To comprehend thoroughly the great importance of making a regular and strong foundation for a road, it should be borne in mind, that roads are structures that have to sustain great weights, and violent percussions, the same rules therefore ought to be followed in regard to them as are followed in regard to the other structures. In building edifices to support great weights, whether a church, a house, or a bridge, the primary and indispensible consideration of the architect is to obtain a permanently firm and stable foundation; well knowing that unless this be first substantially made, no future dependence can be placed on the stability of the intended superstructure.

If the foundation of a road be not sufficient and equal to the pressure it has to sustain, the whole fabric, though in other respects ever so well constructed, must fail in permanent stability, and the hardness of it will be imperfect from its elasticity.

Having now stated all that the rules of science relating to moving bodies suggest, in order to defend the principles of road making, which have been laid down as the proper principle to be adopted, I shall now proceed further to illustrate and support these principles, by referring to experiments of the force of traction of different kinds of roads. These experiments have been made with the machine invented by Mr. McNeil, and may be relied upon for their accuracy, in consequence of their having been carfully examined by several very eminent civil engineers.

These experments uniformly show, that the force of traction, is, in every case, nearly in exact proportion to the strength and hardness of a road. The following are the results: on a well made pavement, the power required to draw a waggon is 33 lb; on a road made with six inches of broken stone of great hardness, laid on a foundation of large stones, set in the form of a pavement, the power required is 46 lb., on a road made with a thick coating of broken stone, laid on earth, the power required is 65 lb.; and on a road made with a thick coating of gravel laid on earth, the power required is 117 lb. Thus it appears that the results of actual experiment, fully correspond with those deduced from the law of science.

It has been considered necessary to enter into these details in showing that no road can be correctly called a good road unless it is so constructed as to be a very strong and a very hard one.

3rd. The resistance produced by gravity, in checking the progress of a moving body on a road, is little or nothing when a road is horizontal, because as gravity acts in a direction perpendicular to the plane of the horizon, it neither accelerates nor retards the motion. But when the road is not horizontal the power of gravity is a great impediment.

4th. The resistance arising from the action of the air is very variable, in some cases, it acts powerfully, but as its influence is the same whether the road be a bad or good one, little need be here said on the subject: it will be sufficient to state, that by experiments detailed in Smeaton's reports, it was found that the force of the wind on a surface one foot square was 1 lb., when the velocity of the wind was 15 miles an hour, or what would be termed a brisk gale, 3 lbs. when the velocity was 25 miles an hour, or what would be termed a very brisk gale, 6 lbs. when the velocity was 35 miles per hour, or what might be termed a high wind; and 12 lbs. to the square foot, when the velocity was 50 miles an hour, or what might be termed a storm. Supposing, therefore, that the surface of that part of a carriage acted upon by the direct influence of the wind to be 50 superficial feet, the resistance it will meet from a brisk gale of wind acting against it will be about 50 lb. when the carriage is slowly moved; but if the carriage be supposed to move directly against the wind with a velocity of 10 miles an hour, and the wind to move with a velocity of 15 miles an hour, the resistance against the carriage will amount to 3 lbs. on the square foot, or 150 lbs. on the carriage, which is fully equal to the power which two horses should be required to exert, when moving with a velocity of 10 miles an hour. From this the difficulty is evident of driving stage coaches at a rapid rate against high winds.

In marking out the line of a road, a great deal of expense in cutting and embanking for forming the bed on which the road materials are to be placed, may be avoided by a judicious selection of the high and low ground which the surface of the country affords. The chief care, where a road must be carried over a high elevation, is to lay it out so that it shall not have any fall till it reaches the summit. The lowering of heights, and the filling of hollows, should be so adjusted as to secure gradual and continual ascending inclinations to the highest point to be passed over. It is a most important part of the business of a skilful engineer to lay out the longitudinal inclinations of a road with the least quantity of cutting and embanking. He must do this by measuring and calculating the quantity of earth to be removed in cuttings, and taking care that it shall exactly make the embankments for raising the hollows to the required heights; a proper allowance being made for the subsidence of the soil according to its quality, without leaving an overplus to be carried to spoil.

When it is necessary to make a deep cutting through a hill, the slopes of the banks should never be less, except in passing through stone, than two feet horizontal to one foot perpendicular; for though several kinds of earth will stand at steeper inclinations, a slope of two to one is necessary for admitting the sun and wind to reach the road. The whole of the green sod and fertile soil on the surface of the land cut through should be carefully kept and reserved, in order to be laid on the slopes immediately after they are formed.

If a sufficient quantity of sods cannot be procured in the space required for the road, the slopes should be covered with three or four inches of the surface mould, and hay seeds should be sown on it; by this plan the slopes will soon be covered with grass, which will be a great means of preventing them from slipping.

When stones can be got the slopes should be supported by a wall raised two or three feet high at the bottom of them. These walls prevent the earth from falling from the slopes into the side channels of the road, and add very much to the finished and workmanlike appearance of a road.

In many cases it may be adviseable, particularly if an additional quantity of earth be wanted for an embankment, to make the slope through the cuttings on the south side of a road of an inclination of three feet horizontal to one perpendicular, in order to secure the great advantage of allowing the sun and wind to reach more freely the surface of the road.

In forming a road along the face of a precipice, a wall must be built to support it. The difficulty of forming a road in such a place is not so great as is imagined, for the face of a precipice is seldom perpendicular, and if the inclination should be half a foot perpendicular to one foot horizontal, this will admit of a retaining wall being built. By building such a wall, say 20 feet, and cutting 10 feet a foot at that height into the rock, and filling up the space within the wall, a road of sufficient breadth will be obtained.

