces no sensible effect, there is no movement in the body of the road, and the wear is confined to the grinding and crushing of the surface of the planks, and although there is a continuous stream of daily traffic, the wear does not seem to have the same effect as on planked covering in other situations. In localities where lumber is cheap, and stone and gravel scarce and expensive, planked roads might be judiciously employed in crossing peaty stretches or bog or swamp.

EARTH OR CLAY ROADS.

Clay is a poor substitute for road covering. If we could only bake it and drive off the water, in combination with the oxide of iron which it contains, we might obtain a crust more impervious to water. Frequent attempts have been made to burn and calcine clay for railway ballast and road material in situations remote from stone or gravel, and it is said with some degree of success. It is, however, a costly operation, which we would not be justified in adopting. We are not ripe enough for costly experiments, and must content ourselves with other and cheaper means. We may, however, reason thus:—Sand stones are made from sand by some slow process, clay stones from clay, and so on, for all geologists believe that rocks are made from secondary causes. Now we can pretty thoroughly imitate rock-making by an admixture of lime and sand, or by the use of certain natural and artificial cements we can consolidate such material into solid rock in a short space of time, six or seven days, and the induration will improve in time. Adobe for roads, as well as for buildings, may yet be capable of practical application. At present in our climate we need a harder and more endurable material than clay or earth to sustain any sort of heavy traffic in the spring and fall seasons. Nevertheless, the writer has seen within our own borders several effective attempts to maintain clay roads, where the traffic is light, by material which is always within easy distance in Nova Scotia. By taking the tops of spruce or fir trees, removing all wood larger than ¾-inch in diameter, and intermixing them with clay to the consistency of adobe, and applying the mixture to the depth of from 9 inches to 1 foot, a tolerably fair road may be maintained. I have been informed that this class of road will wear well for four or five years' traffic. Hemlock tops, wood shavings, straw, or coarse dry grasses might be made use of where the spruce or fir could not be had conveniently. These make shifts should not, however, be attempted on roads where the traffic is heavy. A well-drained road, with a Telford pavement and McAdam covering, is the best we know of at present to meet any requirement of heavy traffic.

SLAG FOR COVERING.

The slag from the furnaces of the Acadia Iron Mines, Londonderry, has been very successfully employed for repairing roads in the neighbourhood of the Mines, and its employment is being year by year extended to quite a distance. The town of Truro has made use of it for repairs of the streets, but not with much success. The writer is under the impression that it has not had a fair trial at Truro. It was made use of in lumps too large, when its proper application should be as near as possible to a powder or very small pebbly state. It may be excellent for a binding material, and should not be denounced without a further and better trial. In a paper by the writer, read before the Canadian Society of Civil Engineers (pp. 92, 93, vol. 2, Transactions Canadian Society of Civil Engineers), the result of experiments on this slag as a mortar was given, and although as a mortar or cement it did not behave so successfully as expected, still as a road covering it might have large possibilities. The barrel of slag supplied from which the briquettes were made, showed the silica in a vitrified condition, also fused silicate of lime already formed with the alumina burnt to a white dry cinder. When there are thousands of tons of this material available, and so situated that it can be loaded into the railway cars from the embankment, where it is dumped, without the cost of repeated removal, we would wish to see it receiving a better and fairer trial before its value as a road covering is condemned.

GYPSUM AS A COVERING.

A coarse crystaline gypsum has been made use of as a covering for clay roads, in the neighbourhood of Maitland. It is the most unlikely kind of material we would consider to adopt as a road material (the Maitland gypsum is an anhydrate, as it contains but little water), yet its application is being continued as an useful and economical substitute for gravel or broken stone. It is applied in lumps as large as 3 and sometimes 4 inches across; it is reduced to powder by the wear of traffic, and seems to intermix with the clay and form a tolerably fair road surface.

Cinders and Coal Shales are made use of in a road in the neighbourhood of our collieries. They make a poor road. They are reduced under the wear of traffic to a fine dust in the summer season, which is blown away by the wind like sand dunes.

There is generally some choice of road materials to be had even from local sources of supply, and if that at hand is not suitable or strong enough to stand the traffic to which it is exposed, it will always be a question whether it will be more economical to go farther for a better material at an increased cost.

