THE CENTURY MAGAZINE.

VOL. XLIII. APRIL, 1892. No. 6.

OUR COMMON ROADS.

THAT the condition of the common road has much to do with the prosperity of both town and country; that it enriches the farmer, and raises him socially, commercially, and financially; that it widens his influence, contributes to the happiness of his family, and brings him in touch with all the improving and civilizing influences of the busier world, there can be no manner of doubt. We are spending, in this country, $140,000,000 every year for the maintenance of our common schools. Official statistics show that an average of more than thirty per cent. of the pupils are absent from school on every school-day of the year, and that of these absentees by far the larger proportion is made up of our farmers' children. To every one acquainted with the difficulties of traveling the ordinary country road, especially during the wet weather of spring and fall, the reason for this immense falling off in attendance at the public schools will be clearly traceable to the impassable state of the farmers' highway; and thousands of farmers in all parts of the country will testify that they frequently are compelled, by this unfortunate condition, to send their children to inferior schools, which have little to recommend them except mere convenience of location, while a better condition of the roads would enable them to give their children the advantages of more thorough schooling. At every political election, too, the question of the common roads plays an important part; and results have repeatedly established the fact that a heavy rain-storm occurring just before a general-election day will reduce the aggregate vote in many of our States to so great an extent as to prevent an expression of the popular will. It is by no means an agreeable comment on the institutions of a great nation to say that the success or failure of an important political principle, or the approval or condemnation of a carefully devised policy of government, may depend in so large a degree upon the weather.

We have in the United States something like 16,000,000 of horses and mules above the age of two years upon our farms, and at the moderate estimate of 25 cents as the cost of feed and care of each of these animals, we see at a glance that the aggregate expense of maintaining them is about $4,000,000 per day. If, by a similarly moderate estimate, we say that they are kept in the stable in a condition of enforced idleness by the deep mud of spring and fall for a period averaging 20 days in each year, we may easily compute that the loss, in this respect alone, will amount to $80,000,000 per year, a sum sufficient to build 16,000 miles of excellent highway. Of course, considering the great variety of conditions, and the consequent number of factors to be regarded, it is impossible by mathematical formula to compute the loss entailed on any community by the continued toleration of these dirt roads in their present condition; but the error in the result of any computation is more likely to show a loss smaller than actually exists, and in whatever way the matter be regarded, it is certain that with the imposed burden of extra help and extra draft-animals, lost time, wear and tear of wagons and harness, the drawing of light loads, and the depreciated value of farm-lands, we are pursuing

a short-sighted policy in permitting the present system to continue. Besides the actual loss, which a moment's reflection will serve to show, we are gaining nothing and saving nothing in that great department of agricultural industry to which the condition of the dirt road is of such marked importance.

By dwellers in cities the actual condition of these country roads during the wet season is scarcely known; while with farmers, to whom all roads are dirt roads, and who have never seen nor known of a highway better than that which they have used from boyhood, the dirt road is an accepted fixture, which long habit and use have impressed upon them as a natural and necessary adjunct to farm life. On this page appears an illustration showing an actual scene on an important road in northern Ohio in the spring of 1891. It is similar in every essential respect to a thousand other views which might have been taken in that region during the same month, and, indeed, not unlike a countless number of scenes which occurred in most parts of the United States in the spring of that year. Farmers were everywhere mud-bound, traffic was suspended, and even the outlying districts and suburban streets of important towns took on the stagnant condition of remote farms, and suspended all forms of wheel traffic for weeks at a time. In the State of New York the country newspapers were printing long editorial complaints of the hopeless condition of the rural highways, and the consequent paralysis of country trade, while commercial reports were published from week to week in which business embarrassments and failures were charged directly to the impassable condition of the country roads. Half-loaded farm-wagons were stalled in deep mud almost in the shadow of the magnificent twenty-million-dollar Capitol at Albany, while, as if to show to what ridiculous ends the perversity of the human mind will sometimes lead us, the good farmers of Albany County were actually sending telegrams to the legislature, asking for the adjournment of a committee hearing, because the roads of Albany County were too bad to permit them to get to town in time to oppose a bill which promised to make them better!

