THE CONSTRUCTION OF ROADS, PATHS AND SEA DEFENCES.

CHAPTER I.

INTRODUCTION.

THERE are few questions which have such a practical bearing on the progress of a nation, the advancement of civilisation, the furtherance of knowledge, and the numerous advantages to be derived from easy intercourse between all parts of a country, as that of the effectual construction and maintenance of roads.

It is a matter of much importance in these days of competitive industry and increasing needs of commerce, bringing in their wake the ever-growing demand for improved facilities of exchange and transport, and the more extensive adoption of modern modes of locomotion, that all roads should be constructed in the most efficient matter, so as to best conform to the requirements of the times; thus their durability of construction and those conditions necessary for safety and ease in travelling should be carefully considered, and the best course adopted, thereby reducing as much as possible the amount of wear and tear to horses and vehicles, and at the same time contributing to the comfort of those whose business causes them to be "on the road."

The economies derived from a system of good roads over even secondary ones must be considerable, but when compared in these days with the bad roads of a century or more ago, the saving to the public must be enormous, besides abolishing an inconvenience which would be absolutely intolerable to the high standard of excellence expected by the public at the present day.

Sir Henry Parnell says:—"The measures necessary to be taken for affording the means of travelling with rapidity and safety, and of transporting goods at low rates of carriage, form an essential

part of the domestic economy of every people. The making of roads, in point of fact, is fundamentally essential to bring about the first change that every rude country must undergo in emerging from a condition of poverty and barbarism. It is, therefore, one of the most important duties of every Government to take care that such laws be enacted, and such means provided, as are requisite for the making and maintaining of well-constructed roads into and throughout every portion of the territory under its authority."

In populous districts, large towns, and health resorts, it is of paramount importance, apart from the desirability of good roads for traffic, that all roads and back courts should be maintained in a proper state of repair, from a sanitary point of view. A residential district with bad and neglected roads and courts cannot be regarded as healthy. Cleanly roads in proximity to dwellings play an important part in the sanitary education of the inhabitants, and no dwelling can be regarded as perfectly sanitary, especially in crowded localities, when abutting on neglected and, perhaps, narrow, sunless, and inefficiently-drained roads.

Since the introduction of railways there is practically greater demand for good roads in and about towns than was previously the case, the fact that railways have set in motion the whole of the people and commerce, calling for the provision of the best facilities for transportation to and from these main centres and arteries of the country.

It is by means of the railways that so many thousands of persons flock to the seaside towns and other health resorts at various seasons of the year, calling forth in no small degree the construction of beautiful roads, promenades, and drives, sometimes entailing much engineering skill and considerable outlay of money.

The railway has, by its rapid conveyance of commerce and passengers from one locality to another, placed the remotest parts of the country within easy touch with the great centres, and has been the means of opening out many delightful and hitherto unfrequented districts, all in their turn requiring improved means of intercommunication.

As the earlier history of the advancement of road making in England is interesting, it is as well that, before entering on to the

present methods of construction, an outline of the past should be briefly sketched.

The Carthaginians have the credit for the invention of paved roads. The Romans, who were in touch with the Carthaginians from about 500 years B.C., became well instructed in the art of road making, and in the year 312 B.C., Appius Claudius partly constructed the most noble of Roman roads, named after him the Via Appia, or Appian Way. Fig. 1 shows the method adopted by the Romans in the construction of their principal roads.

The interest taken in the construction of roads by the Romans was exceedingly great, so much so that under Augustus and Julius Cæsar all the principal cities and towns were made to communicate with Rome by paved roads, which work was followed by numerous similarly constructed roads communicating throughout Europe and continuing through neighbouring continents and

Roman Road

Fig. 1.

islands, the direct lines of the great roads being maintained from shore to shore.

Mr. Tredgold says:—"The Roman roads ran nearly in direct lines; natural obstructions were removed or overcome by the effort of labour or art, whether they consisted of marshes, lakes, rivers, or mountains. In flat districts the middle part of the road was raised into a terrace. In mountainous districts the roads were alternately cut through mountains and raised above the valleys, so as to preserve either a level line or a uniform inclination. They founded the road on piles where the ground was not solid, and raised it by strong walls or by arches and piers where it was necessary to gain elevation."

Pinkerton's Geography contains the following remarks on the Roman roads of England:—*The Roads of England*, "which may still be traced in various ramifications, present a lasting monument of the justice of their conceptions, the extent of their views, and

the utility of their power. A grand trunk, as it may be called, passed from the south to the north, and another to the west, with branches in almost every direction that general convenience and expedition could require. What is called Watling-street led from Richborough in Kent, the ancient Rutupiæ, north-east through London to Chester. The Ermine-street passed from London to Lincoln, thence to Carlisle, and into Scotland. The Foss way is supposed to have led from Bath and the Western regions north-east till it joined the Ermine-street. The last celebrated road was Ikeneld, or Ikneld, supposed to have extended from near Norwich southward into Dorsetshire."