It may be desirable that all roads should be made strong enough for any traffic that may come upon them, but that will be a question of expense. However, until they are so made it is unfair to expect a road to bear heavy loads which it is not intended for. The Highways and Locomotives (Amendment) Act of 1878, whereby highway authorities in England may recover the excessive expenditure occasioned by extraordinary and exceptionally heavy traffic, is a protection to roads in that country and might be well adopted in this. In such neighbourhoods as Bay Verte, where so much material is being hauled, and along the roads affected by the extraordinary traffic caused by railway construction, companies, or contractors, should be required to repair the highways to the extent they may be damaged by such exceptional or extraordinary traffic.

There would be much advantage obtained by having a man in charge of certain lengths of wet or clayey roads. Even if a man is not constantly employed on the surface work of the road, but is engaged in cleaning up drains and some harvest work, in the busy season, he becomes familiar with the peculiarities of his length and with the best way to deal with it, and if he is a good workman he soon will learn to take an interest in the road, which is his business to keep in order.

In a well-built road the process of deterioration will be gradual, if the road has been originally strong enough, when skilfully managed, a careful surveyor can tide over a year or two with reduced expenditure, for expenditure on road maintenance has often to be reduced below what is desirable, that it may not exceed a certain amount.

WIDTH AND TRANSVERSE FORM OF ROADS.

In France four classes of roads are prescribed as follows:—

First, 66 feet wide, of which 22 feet in the middle are paved with stone.

Second, 52 feet wide, of which 20 feet in the middle are stoned.

Third, 33 feet wide, of which 16 feet in the middle are stoned, and

Fourth, a width of 26 feet, of which 16 feet in the middle are stoned.

Telford's Holyhead road, which runs through a hilly country, is 32 feet wide between the fences on flat ground, 28 feet wide on side cuttings, and 22 feet along steep and precipitous ground.

The Cumberland or National road in the United States has a prescribed width of 80 feet, but the prepared roadway is only 30 feet

Wide roads are sometimes finished with a road covering in the middle only, of sufficient width for vehicles to pass each other, whilst the sides are maintained as earth roads for light and fast travel when the soil is comparatively dry and firm.

Engineers differ as to the most advantageous form of cross-sections, some recommending a convex curve approaching to the segment of a circle or a semi-elipse, whilst others prefer two plains gently sloping towards the side gutters and meeting in the middle of the road by a short connecting convex surface. There are obvious objections to both forms in certain situations.

To the former, the convex-road, they are: that the water will stand in the middle; that carriages will keep in or near the middle and cause undue or excessive wear along one line in order to run on the level and avoid the tendency to overturn near the side ditches. To the latter, that if carriages will not run along the centre there must be, owing to the transverse inclination or fall from the apex or centre towards the gutter, an undue tendency for the carriages or vehicles to slide upon the road surface. Regularity of section and evenness of surface is of much more consequence than the slight difference between curves and straight lines. It is essential that rain should flow freely off the surface for the proper and economical maintenance of a road. Water standing in ruts or depressions must be avoided, it greatly increases wear, deepens and enlarges hollows, and weakens or destroys the whole crust of the road. Such a cross-section should therefore be given as will throw the rain-water off quickly, and the necessary inclination to practically effect the purpose must vary with the different materials of which the road is composed. We cannot have, as in Great Britain, one typical form of road or method of road-making, because we must adapt ourselves to the materials at hand or within easy distance.

It is necessary to give a somewhat greater convexity to a new road than it is intended to have eventually; the middle consolidates more by the traffic, and the surface material is scattered towards the sides, so that however carefully it is raked or attended to the road will become flatter as it consolidates.

Cross-sections, showing the form proposed for roads in Nova Scotia, are submitted to illustrate this paper. The volume of traffic to be moved, their suitability to meet the requirements of traffic, and the materials near at hand for construction and repairs, must in a large measure influence the selection.

No. 1—Is a Telford pavement which could be made rapidly and with the drainage shewn would form an excellent highway; it might be covered with gravel or broken stone.

No. 2—Is a cross-section of a road coated with gravel or broken stones.

No. 3—Is a clay road with a six inch gravel covering 8 to 10 feet in width, with a centre drain of stones.

No. 4—Is a clay road with a centre drain of poles where stone cannot be had.

No. 5—Is a cross-section of road made over bog or marsh.

