BA. CB will then represent the force which the waggon presses on the surface of the road, and A B the resisting force of gravity, i. e., the force (independent of friction) which resists the ascent of the wagon, or which tends to drag it down the hill.

To find the amount of this force from the two similar triangles, A B C, and D E F, we get the proportion ; C A is to A B, as D E is to E F; representing the length of the plane by I, its height by H, and the weight of the wagon and load by W, this proportion becomes, W, A B : I, H. Whence A B equals $\frac{W H}{I}$, that is the resistance of gravity due to the inclination is equal to the whole weight multiplied by the height of the plane divided by its length. If the inclination be one in twenty, then this resistance is equal to one tenth of W.

In this investigation, trifling sources of error have been neglected, arising from part of the weight being thrown from the front axles to the hind ones in consequence of this inclination of the traces, from the diminution of the pressure of the weight owing to its standing on an inclined surface, and from the hind wheels bearing more than half the pressure in consequence of the line of gravity falling nearer them.

The results of experiments fully confirm the deductions of theory as to the great increase of draught upon inclinations. The following data has been established :—

Calling the load the horse can draw on the level.....				100
On a raise of 1 in 100	a horse can draw only			90
" " 50	"	"		81
" " 44	"	"		75
" " 40	"	"		72
" " 30	"	"		64
" " 26	"	"		54
" " 24	"	"		50
" " 20	"	"		40
" " 10	"	"		25

In round numbers upon a slope of 1 in 44, or 120 feet to a mile, a horse can draw only three-quarters as much as he can upon a level ; on a slope of 1 in 24, or 220 feet to the mile, he can draw only one-half as much, and on a slope of 1 in 10, or 528 feet to the mile, only one-quarter as much. This ratio will vary greatly with the nature and condition of the roads, for although the actual resistance of gravity is always absolutely the same upon the same inclination, whether the road be rough or smooth, yet it is relatively less on a rough road, and does not form so large a proportional part of the whole resistance. Thus, if the friction upon a road were such as to require upon the level a force of draught equal to one-fortieth of the load, the total force required upon an ascent of one in twenty would be one-fortieth plus one-twentieth, which equals three-fortieths. Here, then, the resistance of gravity is two-thirds of the whole.

If the road be less perfect in its surface, so that its friction equals one-twentieth, the total force upon the ascent will be one-twentieth plus one-twentieth, and here then the resistance of gravity is one-half of the whole.

If the friction increases to one-tenth, the total resistance is one-tenth plus one-twentieth, and here the gravity is one third of the whole. We thus see that, on a rough road with great friction, any inclination forms a much smaller part of the resistance than does the same inclination on a smooth road on which it is much more severely felt and proportionately more injurious just as the gaps and imperfections which would not sensibly impair the value of a common knife would render a fine razor completely useless.

The loss of power on inclinations is indeed even greater than these considerations show, for besides the increase of draught caused by gravity, the power of the horse to overcome it is much diminished in even a greater ratio than that of a man, owing to its anatomical formation and its great weight. Inclinations are particularly injurious where a single steep slope occurs on a long line of road which is comparatively level. It is in that case especially important to avoid or to lessen this slope, since the load carried over the whole road, even the level portions of it must be reduced to what can be carried up the ascent. Thus, if a long slope of 1 in 24 occurs on a level road, a horse can draw up only half of the load he can carry over the level portion.

The bad effects of this steepness are especially felt in winter when ice covers the road ; the slippery surface causes danger in descending as well as increased labor in ascending. The water also runs down the road and gullies it out, destroys its surface and causes a constant expense for repairs.

It is very important never to allow a road to ascend a single foot more than is reasonably unavoidable. If a hill is to be ascended the road up it should nowhere have a change of grade ; but it should be located and have such cuttings and filling as will secure a gradual and uninterrupted ascent the whole way.

In forming excavations the inclinations of the side slopes demand particular attention. This inclination will depend on the nature of the soil and the action of the atmosphere and internal moisture. In common soils, such as ordinary earth formed of a mixture of clay and sand, or compact stony soils, the side slopes would withstand very well the effects of the weather with a greater inclination, although it is best to give them one and a-half feet base to one foot perpendicular ; the roadway will by this arrangement be well exposed to the action of the sun and air, which causes rapid evaporation of the moisture on the surface.

Pure sand and gravel may require a greater slope, according to circumstances. In all cases where the depth of the excavation is great, the base of the slope should be increased. It is not usual to use any artificial means to protect the surface of the side slopes from the action of the weather ; but it is a precaution which in the end will save much labor and expense in keeping the roadway in good order.

