CHAPTER III.

ROAD COVERINGS.

Road Coverings, have for their object the reduction of the force of traction to the lowest practicable limit, at the least cost for construction and maintenance. They should be composed of hard, tough and durable materials, laid upon a firm bed, or upon an artificial foundation, from which water is excluded by suitable drainage.

The *basaltic*, the *doleritic* and other trap rocks, known also as green stone, the *sienitic* granites, and generally the hardest and toughest of the *feldspathic* rocks, and some of the *limestones* of the transition and carboniferous formations, furnish the most valuable road coverings, whether used in the form of rectangular blocks, or in small angular fragments, or as cobble-stones, gravel, or coarse sand. Slag from blast furnaces, and cinders and clinker from cement kilns, are also used for this purpose.

Wood in the form of blocks, or sawn into planks or slabs, is sometimes employed for the road-surface, but with little satisfaction or advantage. Its employment for foundations is sometimes expedient and even necessary in the absence of better materials.

The *covering* of most of the roads in the United States, and in all new countries, is the natural soil excavated from the side ditches and thrown into the middle of the roadway. 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.

Classification of Roads.

Country roads, as distinguished from *paved streets* in cities and towns, may be classified with respect to their coverings 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 of gravel.
8. Stone sub-pavement 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.

Earth Roads.

Earth roads necessarily possess so many defects of surface, that whatever amelioration their condition is susceptible of, by a 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 the centre toward the sides, the side

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 should 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 six inches 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 in rainy weather.

The material used in filling up ruts and hollows should be composed largely of gravel and coarse sand, free from sod, muck and mould. It should not contain cobble-stones, or larger fragments of rocks, which would form hard and unyielding lumps on one side of the wagon track, soon resulting in corresponding ruts and hollows on the other. All ruts should be filled in with good materials as soon as formed.

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, by promptly filling in the ruts, and by maintaining the required slopes from the centre toward the sides. It

will seldom be found that the material obtained by cleaning out the side-ditches is fit to put upon the roadway.

Corduroy Roads.

Straight logs of timber either round or split, if cut to suitable lengths and laid down side by side across the road way, scarcely deserve the name of road. They are nevertheless vastly superior to a soft marsh or swamp, which, in some seasons of the year, would be absolutely impassable for wheeled vehicles of any description. They are commonly known as *corduroy* roads from their ribbed character. In heavily timbered districts nearly all the logs for such a construction would be procured in clearing off the usual width of 4 rods—66 feet—prescribed for most country roads, the width of the road-covering itself, or the corduroy, being restricted to about 15 or 16 feet, so that two vehicles can pass each other upon it without interference. The logs are all cut to the same length, which should be that of the required width of the road, and in laying them down such care in selection should be exercised, as will give the smallest joints or openings between them. In order to reduce as much as possible the resistance to draught and the violence of the repeated shocks to which vehicles are subjected upon these roads, and also to render its surface practicable for draught animals, it is customary to level up between the logs with smaller pieces of the same length but split to a triangular cross-section. These are inserted with edges downward, in the open joints, so as to bring their top surfaces even with the upper sides of the large logs, or as nearly so as practicable. Upon the bed thus prepared a layer of brushwood is put, with a few inches in thickness of soil or turf on

top to keep it in place. This completes the road. The logs are laid directly upon the natural surface of the soil, those of the same or nearly the same diameter being kept together, and the top covering of soil is excavated from side-ditches. Cross drains may usually be omitted in roads of this kind, as the openings between the logs, even when laid with the utmost care, will furnish more than ample waterway, for drainage from the ditch on the upper to that on the lower side of the road. When the passage of creeks of considerable volume is to be provided for, and in localities subjected to freshets, cross-drains or culverts are made wherever necessary by the omission of two or more logs, the openings being bridged with planks, split rails or poles laid transversely to the axis of the road, and resting on cross beams notched into the logs on either side.

Plank Roads.