Upon the Roman power being broken up, their successors allowed the roads to fall into a bad state of repair, in fact cared little or not at all for them, so that in course of time these magnificent roads were practically ruined by absolute neglect and contempt.

It was not until comparatively recent date that successful road making was practised by modern nations. England and France gave but very little attention to the construction and repair of roads until about the seventeenth century. Prior to this time the roads of this country were allowed to remain in the most disreputable condition, and in some places were almost impassable. As recently as 1770 a publication by Mr. Arthur Young, describing his tour in the North of England, gives some very striking accounts of the state of the roads at that time. In describing some of the turnpike roads, he explains that the road from Wigan was so bad that he measured ruts in its surface 4ft. in depth, and that the road's surface was mended merely by "tumbling in some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner." The road to Newcastle appears to have been even worse than the Wigan one. Mr. Young says: "A more dreadful road cannot be imagined," and that he was obliged to hire two men at one place to prevent his chaise from overturning. He says:—"Let me persuade all travellers to avoid this terrible country, which must either dislocate their bones with broken pavements or bury them in muddy sand."

Mr. Thomas Codrington, in his work on "The Maintenance of Macadamised Roads," says: — "On the ordinary highways, improvement was hindered by the system of statute duty, and by

parish management under a person chosen yearly to serve the office of surveyor of highways. Everyone who kept a team of horses was liable to be called upon to do six days' team work, and those who did not keep horses paid money instead. The parish surveyor generally had no special knowledge of road repairing, and the team labour and other work were seldom well applied."

Under this system the responsibility of maintaining roads near towns or between towns would come very heavy upon those few persons who were expected to provide the funds for carrying out the necessary repairs.

The first attempt to improve the highways was by the introduction of the turnpike system.

The first turnpike road was established by law in 1653, by means of which a toll was imposed upon all but pedestrians who passed through the gate. This toll was then used for purposes of road-making. It appears, however, that the people were prejudiced against the system of toll gates, and that for many years the turnpikes were few.

At the end of George the Second's reign the system was put into more general operation throughout the country.

It was, therefore, the end of the 18th century before any marked improvement was made in the defective state of the roads.

The following extract from an essay on the "Construction of Roads, dated 1813," by Mr. Edgeworth, will show the defective condition of roads that existed even in the early part of the 19th century. Mr. Edgeworth says:—"In many parts of this country, and especially near London, the roads are in a shameful condition; and the pavement of London is utterly unworthy of a great metropolis."

Early in the 19th century rapid changes began to take place in road making, largely due to the labours of Metcalf, Telford, Macadam, and others.

Mr. Macadam, in his "Remarks on the Present System of Road-making," says the then existing practice of making a road in England and Scotland was "to dig a trench below the surface of the ground adjoining, and in this trench to deposit a quantity of large stones, after this a second quantity of stones, broken smaller, generally to about 7 lb. or 8 lb. weight; these previous beds of stone are called the bottoming of the road, and

are of various thicknesses according to the caprice of the maker, and generally in proportion to the sum of money placed at his disposal. On some new roads made in Scotland in the summer of 1819 the thickness exceeded 3ft. That which is properly called the road is then placed on the bottoming by putting large quantities of broken stone or gravel, generally 1ft. or 1ft. 6in. thick, at once upon it, and from the careless way in which it is done the road is as open as a sieve to receive the water which is retained in the trench, whence the road is liable to give way in all changes of the weather."

CHAPTER II.

THE NECESSITY OF GOOD ROADS FOR TRACTION.

SIR ISAAC NEWTON, writes Parnell, "has laid it down as a general principle of science, that a body, when once set in motion, will continue to move uniformly forward in a straight line by its momentum, until it be stopped by the action of some external force. This proposition is admitted and adopted by all natural philosophers as being perfectly true, and, therefore, in order to apply it to roads, it is necessary to inquire what kind of external forces act in a manner to diminish and destroy the momentum of carriages passing over them."

Sir Henry Parnell remarks, "As a carriage for conveying goods or passengers when put in action becomes a moving body, in the language of science, the question to be examined and decided is, how a carriage when once propelled can be kept moving onwards with the least possible quantity of labour to horses, or of force of traction."

Each of these great philosophers admits that some more or less controllable influences are constantly at variance with the principle of science known as the "first law of motion," and that the causes thus offering resistance should be ameliorated to as great a degree as possible. In this respect due regard must also be given to the necessary requirements for the comfort and safety of those who produce the propelling force to such traction, as well as keeping the object in view of reducing the force of traction.

Resistance to rolling is principally due to four causes, viz., surface protuberances and irregularities, surface and wheel friction, surface grades, and wind pressure.

