speed of the piston diminishes until, if it were possible to have a connecting rod of infinite length, we should have both halves of the piston stroke performed in the same time.

It is, perhaps, not very generally known that the acceleration of the piston, which is the quantity determining the balance or want of balance in an engine, is considerably greater at the head than at the crank end of the stroke. Engines are built, such as the Wells, which profess to be perfectly balanced because they have two pistons of equal weight on the same centre line, on the same side of the crank, and which act on cranks set oppositely to each other. This is not the case; such an engine is out of balance at the ends of the stroke by the amount $\frac{MV^2}{gr}2n$, where the symbols have the same meaning as above and M is the mass of either piston.

For The Canadian Engineer

ROAD ENGINEERING.

BY W. H. BREITHAUPT, M. AM. SO. C.E.

The social and commercial well-being alike of modern communities depends on the facility of communication. The cost of every ton of goods or produce brought to a town is dependent on the quality of the road over which it is hauled. The construction and maintenance of roads require special skill and care, and yet no department of public works has in times past been so frequently slighted.

The question of first cost is usually the great impediment in the way of obtaining good roads. It is difficult to convince the average taxpayer of the fact that a road, of which the first cost is comparatively small, but of which the maintenance amounts, every few years, to as much as the first cost, is more expensive, besides being much less serviceable, than a properly built road costing little to maintain. The road, or pavement, which is truly the cheapest, is that which gives the best returns for the money expended on it. The maintenance, together with interest on first cost, of a good pavement, will generally amount to less than the like charges on a poor one. From this point of view the question should be considered.

The relative merit of different road-coverings has been made the subject of much experiment and study. The vast difference between good and poor road surface is shown by the following table, which joins the average cost of transporting one ton a distance of one mile over different surfaces:

Asphalt pavement, good condition	2.7 cents.
Broken stone (Macadam)	5.2 to 14 "
Earth dry and hard	16 "
Earth ruts and mud	39 "
Gravel loose	42 "
Gravel compacted	12 8 "
Sand wet	32 "
Sand dry	64 "

As compared with the above, it will be interesting to note that the average cost of transportation by railways is now six-tenths of a cent per ton per mile.

Could the average cost of wagon transportation be reduced to say five cents a ton per mile, it would mean an annual saving of millions of dollars, and bring into market many tons of produce that cannot now be moved with profit.

In some European countries it is common to haul on country roads three tons, and in the cities from three to five tons, with one horse. On such roads the cost of wagon transportation is less than one-third of what it is in general in America.

The following table gives the tractive force, say in number of horses or horse powers, required to move a given load on a level on different road surfaces as compared to asphalt pavements.

Asphalt pavements, good condition	1
Gravel loose	16
Gravel common road	8.2
Gravel best, hard rolled	4 4
Turf wet	16.6
Turf dry and hard	7.3
Earth ordinary road	13 3
Earth dry and hard	4.4 to 6
Macadam ordinary	3 8 to 5.3
Macadam best	1.9
Sleighs on snow, temperature 26°	4 4

The increase of tractive force due to grades is shown in the next following table, which gives the resistance, in pounds per ton (2,000 lbs.), due to gravity, on different grades. Per cent. of grade is the number of feet rise in a distance of 100 feet.

Per cent. grade	5	3⅓	2½	2	1⅔	1¼	1
Rise in ft per mile	264	176	132	105	88	66	52
Res. in lbs per ton	110	66	50	40	34	25	20

To these values must be added the tractive force on a level to obtain the entire tractive force required. On good macadam, for instance, the tractive force required is 36 lbs. per ton. The required tractive force on a one per cent. grade would then be 56 lbs. per ton, on a two per cent. grade 76 lbs., &c.

The loss of tractive power in grades is greater than these figures show, for the reason that the power of a horse is much diminished by fatigue in long ascents. A horse can, however, for a short time, exert more than twice his average pull. So long, therefore, as the incline is short, and not too steep, it is not very detrimental. A steep grade, or a long uninterrupted one, is particularly objectionable on an otherwise good road, in that it determines loads which, but for it, could be several times as large. In France, the country preeminent for the excellence of its roads, having a special government organization for their care, and a corps of engineers, styled engineers of bridges and roads (Ingenieurs des ponts et chaussées) who devote their whole time to the construction and maintenance of the public roads, the maximum grade adopted for highways is 5 per cent.

The kind of vehicles used on a road has much to do with its endurance. Springs decrease the hammering of a wagon. Broad tires and large wheels distribute the load over a greater area, and thus diminish wear of the road-surface. For heavy hauling wheels with tires 2½ inches wide, for instance, cause double the wear of wheels with tires 4½ inches wide. The proper width of tire is dependent on the load to be carried. In a number of European countries this width is strictly regulated by law. It varies from about 4 inches to 6 inches for freight wagons, the latter width being for four wheeled wagons carrying six tons. In France it is usual to have the gauge of the rear pair of wheels larger than the front pair, so that the rear wheels run about an inch outside of the line of the front wheels. This distributes the wear over twice the surface, and prevents ruts. On account of their irregular twisting motion, two-wheeled carts do much more damage to a road than four-wheeled wagons, carrying the same load per pair of wheels.

A properly constructed road consists of two distinct parts, the road-bed and the final surfacing. The road-bed is made by bringing the natural surface of