No. 6—Is a section of road to be made over a peat bog.

No. 7—Is a section of road to be made on hill side ground.

No. 8—Similar to No. 7, but with embankment retained by crib-work or a stone wall.

No. 9—Similar to No. 8, but both plank and cutting are retained by crib-work.

Nos. 10 and 11 are sections that could be adopted to rock side-hill.

In locating a line of road departures from a straight line are determined by many considerations. In crossing a dividing ridge between two valleys the lowest depression in the summit is generally taken. A continuous hill side without serrated ravines or secondary water courses is also sought for. Next find by an aneroid barometer the height to be overcome and the distance along the side hill which it is practical to climb to or descend from the summit. If the height is divided into the distance it will give the rate of incline or the gradient obtainable, and if with a level the engineer or surveyor commence above and descend with that rate of grade following an inclining contour, he must obtain the best location available. It may be necessary to diverge from such an ideal line to avoid bridging ravines, crossing expensive rock ledges, avoiding swamps and many other causes, all of which, and many others, may have to be considered, but are seldom taken into account in Nova Scotia. If any thoroughly practical system of road making is adopted in this country it will be necessary to alter many of our present great roads so as to obtain easier traction and better surface.

"In selecting among the different lines of survey the one most suitable for a common road, the engineer is less restricted, from the nature of the conveyance used, than in any other kind of communication. The main points to which he should confine his attention are, (1) to connect the points of arrival and departure by the shortest or most direct line; (2) to avoid all unnecessary ascents and descents within the smallest practical limits; (3) to adopt such slopes or gradients for the centre line of the road as the kind of conveyance used may require; (4) to give the centre line such a position with reference to the natural surface of the ground, and the various obstacles to be overcome, that the cost of labor for excavations and embankments required by the gradients adopted and also the cost of bridges and other accessories, shall be reduced to the smallest amount." (Prof. Mahan.)

GRADES AND TRACTIVE FORCE.

"Upon common roads the grades, or the angles which the axis of the road should make with a horizontal line, depend so much upon the kind of vehicles employed for traffic, the character of the road coverings adopted for the surface, and the condition in which the surface is maintained, that no empyrical rule can be laid down. The grade should not be as great as to require the application of brakes to the wheels in descending, or to prevent ordinary vehicles carrying passengers at a trot. In general, the gradient should be somewhat less than the angle of *repose*, or angle upon which the vehicle in a state of rest would not be set in motion, by its own weight, but would descend with slow, uniform velocity if very slight motion be imparted to it. The grades, therefore, suitable for any road will depend upon the condition with respect to smoothness and hardness, in which the surface is to be maintained, and hence upon the kind of road-covering used; and as the force of gravity is the same whether the road be rough and soft, or smooth and hard, steep grades are more objectionable on good roads than upon bad." (General Gilmore.)

The general conclusions arrived at by M. Morin from his experience on draught are as follows:—

The resistance to rolling of vehicles on solid metalled roads and pavements is proportional to the weight and inversely proportional to the diameter of the wheels.

On solid roads the resistance is very nearly independent of the width of the tires when it exceeds 3 to 4 inches, but on compressible surfaces it decreases in proportion to the width of the tire.

The resistance increases with velocity on hard roads, but is independent of velocity on soft surfaces.

Springs diminish the resistance at high speeds, but not at slow speeds.

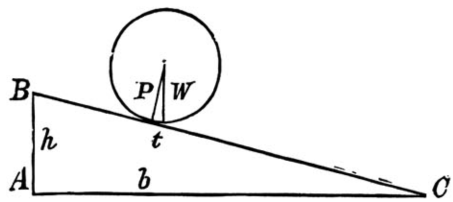
From trials made with a dynomometer attached to a wagon, moving at a slow pace upon a level, the following table gives the force of traction in pounds upon several kinds of road surfaces in a fair condition, the weight of the wagon and load being one ton of 2.240 pounds:

1.	On best stone trackways.........	$12\frac{1}{2}$	pounds
2.	A good plank road...............	32 to 50	"
3.	A cubical block pavement........	32 to 53	"
4.	A macadamized road, small broken stone......................	65	"
5.	A Telford road, made with broken stone on a pavement.........	46	"
6.	A road covered with 6 inches of broken stone or concrete foundation..........	46	"
7.	A road made with a thick coating of gravel laid on earth... ...	140 to 147	"
8.	A common earth road...........	200	"

In order to apply these results in establishing suitable grades take the case of the macadamized road, No. 4, in which the tractive force is 65 pounds on a level road:

Let W=the weight of the vehicle and load in pounds.
p=pressure normal to the road surface.
t=force of traction in pounds on a level road.