The simplest means that can be used for the purpose consists in covering the slopes with good sods, or else with a layer of vegetable mould about four inches thick, carefully laid and sown with grass seed. This means will be amply sufficient to protect the side slopes from injury when they are not exposed to any other causes of deterioration than the wash of the rain and the action of the frost on the ordinary moisture retained by the soil. The side slopes form usually an unbroken surface from the foot to the top. But in deep excavations, and particularly in soils liable to slips, they should be formed with horizontal cuttings, termed benches or small terraces, which are made a few feet wide, and have a ditch on the inner side to receive the surface water from the portions of the side slopes above them. These benches catch and retain the earth that may fall from the portions of the side slopes above them, besides rendering slides less liable. When side slopes are not protected, it is well in localities where stone is plentiful to raise a small wall of dry stones at the foot of the slopes to prevent the waste from being carried into the roadway.

In excavating through solid rock which does not disintegrate on exposure to the atmosphere, the side slopes should be made perpendicular ; but as this would exclude to a great degree the action of the sun and air, which is essential to the keeping of the road in good order, it will be necessary to make the side slopes with an inclination varying from one foot base to one foot perpendicular, to two feet base to one foot perpendicular, according to the locality, the inclination on the south side, in northern latitude, being greater to expose better the road surface to the sun's rays.

Slaty rocks generally decompose rapidly on the surface when exposed to moisture and to the action of the frost. The side slopes in this material may be cut into steps, and then be covered with a layer of vegetable mould sown in grass seed, or else the earth may be sodded in the usual way. The soils which are liable to slip are the stratified soils, which have a dip or inclination to the horizon. These slides are caused by the action of the frost or from the pressure of the water which insinuates itself between the strata. Soils formed of alternate strata of sand or clay are of this character, particularly if the clay is of a nature to become semi-fluid when mixed with water. Drainage is the best system to adopt as a preventative in cases of this kind to stop the surface water from running down the slopes and to cut off all springs which run towards the roadway from the side slopes. A ditch constructed on the uphill side of the road will answer to cut off the surface water, as it will prevent it reaching the slope. It frequently becomes a very difficult task to secure side slopes where slides are caused by the action of springs. Drains formed of broken stones covered with good sods, laid with the grass side down to prevent the drain from becoming choked with earth, will prevent the action of water if the sources can be easily reached by excavating into the slopes. Where the sources are not isolated, and the whole mass appears saturated, the drainage may be effected by excavating trenches at intervals to a depth of a few feet into the side slopes, and filling them with broken stones, or else a general drain of broken stone may be made throughout the whole extent of the slope by excavating into it. The drain should be arranged like an ordinary retaining wall, with buttresses at intervals extending into the earth farther than the general line of the drain. In forming embankments the side slopes should not be less than one and one-half feet base to one foot perpendicular. The surface water from the top of the roadway should not be allowed to run down the sides of the hill, as it would soon cut them into gullies and destroy the embankments. To prevent, as far as possible, the settlement which takes place in fills, great care should be exercised in making them ; the earth should be laid in successive layers of about five feet in thickness, and each layer settled with heavy rammers. This method, on account of the great expense, is seldom resorted to ; but where the fill is carried out from one end, taking the work forward on a level with the top surface, there is a want of compactness in the mass, and it is better to form the outside of the embankment first, and to gradually fill in toward the centre so that the earth may arrange itself in layers with a dip from the sides inward ; this will in a great degree counteract any tendency to slip outward.

The perpetual advantage of an easy grade should be secured at the beginning. Straight lines are the best on light grades, and are also the cheapest. It is economy, however, to secure easy grades at the expense of straight lines where such grades are otherwise unobtainable, because the perpetual advantage to all users of the road more than off-sets the disadvantage to the land-owners from ill-shapen fields.

Drainage.

A road bed cannot be rendered satisfactory unless great care is taken with the drainage of the road surface and the formation of proper gutters and side ditches, and also the drainage of the road bed and adjoining lands. Where the road is to be constructed on a wet and retentive soil, a perfect system of underdraining must be provided, by cutting trenches diagonally across the road bed and discharging into the side ditches. These trenches should be from eighteen inches to two feet deep, and about one foot wide across the bottom, with a slight side slope outward. In these should be constructed porous drains composed of clean, coarse broken stone, brickbats, or some other suitable material. The trenches should be filled up to the level of the subgrade. They should be placed much closer when in loose soil. They should have a good fall and a free outlet. In