DRAWN BY HARRY FENN. ENGRAVED BY P. AITKEN.

THE FARMERS' SLOUGH.

(THE MAIN ROAD BETWEEN CLEVELAND AND WARRENVILLE, OHIO, ABOUT TWO MILES FROM CLEVELAND CITY LIMITS, APRIL 7, 1891.)[1]

But aside from the social and political features of this question, and the direct bearing which it has upon the personal income, expense, and economy of the farmer, a bad road increases the first cost of produce — an increase which tends to enhance the price paid by every consumer; and this consideration, if no other, brings the road question home to every reader. On the day of this writing the people of the city of New York are paying $1.10 per hundred pounds for baled hay which fifteen days ago was selling for 80 cents per hundred in the same market. This increase of price represents

[1] All the pictures in this article, with the exception of the diagrams, are after photographs from nature.

DRAWN BY HARRY FENN. ENGRAVED BY A. NEGRI.

VIEW ON HUNTING PARK AVENUE, PHILADELPHIA, ABOUT FOUR MILES FROM THE CITY HALL, FEBRUARY 23, 1891.

nothing to the farmer, who during the last fifteen days has had no connection with the local market by reason of the deep mud in the country roads. It simply represents an added profit of about 37 per cent. to the middleman or speculator, who, following the unbending rule of supply and demand, trades upon the helplessness of the consumer in a market where he is unhampered by competition.

How long should this costly and paralyzing condition be permitted to continue? Measured by every rule of economy, public or private, these common roads of the United States are not only the worst in the civilized world, but in labor and money we are spending more to carry on a "system" of inefficient and shiftless maintenance than would be sufficient to keep in proper repair double the length of high-class roads under the methods pursued by France, Italy, and other European states. In our struggle for road reform we are following in the footsteps and repeating the history of European nations, where, in the beginning, the same objections were urged, and the same obstacles interposed, which meet the later-day American who is engaging in the same good work. A writer of early English history, referring to the difficulties of agriculture, says:

Roads were so bad, and the chain of home trade so feeble, that there was often scarcity of grain in one part and plenty in another part of the same kingdom. Export by sea or river to some foreign market was, in many cases, more easy than the carriage of corn from one market to another within the country. The frequency of local dearths and the diversity and fluctuation of prices were thus extreme. It was out of this general situation that the first corn-laws arose, and they appear to have been wholly directed toward lowering the price of corn. Exportation was prohibited, and home merchandise in grain was in no repute or toleration.

Writing of a later period, Macaulay makes graphic reference to the difficulties of travel upon English country roads at a time when the English farmers indulged in the same periodical diversion of "working out" their road taxes that is provided for in the antiquated American statutes which we still keep in force for the maintenance of our own highways. He states that in rainy weather the English coaches of that day were compelled to travel along roads which, for miles in succession, were little better than quagmires, and it is said to have been a matter of common occurrence for an English coach to become hopelessly mired in a slough on the public road, and to remain there until

lifted out by the aid of a yoke of cattle from some neighboring farm. Not so are the English roads of to-day. By experiment, and by the better light of experience, the English people and their neighbors all over the European continent have learned that true economy in the construction and repair of the common roads, as in the construction and repair of the great railroads, consists in the scientific making and the systematic maintenance of these roads according to fixed rules, and under the direction of an intelligent head.

In the perfection of this enlightened system it is probable that France leads the world. Although her area is only about four times as great as that of the State of New York, France has spent about $600,000,000 in the construction of her common roads, and now annually spends about $18,000,000, or three per cent. of the first cost, in keeping them in repair. France has eighty-seven departments, answering somewhat to our counties, and within these are various forms of local governments bearing some resemblance to that generally adopted in our cities and towns. The Government maintains a large body of trained engineers in its special department of roads and bridges, to whom is intrusted the practical work of constructing and repairing the common roads. These comprise: first, national roads, which generally cross several departments, connecting important cities and towns; and secondly, departmental roads, which connect the chief cities and towns within the department. The less important roads are still further classified and divided; but the roads within a department are under charge of an engineer-in-chief, whose directions to his corps of subordinate superintendents and overseers must be implicitly followed. No part of the road system of France escapes attention, and every road is subdivided into sections varying in length according to its importance, each section being placed in charge of a man who is held responsible for the constant excellence of its condition. Referring to the economic worth of these roads to the French government, Mr. Francis B. Loomis, commercial agent at St. Etienne, makes report to our Department of State, within the last year, as follows:

DRAWN BY MALCOLM FRASER.