Surface protuberances and irregularities.—When a wheel comes in collision with any hard road obstruction it becomes necessary for a horizontal force to be exerted at the axle to raise such weight carried by the wheel to a height equal to that of the obstacle to be

passed over. In comparing a road of considerable protuberances and irregularities with one of smooth surface, the comparative loss of energy in drawing a heavy load must be a matter of no little moment. These irregularities are further responsible for resistance caused by the shocks, which are greater when a vehicle is drawn at a high speed than at a low one.

On ordinary hard roads the resistance attributable to the actual raising of the weight over trifling obstructions is, perhaps, less to be taken into account than that reponsible for the concussions which take place as the load is drawn over roughly paved surfaces, and in which, as M. Morin determined in his experiments, the resistance to traction is increasing with the speed.

In the case of the want of uniformity in the road surface the resistance may readily be arrived at by the application of the following formula :—

Let P = the force required.
W = the weight, for example taken at 300 lb.
R = the radius of wheel ,, 30in.
O = the obstacle ,, ,, 2in.

$$\text{Then} \quad P = W \frac{\sqrt{R^2 - (R - O)^2}}{R - O}$$

$$\therefore \quad P = 300 \frac{\sqrt{30^2 - (30 - 2)^2}}{30 - 2}$$

Springs to vehicles have a tendency to diminish the resistance offered by road inequalities at high speeds. Mr. Codrington says regarding this : "The effect of springs in reducing draught is that they enable the wheels to rise and fall over inequalities over the road, while the load on them moves forward without being sensibly raised. The more perfect the elasticity of the springs in a vertical direction the greater is the reduction of draught, but any elasticity in the direction of the traction tends to increase the draught."

Surface and wheel friction.—This form of resistance varies according to the material used in making the road, whether it be hard or soft ; also, to some extent, according to the size of the wheel. On soft roads the wheel will, to some extent, penetrate the surface, so that when in motion it will be obstructed by a force in front of it of either grit, dust, or by the weight of the

vehicle causing an indentation sunk in the material itself. This, consequently, has the constant effect of causing the wheel to climb an irregularity equal to the depression so formed. The amount of penetration is less for large wheels than for small, but it is sufficient for general purposes, and for wheels of ordinary sizes, to calculate the resistance thus caused by penetration by the weight multiplied by a ratio to be determined on by the nature o the road surface, whether it be hard, soft, or medium. The following tables are the results of experiments by Sir John Macneil (made with an instrument he invented for the purpose) as to the resistance to traction of various descriptions of roads.

A wagon weighing 21 cwt. was used on different kinds of roads with the following results :—

	lb.
On well-made pavement the draught is	33
On broken stone surface, or old flint road	65
On gravel road...	147
On broken stone road, upon rough pavement foundation ...	46
On broken stone surface, upon a foundation of concrete formed of Parker's cement and gravel	46

The following empirical formulæ are given by Sir John Macneil for calculating the resistance to traction on level roads for (i.) a stage wagon ; (ii.) a stage coach :—

P = force required.
W = weight of vehicle in lb.
w = weight of load in lb.
V = Velocity feet per sec.
C = A constant number depending upon the nature of the surface over which the carriage is drawn.

Then $$P = \frac{W + w}{93} + \frac{W}{40} + C\,V \quad \ldots \quad \ldots \quad \text{(i.)}$$

and $$P = \frac{W + w}{100} + \frac{W}{40} + C\,V \quad \ldots \quad \ldots \quad \text{(ii.)}$$

The value of C is as follows :—

On timber surface ... ... C = 2
On paved surface ... ... C = 2
On a well-made broken stone road ... C = 5

On a well-made broken stone road, covered with dust...	C = 8
On a well-made broken stone road, wet and muddy	C = 10
On a gravel or flint road, in a dry, clean state	C = 13
On a gravel or flint road in a wet and muddy state	C = 32

Example :—To find the force necessary to move a stage coach at a velocity of 10ft. per second, the coach weighing 1500 lb. and carrying a load of 700 lb., and the surface of the road being well-made of broken-stone, but wet and muddy.

Then, according to (ii.).

$$\frac{1500 + 700}{100} + \frac{700}{40} + (10 \times 10)$$

Grades.—Surface grades bring into account the additional force of gravity.

The tractive resistance due to the grade is that force which is necessary to support a wheel on an incline and to prevent it from running down, under the pressure of its load + the effects of friction.

Therefore the total tractive resistance to be arrived at is the sum of a given load hauled over a level road + the extra force required to draw the same load up to a graded road.

The following diagram (Fig. 2) is to represent a wheel C loaded with a weight W.

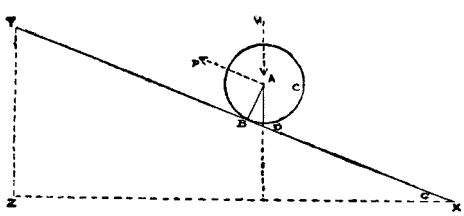

Fig. 2.

The wheel is in contact with the inclined plane X Y at B, and P is the force required to haul the load up the incline, and acting parallel to the road.