At the angle of repose of an inclined road, the force, acting parallel to the line of grade, necessary to sustain a carriage and its load in its position on the incline, or to prevent its moving back by its own weight, is equal to the traction force t, which would just move the carriage and load on a level road. Let h be the perpendicular and b the base of a right angle triangle, of which the hypothenuse $B\ C$ represents the slope of the angle of repose:



which somewhat exceeds the greatest admissable gradient. For simplicity the load may be supposed to rest on a single wheel, shewn in the figure. In the smallest triangle T is the perpendicular, P the base, and W the hypothenuse in which

$$P = \sqrt{W^2 - t^2}$$

From the two similar triangles

$$t : p :: h : b \text{ or } \frac{t}{P} = \frac{h}{b}$$

by substitution

$$\frac{t}{\sqrt{W^2 - t^2}} = \frac{h}{b} \text{ but } \frac{h}{b}$$

being the perpendicular divided by the base, represents the angle at the base or the angle of repose, and this is the maximum admissable gradient. Hence the gradient should not exceed the quotient obtained by dividing the force of traction by the square root of the difference between the square of the load and the square of the traction. Upon good roads t is so very small in proportion to W that it may be omitted in the denominator, and we have practically for the angle of repose $\frac{t}{W}$ or the force of traction divided by the weight of vehicles and load.

For No. 4 the formula becomes.

$$\frac{65}{\sqrt{2240^2 - 65^2}} = \frac{1}{34} \text{ nearly.}$$

or 1 perpendicular to 34 base, and generally the proper grade for any kind of road, or the ratio of the vertical to the horizontal line will be equal to the force necessary to draw the load and the load itself upon the same road when level.—Gilmore, pp. 24, 25. (Experiments from Morin, and Sir J. McNeil.)

In practice the steepest grades on good roads is about 1 in 20, it having been determined by experience that a horse can draw up this incline his ordinary load for a level road without the help of a second animal; also that he can attain at a walk, a given height, upon a gradient of 1 in 20 without more apparent fatigue, and in nearly the same time as he would require to reach the same height over a proportionally longer slope so gentle—say $\frac{1}{34}$—that he could ascend it at a trot.

WHEELS AND WEIGHTS ON THEM.