VILLAGE STREET, SOUTHPORT, CONNECTICUT, WITHIN ONE THIRD OF A MILE OF RAILROAD STATION, APRIL 13, 1891.

The road system of France has been of far greater value to the country as a means of raising the value of lands, and of putting the small peasant proprietors in easy communication with their markets, than have the railways. It is the opinion of well-informed Frenchmen, who have made a practical study of economic problems, that the superb roads of France have been one

DRAWN BY HARRY FENN.

SUBURBAN DESOLATION.

(WAGONS ABANDONED IN DEEP MUD NEAR INTERSECTION OF OGDEN AVENUE AND 22D STREET, CHICAGO, APRIL 6, 1891.)

of the most steady and potent contributions to the material development and marvelous financial elasticity of the country. The far-reaching and splendidly maintained road system has distinctly favored the success of the small landed proprietors, and in their prosperity, and the ensuing distribution of wealth, lies the key to the secret of the wonderful financial vitality and solid prosperity of the French nation.

In a similar report to the home Government, United States Consul Oscar F. Williams, writing from Havre under date of May 29, 1891, says:

Every freighting- and market-cart here is a road-maker. Its tire is from three to ten inches in width, usually from four to six, and so rolls the road. With the few four-wheeled vehicles used, the tires are rarely less than six inches, and the rear axle is about fourteen inches longer than the fore, so that the rear or hind wheels run in a line about an inch outside of the line rolled by the fore wheels: thus, with a six-inch tire two feet of road width is well rolled by every passing wagon. The varied gauge is also usually observed with cabs, hacks, and other four-wheeled vehicles, so that they become road-makers instead of rut-makers, as in our country. The cost of highway transportation over the properly built roads of France does not exceed one third the like expense in the United States, it being common in the rural districts of France to haul three tons, and in the cities from three to five tons, freight net with one horse.

Differing somewhat in manner of construction from the best roads of France, but still in many respects admirable examples of road-construction, are the important roads of Norway, of which the great highway extending from Christiania to Leirdalsören is conspicuously prominent. This highway is about one hundred and fifty miles long, has a stone foundation, and is thoroughly underdrained — a precaution adopted in the construction of all first-class roads, and uniformly followed by the road-builders, of Europe. For the greater part of the distance this road winds through the mountains of Norway, and in many places great masses of rock have been blasted out along the edge of the river or mountain stream (there is always a river) to make space for the construction of the road. The road-surface is composed of a fine, gritty material, which might be called "pin gravel," combined with a smaller proportion of clay, which seems to serve as an efficient binding material, and, when finished, possesses peculiarly elastic properties, which

DRAWN BY MALCOLM FRASER.

BREAKING STONE FOR THE COUNTRY ROAD.
(A FAMILIAR ROADSIDE SCENE IN GERMANY.)

forbid the presence of any kind of jarring and give to the rider a delightful sensation resembling that which might be felt by a person traveling over a surface of velvet.

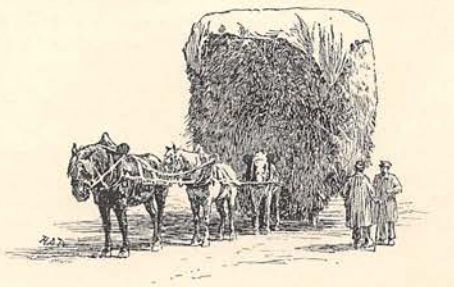
Contrived and maintained under systems bearing much likeness to that of the French government, the roads of Italy, Switzerland, Austria, and some of the German states are but little inferior in quality to, even though less extended than, the roads of France; and, indeed, in every country where the hand of the government has been directed to the making and keeping of the main roads, there seems to have followed an effort at emulation by the local authorities which has led to the similar improvement of the branch roads, and finally to the welding together of all the systems for mutual benefit.