In forming a road along the face of a hill that is indented with ravines, in place of carrying the road over the natural surface of the land, the projecting points should be cut through and the earth laid across the hollows so as to straighten the line.

In forming the bed of the road materials, care should be taken, except when cutting into the surface is wholly unavoidable in order to obtain the proper longitudinal inclinations, to elevate the bed with earth, two feet at least, above the natural surface of the adjoining ground; by following this course the road will not be affected by water running under or soaking into it from the adjoining land. In arranging the inclinations, they should be obtained by embanking, when that is practicable, in preference to cutting.

Great care is necessary to be taken in making high embankments. No person should be entrusted with these works who has not had considerable experience as a canal or road maker, for, if the base of an embankment be not formed at first to its full breadth, and if the earth be not laid on in regular layers or courses of not exceeding four feet in thickness, it is almost certain to slip. In forming high embankments the earth should be laid on in concave courses, in order to give firmness and stability to the work.

It is not uncommon at all in many parts of the country to see embankments formed convexly; the consequence of which is, that they are forever slipping. In forming embankments along the sides of hills, or what is called side forming, the rule that should be followed is, that the slope to be covered should be cut into level steps to receive the earth, otherwise it will be very liable to slip down the hill; in such cases, the earth should be well compressed, and great care should be taken to intercept all the land springs about it by proper drainage. For this purpose, a drain should be cut on the upper side of the road, and open drains should be made on the side of the hill above the road, to catch the surface water of the hill.

So much depends on the proper draining of a road, that too great attention cannot be given to this part of the business of road making. This operation should be carried on at the same time with the forming of the road, when a road is to be made over flat and wet land, open main drains should be cut on the sides of the road; these drains should communicate with the natural water courses of the country, their size should depend upon the nature of the country and the local circumstances of the road.

In general, these side drains should be cut at least three feet deep below the level of the bed of the road; they should be one foot wide at bottom, and five feet wide at top.

If main open drains cannot be formed, in consequence of the road running along the side of a hill, or of its passing through a cutting of a hill, or of buildings or other obstructions lying close to the road, it then becomes necessary to make covered drains on each side of the road. These should be formed of stone or brick and be strongly and substantially built, —they should be 18 inches high and twelve inches apart.

Particular care must be taken that the covering stones have a bearing of at least four inches on the side walls. They should have a layer of brushwood put over them; and the drain should then be filled with gravel or small stones.

If springs rise in the side of the road, or in the slopes of deep cuttings, stone drains should be made into them, so as completely to carry away all the water.

In cuttings it is necessary to make drains of small dimensions from the centre of the road to the side drains. These drains should form an angle in the centre of the road, in the form of a V, technically called mitre drains: the angle or splay of these drains should depend upon the inclination of the road; it should not make the inclination of the drains exceed 1 inch in 100; for if it be greater, the run of the water will undermine the sides, and injure them. These mitre drains should be nine inches wide at bottom, twelve inches wide at top, and ten inches deep. These drains should be placed at about 60 yards from each other, or about 30 in the mile; but if the soil be wet, this number should be considerably increased. They are to be filled with ruble stone or cleansed gravel. If gravel is used, a draining flag should be laid along the bottom before the gravel is put on.

The upper part of these mitre drains should communicate with the road materials, so as to draw the water from them.

According to the inclinations of a road and the form and wetness of the country through which it passes, cross drains of good masonry should be built under the road.

One of these drains should be made whenever the water could be on one side of the road, and can only be got rid of by carrying it to the other side. When the road passes along the slope of a hill or mountain, a great number of these drains are necessary to carry off the water that collects in the channel of the road on the side next the high ground. They should be placed at from 50 to 100 yards distance from each other, according to the declivity of the hill; so that the side channels may not be cut by carrying water too far. In these situations inlets should be built of masonry, to carry the waters from the side channel of the road into the cross drains. Numerous outlets should also be made from the side channels of the road.

In mountainous countries, where the rode passes along the slopes of the hills, it is necessary to carry open or catchwater drains, branching from the upper ends of the cross drains, in an inclined direction, so as to catch the surface water before it can reach the road.

After all these precautions have been taken, the preservation of the surface of the road from injury by water should be further secured, by giving to the surface of it a proper convexity in its cross section, and by making regular side channels.

These side channels will be formed by the angle where the slope of the side parts of the surface of the road abuts against the edge of the slope of the bank, or other defining bounds of the roadway. They will be capable of carrying a great quantity of water, without being made into the form of a square sided drain.

On all hills the greatest care should, also, be taken to keep the side channels always open; for, if they are obstructed with dirt, the water will find its way over the middle of the road, and cut channels in it. The side channels of a road should be all thoroughly repaired as well as all the road drains, before the approach of winter, and again after the winter is over; but, besides these repairs at fixed periods, daily attention should be given to take care that no obstruction gets into them.

In addition to all these means recommended to be adopted for securing the drainage of a road, it is of the utmost importance that evaporation should have full effect in drying up the surface of a road, by allowing the sun and wind to act upon it in the freest manner.

If roads be kept dry, they will be maintained in a good state, with proportionally less expense. It has been well observed, that the statuary cannot saw his marble, nor the lapedary cut his jewels, without the assistance of the powder of the specific materials on which he is acting: this, when combined with water, produces sufficient attrition to accomplish his purpose.

A similar effect is produced on roads, since the reduced particles, when wet, assist the wheels in rapidly grinding down the surface.