Plank roads were much in vogue twenty-five to thirty 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 used to turn out upon, and for travel during the dry season. The method of construction most commonly followed, is to lay down lengthwise of the road, two parallel rows of plank 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 shall not be in a line but form short offsets at intervals of 2 to 3 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 turn-out. 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.

A capital distinction 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 and river-side gravel, consisting almost entirely of water-worn and rounded pebbles of all sizes, which easily move and slide upon each other, is unsuitable for a road-covering, unless other materials be mixed with it, while pit gravel generally contains too much earthy matter. The gravel for the top layer at least, should be hard and tough, so that the wear will not pulverize it and convert it into dust and mud. It should be coarse, varying in size from

half an inch to an inch and a half in largest dimensions. It should not be water-worn, and should contain enough sandy and clayey loam to bind it together firmly.

Screening the Gravel.

Pit gravel usually contains so much earthy material that it should be screened, to render it entirely suitable for the surface layer. For this purpose two wire screens will be necessary, one with the wires 1½ to 1¾ inches apart, while in the other they should not be more than ½ to ¾ inch apart. The pebbles which do not pass the large screen are to be rejected, or if used, are broken up into smaller fragments; while the earth, small gravel, and sand that pass the smaller one, although unsuitable for the road surface, will answer for a sub-layer or bed for the road material to rest upon, or for side-walk coverings.

If the bed of the road is rock, a layer of earth should be interposed between it and the gravel, to prevent the too rapid wear of the latter.

Applying the Covering.

In ordinary soils an excavation to the depth of 10 to 12 inches, and of the required width, is made for the reception of the gravel. The surface of this excavated form, called the *sub-grade*, may be made level, or preferably, it may be arranged parallel to the finished road surface by sloping it from the centre toward the sides. A layer 4 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. The gravel will usually be carried upon the road in wheel-barrows or

carts, and adjusted to an even layer with rakes. The work may be hastened by using a cylindrical roller 2½ to 3 feet in diameter, and 5 to 6 feet long, weighing 1½ to 2 tons. A better design is to have two such cylinders arranged in a frame one behind the other, each being composed of two short cylinders 2½ to 3 feet in length, placed abreast upon the same axis. For compacting the bottom layers, and for the preliminary consolidation of the upper layers, a heavier roller cannot be used. A roller weighing from 5 to 7 tons and upwards may be used advantageously on the top layer, and if the light roller is not so constructed as to admit of loading, it would be well to have two.

The heavy roller constructed for the New York City Department of Parks, weighed six and a half tons, and could be loaded up to twelve tons. "It was composed of two hollow cylinders of cast iron, set abreast on a strong wrought-iron axle, making together a length of five feet, with a diameter of seven feet." The cylinders were set in a timber framework, and had apertures in the ends through which broken stone and gravel could be introduced into interior compartments, by means of which the aggregate weight could be increased to twelve tons. This roller is shown in Fig. 34, most of the shafts being omitted for want of space.

For making gravel roads a roller weighing 6 tons will suffice, the 12 ton roller being well adapted to the construction of broken stone or Macadam roads.

A horse road-roller designed and used in Germany is so arranged that the cylinder can be filled with water, when heavy rolling is to be done. When not in use, or when about to move from place to place the water is emptied out, and the weight materially lessened. A full description of

this roller will be found in Mr. Clemens Herschel's "Treatise on the Science of Road-making," published with the executive reports of the Commonwealth of Massachusetts for the years 1869–'70. Road-rollers propelled by steam power have been used to some extent, but no description of them is deemed necessary here.

During the consolidation of the first layer by the light roller and by the traffic over it, men with rakes should be kept engaged in filling up the ruts as fast as they are formed

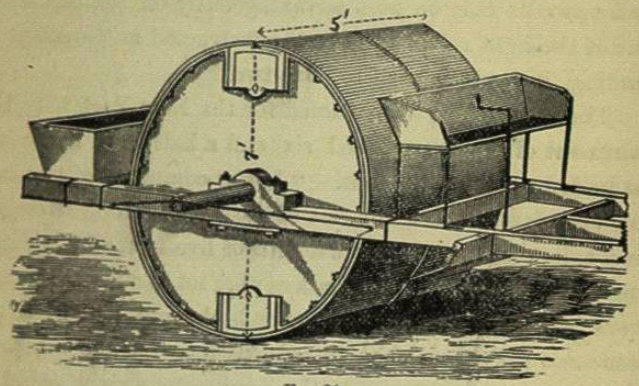

FIG. 34.