Have we no excellent roads in the United States? Yes: many miles in the aggregate; but in comparison with the immense mileage of important highways which are substantially neglected, and left in a condition unfit for traffic, our good roads are but oases in the great desert of mudways which covers the face of the country. The suburban districts of Boston, the new roads of Union and Essex counties, New Jersey, the celebrated pikes of Kentucky and Tennessee, and the highways of a few other localities, might receive honorable mention in the history of our practical pioneer work; but the failure of the National and State governments to take the lead in a general movement for better roads, and the consequent discouragement of a general engineering knowledge of the maintenance and repair of common roads, have led to the neglect, and in some cases to the actual disintegration, of roads which were well constructed and intended to last through many generations. The need of a law by which the main roads may be reconstructed and cared for by the State governments is every day becoming more clearly apparent.

HOW ROADS SHOULD BE MADE.

If you take four pieces of white paper, each having a superficial area equal to about one twentieth of the printed portion of this page, and place them on a hard floor, locating one at each corner of an imaginary rectangle about four feet and a half by six feet in size, they will represent in dimension and relative location the four points of contact upon which the wheels of an ordinary farm-wagon will rest, if made to stand upon the same floor, while each piece of paper will also show, with tolerable accuracy, the entire area of actual contact between the wheel and a hard road-surface in good condition. Here, then, is a foundation of eight square inches or less upon which must be rolled across the country a load varying anywhere from five hundred pounds to ten gross tons in weight; and it is obvious that the mechanical advantages of the wheel can be profitably brought into play only by preserving these points of contact, or tangent points, at their minimum size. Of course, to maintain even a quiescent load of several tons upon so slight a foundation without settling would require a well-made and substantial foundation; but when it is remembered that the foundation is a moving one, and that in its transit along the public highway it is made to carry a rolling, jolting, and pounding burden of perhaps several tons, it is all the more clear that the foundation — to wit, the road-bed and -surface — should be of a smooth and unyielding kind. When, by reason of an excessive load, or the inferior condition of the roadway, the wheel is pressed into the surface of the road, the point of contact is enlarged in proportion to the depth of the depression, and this enlargement continues until the wheel is half submerged; but whether it be great or slight, every increase of the surface of contact involves a corresponding increase of the power required to move the loaded vehicle.

To this fact is mainly due the superior tractive qualities of the Macadam or Telford surface over that of the ordinary dirt road. If the



DRAWN BY H. D. NICHOLS, AFTER A PHOTOGRAPH BY ARTHUR C. COLLINS.

A LOAD OF HAY IN NORMANDY.

wheels of a loaded wagon be made to roll over a hard Macadam surface in direction from M to N, as shown in fig. 1, the force required to move the wagon is manifestly small, depending for its amount principally upon the weight of

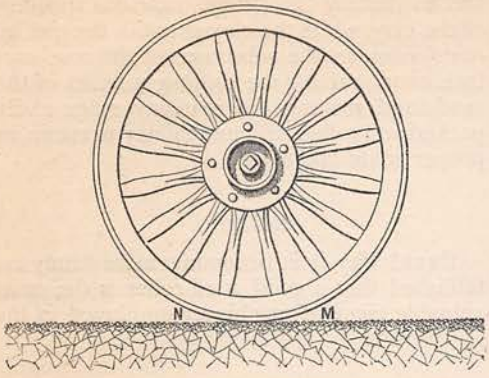


FIG. 1. SHOWING WAGON-WHEEL SUSTAINED AT SINGLE POINT OF CONTACT ON HARD, SMOOTH SURFACE OF COMPACT MACADAM OR TELFORD ROAD.

the load and the hardness and smoothness of the road-surface. But if the same loaded wagon be moved over the surface of an ordinary dirt road, as in the direction of the arrow shown in fig. 2, the weight of the load and wagon will, in most cases, cause a depression of the surface beneath each wheel, by which a continual obstruction is formed at N′ to impede the forward movement of the wagon. Thus a greater amount of power is necessary to draw the wagon, and its computation is made complex and difficult.