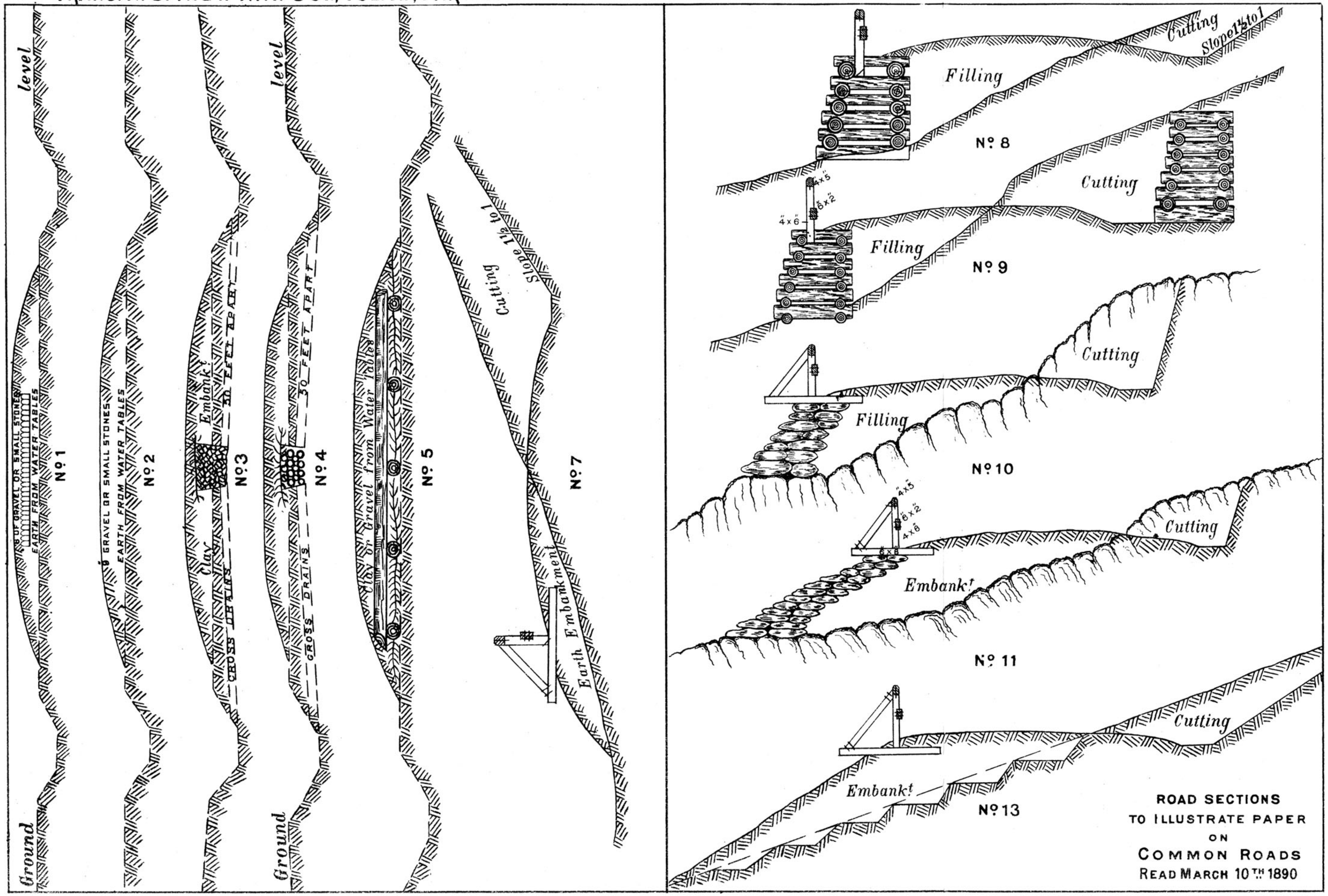
The regulation of the form of construction of wheels has been the subject of legislation in Great Britain since the beginning of the century. One of the results was to bring into use an excessively broad conical wheel with a tire considerably rounded. The conical or dished wheel had its advocates and its enemies. The width of the wheel and the weight carried on them have an important influence on the wear of roads. The restrictions at present in force in England are those of the General Turnpike Act (3 Geo. IV. cap. 126), which regulates the weights to be allowed to wagons, carts, &c., in winter and in summer according to the following table:

Description of Vehicles.	Weight of Carriage and Loads.				Pressure per inch. Width of Tire.	
	Summer.		Winter.		Summer.	Winter.
	Tons.	Cwt.	Tons.	Cwt.	Cwt.	Cwt.
Waggon with 9 in. wheels,	6	10	6	0	3.6	3.3
Cart " "	3	10	3	0	3.9	3.3
Waggon, 6 in. wheels.....	4	15	4	5	4.0	3.5
Cart "	3	0	2	15	5.0	4.6
Waggon with 4½ in. wheels,	4	5	3	15	4.7	4.1
Cart " "	2	12	2	7	5.8	5.2
Waggon with less than 4½ in. wheels............	3	15	3	5	2½ inch tires } 7.5	6.5
Cart with less shan 4½ in. wheels..............	1	15	1	10	2½ inch tires } 7.0	6.0

The pressure per inch of width of tire cannot always be taken as a fair measure of the load on a road; a good deal will depend upon the sort of road. A strong, hard road, on a good foundation, will bear a considerable load on narrow tires without perceptible damage being produced, while a more yielding road will break down, although the pressure per inch of tire is far less.

The table given applied to McAdam and Telford roads, and would not at all apply to the soft or more yielding surfaces of roads in Nova Scotia.

The diameter of the wheels, as influencing the pressure on the road, may be left out of account for wheels of common size on ordinary road surfaces.



ROAD SECTIONS
TO ILLUSTRATE PAPER
ON
COMMON ROADS
READ MARCH 10TH 1890

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