When the bottom layer is tolerably well, though not thoroughly compacted, a second layer of 3 to 4 inches is added and treated in the same manner. Successive layers follow until the road is made up to the required height and form of transverse section. The aggregate thickness of the several layers need not exceed 10 to 12 inches.

If the gravel be too dry to consolidate promptly it should be kept moist by sprinkling-carts, care being taken not to make it so wet that the earthy material will become semi-fluid and collect on the surface.

If the screened gravel of the top layer is so deficient in binding material that it will not pack firmly under the ordinary traffic on wheels, a thin layer, not exceeding one inch in depth, of sandy and gravelly loam and clay, or indurated sand and clay known as *hard pan*, or the scrapings from stone yards, should be spread over it and slightly moistened by sprinkling-carts before the rolling is begun, the light roller being invariably used first. A better practice would be to thoroughly mix the binding material with the gravel for the top layer before it is spread upon the road.

The sides of the road should be rolled first, to such 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 toward the side-gutters will be resisted. During the consolidation of the top layer the material must be kept properly moistened, and men with rakes should be in constant attendance to fill in ruts and depressions so as to give the surface the required form, and secure uniform density in the road-covering. When finished, the light coating of binding material will have been forced down several inches into the top layer, forming a kind of matrix which holds the gravel firmly in place, and provides a nearly water-tight covering for the road bed. Gravel beds generally contain a greater or less quantity of large rounded pebbles, of 5 to 8 inches in longest dimension, which if not broken up into small fragments and incorporated with the road-covering, may be advantageously employed instead of sods, for facing the inner edge of the foot-path to protect it from the wash of the side gutters, and in forming the small drain under the foot-path from the gutter to the side-ditch.

Good Gravel Roads.

A gravel road carefully constructed in the manner above described, upon soil of such sandy or gravelly character that the side-ditches will thoroughly drain the road bed to a depth at least 12 to 15 inches below the bottom of the road-covering, thereby rendering cross drains unnecessary, will possess all the essential requisites of a good road. In soils where the side-ditches will not secure good sub-drainage, cross-drains, which cost but little, should be introduced under the road covering at suitable intervals.

Inferior Gravel Roads.

Country roads made with gravel are too frequently of a very inferior kind, being formed either by simply carting pit-gravel upon the road, and dumping it into the ruts and wheel tracks, and the gutter-like depressions worn by the tread of the animals, until the middle of the roadway gradually becomes covered to a width of 8 to 8½ feet, and a depth varying from 3 to 4 inches in the centre and 6 to 10 inches under the wheels, or by constructing an ordinary earth road with a single top layer of gravel 4 to 6 inches deep and 8 to 9 feet wide along the centre, the sides or wings being finished out with ordinary soil. Wheel ruts will form rapidly on such a road, which should be promptly filled with gravel. By this means the thickness of the gravel covering will be gradually increased under the wheels to 8 and 10 inches and upward.

Macadam Roads.

Macadam roads, Fig. 35, are constructed with successive layers of broken stone, applied in a manner similar to that

above described for gravel roads. If the best quality of stone cannot be procured for the whole of the road covering, care should be taken to select the hardest and toughest stone for the upper, or preferably for the two upper layers, having an aggregate thickness of about 6 inches. The stone should be broken into fragments as nearly cubical in form as possible, the largest of which should not exceed 2½ inches in longest diagonal dimensions. For inspecting the broken stone, an iron ring 2½ inches in diameter may be used with advantage.