Many soils are possessed of elastic qualities, and these are sometimes deemed to be of advantage; but in point of economy in the use of power they are not to be considered in comparison with the Macadam surface, for no dirt surface, however elastic, will rise and give back to the passing wheel (as at M′ in fig. 2) the same force which it destroys by the obstructing qualities which it offers to the forward movement of the vehicle.

In all that is hereafter written, then, let it be remembered that hardness and smoothness of surface are two prime qualities in every good highway, and that the insistence of the writer upon thorough drainage, which prevents the softening of the road by rain and flood, and upon thorough rolling, which insures the hardening results of continued pressure, is due to the importance of these qualities of smoothness and hardness in the maintenance of every high-class road.

Of course within the necessary limits of this article no elaborate treatment of the technical side of road-making can be attempted; but avoiding reference, as far as possible, to those methods and details about which road-builders radically disagree, the writer will attempt to set forth briefly a few time-proved directions which may safely be followed in ordinary cases where the construction or improvement of a road is undertaken.

DIRT ROADS.

By this term is meant those roads which are formed of the natural soil found in the line of the roadway. They are so common as to be almost our only roads outside of town and city limits, and will for many years be used largely in country districts, and especially on the lines of cross-roads which connect the main highways. Dirt roads, at their best, are greatly inferior to Macadam and Telford roads in every essential of a good highway; in durability, cost of maintenance, drainage, tractive qualities, and, in many locations, in point of economy also. But the dirt road is here, and the public hand must be directed to its treatment. The first and most important thing necessary for the maintenance of a dirt road may be stated in a single word—*drainage*. It is the one thing that can neither be dispensed with nor neglected. Most dirt is soluble, and is easily displaced under the softening influence of rain, and this process is hastened in the dirt road by the passing of heavy wagons over the wet surface. On every mile of roadway within the United States there falls each year an average of 27,000 tons of water—a heavy, limpid fluid, always directing itself to the nearest outlet and seeking the lowest level. Water is hard to confine and easy to release, and yet, through sheer neglect of the simplest principles of drainage, water is the most active destroyer of our country roads.

In providing for the drainage of a dirt road we should first consider the material of which

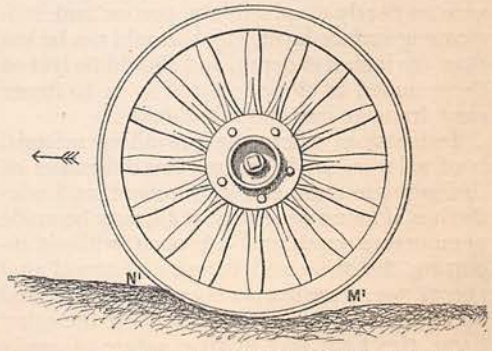


FIG. 2. SHOWING WAGON-WHEEL PRESSED INTO THE SURFACE OF A DIRT ROAD, ENLARGING THE AREA OF CONTACT AND IMPEDING THE FORWARD MOVEMENT OF THE VEHICLE.

the roadway is composed. If a heavy, viscous clay predominates, the ordinary side-ditches should be of good depth, and will even then,

in many cases, be inadequate for thorough drainage without the addition of a center-drain running midway between, and parallel with, the side-ditches. The center-drain should of course be filled with loose irregular boulders, cobble-stones, broken bricks, or similar filling, covering a line of tiles or fascines at the bottom, and should be connected with the side-ditches by cross-drains carrying the water outward from the center-drain at proper intervals along the length of the roadway. These center- and cross-drains, and, indeed, the side-ditches also, may be made cheaply after the manner shown in the cross-sections, figs. 5 and 6 on page 812. Center-drains, though often greatly needed for the improvement of country roads, are not in common use. They add somewhat to the cost of the roadway, but, in most cases, considerably more to its value, and should be employed in all situations where sand or gravel cannot be had to relieve the heaviness and water-holding properties of the clay. If gravel, sand, or other porous material can be conveniently or cheaply obtained, the center- and cross-drains may often be dispensed with by mixing the gravel or sand in plentiful quantities with the clay roadway, so as to insure as nearly as possible a porous and self-draining surface-layer, which should not be less than ten inches in depth, and should be laid on the rounded or sloped subsoil so as to insure easy drainage into the side-ditches.

In locations where the prevailing material is of a loose, sandy nature, the difficulties of drainage are more easily overcome, and side-ditches, if found necessary at all, may be made of moderate depth and left open, without incurring the risks and dangers of travel that prevail where the deeper open ditches are used for draining heavier soils. But, on the other hand, the light and shifting nature of sandy road-material destroys its value as a surface layer for an earth roadway, and its deficiency in this respect is most easily remedied by the addition of a stronger and more tenacious substance, such as stiff clay. When mixed with sand in proper proportions (which in each case depend upon the nature of the clay and sand used, and which can best be determined by experiment), this composition affords many advantages which make it superior to a roadway composed of either sand or clay when used alone. The sand serves to quicken the drainage and to destroy the sticky, tenacious qualities of the clay, while the clay supplies the quality of cohesion in the substance of the road-surface, counteracting the shifting qualities of the sand, and making the roadway more easily packed and rolled, and more likely to retain its proper grade and slope.

ROLLING.

EVERY day it is becoming more firmly established that a good road-roller is the most valuable piece of machinery employed in the road-maker's art; and indeed, without it, neither can the foundation or subsoil of the roadway be made uniformly hard and reliable, nor the surface-layer be given that uniform compactness and solidity which give excellence to the road and insure a perpetual economy in the cost of maintenance and repairs. To one who has seen a heavy road-roller used in compacting the soil of a new roadway these facts will be very evident. If a length of one thousand yards in an ordinary earth road be cut to an exact and uniform grade one foot below the original surface of the road, it will be found in most cases that the new surface thus exposed will present an appearance which, to the ordinary observer, is of a uniform material and even hardness from end to end: but the passage of a roller weighing from ten to fifteen tons over this new surface will soon disclose defects and soft spots located at irregular intervals throughout the length of the work; and as the process of rolling continues, the uniformity of the grade will disappear, and what at first appeared to be a tolerably satisfactory surface will develop into a succession of humps, holes, and undulations. In the using of the roller in actual work these depressions and soft spots are carefully filled

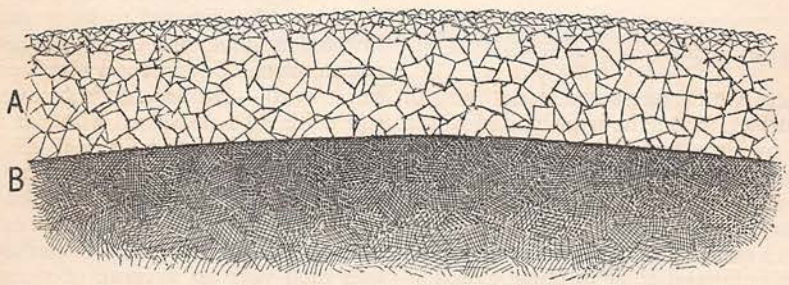


FIG. 3. CROSS-SECTION OF MACADAM ROADWAY LAID ON COMPACT EARTH, AND MADE SOLID AND PERMANENT BY HEAVY ROLLING.

and brought to the line of the required grade, while the successive passing of the heavy roller over the filling gives to the entire road that form and consistency which are so essential to every good highway. It is true that heavy rollers are rarely used in the construction or improvement of dirt roads; but this is owing as much to a lack of knowledge of the real value of a good roller as to the apparently formidable outlay involved in its first cost. All dirt roads become hard and passable by the use of a roller. Every wagon-wheel acts as a roller upon the road-surface, and the value of its rolling qualities depends upon the width of the wheel-tires and the load which the wheel sustains; but the wagon-wheel is generally made so narrow as to create ruts in many cases, and its use always tends to develop the weak spots, humps, holes, and undulations which are so quickly revealed in the use of the regular roller. Moreover, the county authorities in the fact that a good road-roller, when not profitably employed upon the higher-class Macadam or Telford roads, may often be made to serve with value and economy in the improvement of adjacent dirt roads. In the grading of a dirt road the work may generally be cheapened and improved by employing one of the various forms of "road-machines" which have come into use within the last few years. In its common form this machine is provided with an adjustable steel-shod blade which cuts, scrapes, and forms the earth to the desired grade, and, when drawn by one or two teams, generally performs its work in a commendable and satisfactory way.