If the material be very tough and hard, like most of the basaltic and trap rocks and the sienitic granites, or if the traffic upon the road be light and its amount not large, the stone

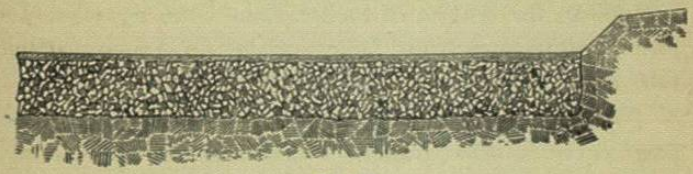

Fig. 35.

may be broken smaller, without danger of their crushing too easily or wearing too rapidly. The smaller the fragments, the less will be the volume of voids in the road covering liable to become filled with water and mud, and the sooner will the surface become hard and smooth when opened to traffic, or while being compacted with rollers.

In Macadam's matured practice upon the Bath and Bristol roads, England, he did not allow any stone above three ounces in weight (equal, with the material he had, to cubes of 1½ inches or 2 inches in their longest diagonal length) to be used. He caused splinters and thin slices and spalls to be excluded as far as possible, and laid considerable

stress upon uniformity of size, and perfect cleanliness or freedom from dust, sand, or earthy matter. The French engineers, on the contrary, are indifferent as to cleanliness, and upon their broken stone roads make use of all sizes from the dust and detritus produced in breaking, up to 1½ inch cubes, upon the assumption that the smaller particles occupy only a portion of the original void space between the larger fragments, the whole of which will sooner or later become entirely filled with dust and mud; an assertion which must be accepted in a modified sense, for it is certain that a well constructed and properly maintained Macadam road should allow, and will allow all surface water which finds its way through the crust of the road surface, to percolate freely through to the bottom of broken stone covering, where its prompt escape is provided for by suitable sub-drainage, upon soils where such a precaution is necessary.

The stone, if broken by hand hammers, will comprise fragments of all sizes, from the largest allowable dimensions, down to small particles and dust, and of various angular, prismoidal, and cubical forms.

It is not customary or necessary to screen hand-broken stone, but in loading it into the barrows or carts for transportation to the road, the detritus and most of the finer particles may be left behind by using the broad forks already described. (Fig. 32.) If the prevailing forms are angular, and of all sizes below the maximum prescribed, the fragments will unite and dovetail together more firmly and compactly than cubes, and very little if any binding material is necessary. If the smaller fragments and detritus be carefully excluded by screening, the road cannot be compacted into a smooth hard surface by rolling or by traffic.

Mr. Wm. H. Grant, Superintending Engineer of the New York Central Park, in his report upon the park roads, says, "At the commencement of the Macadam roads, the experiment was tried of rolling and compacting the stone by a strict adherence to Macadam's theory—that of carefully excluding all dirt and foreign material 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 about its practical limit) an even and regular surface, but the top layer—with the use of the heavy roller loaded to its greatest 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. No amount of rolling was sufficient to produce a thorough binding effect upon the stones, or to cause such a mechanical union and adjustment of their sides and angles together as to enable them mutually to assist each other in resisting displacement. 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 angular parts wearing away, and the weaker and smaller ones being crushed. The experiment was not pushed beyond this point. It was conclusively shown, that broken stones of the ordinary sizes, and of the very best quality for wear and durability, with the greatest care and attention to all the necessary conditions of rolling and compression, would not

consolidate in the effectual manner required for the surface of a road, *while entirely isolated from, and independent of* other substances. The utmost efforts to compress and solidify them while in this condition, after a certain limit had been reached, were unavailing."

Examination and Tests of the Stone.

In order to decide upon the fitness of any particular kind of stone for road covering, and especially when there are several kinds equally available, or so nearly so that the question of selection should be governed by the quality alone, an examination and tests of the varieties should be made, in order to determine their relative toughness, hardness, and power to resist abrasion. In some cases the difference of quality is so pronounced and so well known, that the opinion of intelligent stone-cutters of the neighborhood, who have been accustomed to work the several kinds of stone into various forms with different tools, will be sufficient to indicate their order, though not their degrees of merit, for the purposes in view. When, however, the information thus obtained is deemed inadequate or inconclusive, the examination may be continued as follows :

First. Average samples of the several stones—say a ton of each—should be collected together, and placed in separate piles in some convenient place. A practical stone-breaker should then be set to work with the ordinary stone hand-hammer, with directions to break up the material into sizes suitable for road metal, devoting an hour to each pile alternately, under the constant observation of the individual conducting the investigation. By this means the order of toughness of the several kinds of stone under examination

will be ascertained, for it is the toughness, especially when in small fragments, which enables a stone to resist fracture from the repeated blows of a blunt tool harder than itself.

Second. The power to resist abrasion, or at least the order of quality in this respect of the several kinds of stone under trial, may be ascertained by grinding them under equal pressure, upon an ordinary grindstone run by power at a uniform speed. For this purpose bars of the same size, about 2–in. by 2–in. by 6–in. should be prepared from each sample under trial, in some of which the laminæ should be parallel to the end of the block, and in others perpendicular thereto. The blocks are then tested one after the other, by putting them endwise in a long box open at the lower end and closed at top, arranged vertically over the grindstone, with its lower end nearly touching the grinding surface. The box is firmly held in this position by framework attached to the grindstone frame. In the upper end of the box, directly above the specimen, there is placed a spiral spring, which is strongly compressed upwards against the top of the box, by the insertion of the stone specimen from the lower or open end. This spring supplies the force which presses the lower end of the specimen against the grinding surface, and of course exerts an equal force upon blocks of equal length. The amounts ground in equal times from the several blocks, as determined by their lessened weight, will give the inverse order of their powers to resist abrasion.

Third. The compressive strength of the stones in small (say 2–inch) cubes, although less directly indicative of their fitness for road covering than the foregoing tests, should also be ascertained, when it is convenient to do so, as

corroborative data. With the information thus obtained it will not be difficult to make a judicious selection.

Stone-Crusher.

Blake's stone-crusher, of which a longitudinal section and a perspective view of the essential parts is shown in Figs. 36 and 37, is an excellent machine for breaking stone for concrete or for road-coverings. AA is a frame of cast iron

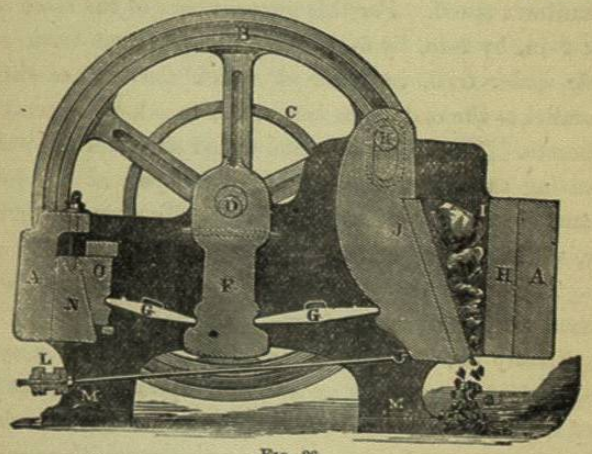

Fig. 36.

in one piece, which supports the other parts. It consists of two parallel cheeks shaded dark in the drawing, connected together by the parts AA. B represents a fly wheel working on a shaft having its bearings at D, and formed into a crank between the bearings. It carries a pulley C, which receives a belt from a steam engine. F is a rod or pitman connecting the crank with the toggles GG. The end of the frame A, on the right of the figure, supports a fixed jaw H against which the stones are crushed. J is the movable

jaw pivoted at K. L is a spring of India rubber which being compressed at each forward movement of the jaw J, aids its return. Every revolution of the crank causes the pitman F to rise and fall, and the movable jaw to advance a short distance toward the fixed jaw and return, so that a stone dropped in between the jaws J and H, will be broken

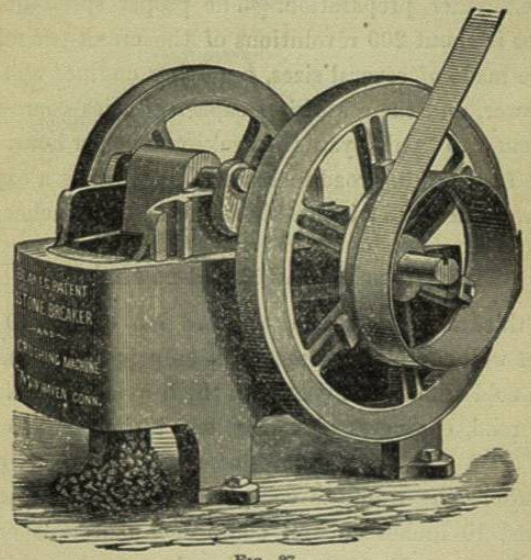

Fig. 37.

at the next succeeding bite. The fragments will then fall lower down and be broken again and again at each revolution until they pass out at the bottom. The bottom of the opening between the jaws may be set so as to deliver any required size of broken stone, by suitably adjusting the wedge N, inserted against the toggle block O. The crushed stone passes from the machine directly into a revolving cylindrical screen, inclined to the horizon, the meshes of which are

small at the upper end, and of medium size, or about 2½ to 2¾ inches square in the middle and lower portion. The dust and small particles pass through the meshes in the upper end, while the large fragments which issue out of the lower end of the cylinder, are returned to the machine to be broken again. The rest is suitable for road-covering without any further preparation. The proper speed of these machines is about 200 revolutions of the crank per minute. They are made of several sizes, requiring engines of 4 to 12 horse power, and their working capacity varies correspondingly from 3 to 7 cubic yards of broken stone per hour. The best size for breaking road material is one having a capacity to receive stones 8 to 9 inches thick and 14 to 15 inches wide.

Thickness of the Road-covering.

The thickness of the covering need not exceed 10 or 11 inches of well consolidated materials on a good road bed, for roads in cold climates subjected to the heaviest traffic. The French road engineers consider ten inches sufficient in France, upon the most important roads, and 6, 7, and 8 inches where the traffic is comparatively light. Macadam considered 10 inches of well compacted materials enough for very heavy traffic, and generally advocates less thickness than most English constructors. Six inches for the minimum and ten for the maximum thickness appear to have been his limits. In one instance he speaks of a road which "having been allowed to wear down to only three inches, this was found sufficient to prevent the water from penetrating, and thus to escape any injury from frost," and in another, states that "some new roads of six inches in depth were not at all affected by a very severe winter."

Applying the Road-covering.

The drainage of the road bed having been provided for by side-ditches, and if necessary by suitable cross-drains, an excavation is then made to the sub-grade for the reception of the road materials, sloping from the middle toward the sides the same as the finished road surface, the depth of the excavation being regulated by the thickness adopted for the covering. It would be well, especially in made ground to consolidate the bed by rollers, or by ramming.

A layer of broken stone three inches in thickness is then applied, care being taken, if dumped from carts or barrows, to spread it evenly with a rake. The road is then opened to travel in order that it may be compacted before the addition of more stone. This operation may be greatly hastened by rolling, beginning with the light and ending with the heavy roller. If the road bed be soft and yielding, whether naturally so at all times, or exceptionally so from recent rains, it may be necessary to omit using the heavy roller, for fear of forcing the bottom stone down into the soil.

Ruts must be carefully raked in as fast as they are formed. Experience has demonstrated that 3, or at most 4 inches of broken stone, is the greatest thickness that can be well compacted at one time.

The "Wings" of Country Roads.

As it will seldom be necessary, except near large towns and cities, to apply the broken stone over a greater width than 16 feet, pit gravel, or sandy or gravelly earth may be used for extending the layer over the "wings.' This should be laid on and consolidated at the same time with the broken