MACADAM ROADS.

In the construction of a Macadam road the experience of a century has warranted modern

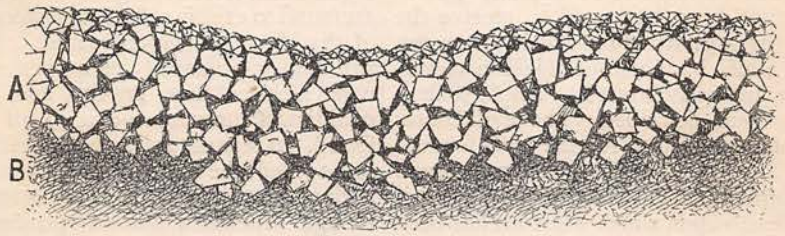


FIG. 4. CROSS-SECTION SHOWING WASTEFUL USE OF MACADAM MATERIAL.

rolling qualities exerted by the wheels of passing traffic are never bestowed uniformly upon the entire width of the roadway, but are confined throughout the length of most country roads to the two narrow lines of travel which marked the tracks of the wheels of the first passing vehicle, and which seem to have been followed with scrupulous care by all the vehicles which came after. The result is that the roadway on both sides of these beaten tracks is often left in a soft, muddy, or rutty condition, and when two heavily loaded vehicles are compelled to pass each other, the necessity of turning out results in a break-down, or in the delay and difficulty which are familiar to every farmer just in proportion to the number of times that he has been stuck in the mud by reason of the conditions here described. The writer has made mention here of the value and use of a road-roller in connection with the maintenance of the ordinary dirt road, not with the belief that expensive road-rollers will be purchased for use solely upon the dirt roads in our country districts, but rather because it is believed that in the near future every progressive county will make use of the road-roller in the making and keeping of its important roads and streets, and that a hint given here may serve to instruct road-builders in departing somewhat from the rules which Macadam believed to be imperative; but in its prominent features the Macadam road, properly so called, is to-day not unlike that built by its original maker. The first consideration to be looked after in the construction of a Macadam road is the probable traffic, and consequent wear and tear, to which the road will be subjected. Macadam roads are by no means the best in locations where heavy traffic is to be provided for, and are generally inferior to the Telford road for reasons which may presently appear. But Macadam roads, when made with care, are infinitely superior to the ordinary dirt roads, and are most excellently adapted to suburban localities where the travel is not too heavy, and where the earth bottom can be made firm and compact. It is not uncommon in some of our States to find the idea prevalent with town authorities that the purchase of a stone-crusher, and the turning out of a large mass of broken stone which can be dumped in irregular quantities along the length of a country road, to be leveled and worn down by passing traffic, will result in the formation of a Macadam road, and such a process is sometimes miscalled macadamizing. To say nothing of the false economy generally en-

tailed by such a process, it may be asserted to be not only wholly unlike the method of road improvement which Macadam instituted, but it is in direct violation of the principles upon which he most strongly insisted.

The evil results of this shiftless and unsystematic use of broken stone may not only be seen in the long and toilsome process of rolling this material into passable shape by the wheels of wagon traffic, but it involves questions of economy in the use of material, and in the permanency of the road itself, which ought to be considered. In fig. 3, page 810, the writer has attempted to show the permanent form of cross-section which a well-laid and well-kept Macadam road will always retain. The earth foundation B, having first been consolidated by the use of a heavy roller passed over its surface many times in preparing it for the stone, and having also been shaped into a convex cross-section so as to insure the quick drainage of such water as may find its way through the upper surface, is well adapted to receive the stones of the superstructure which are shown at A, and which have also been laid in successive layers and consolidated by ample rolling, as is elsewhere described. The evil consequences of neglecting to roll the earth foundation, and to give it the proper form to insure drainage, are illustrated in fig. 4, in which B is again the earth upon which the stone has been laid. The dumping of loose stone upon the soft and flattened earth foundation in this case invites disaster in many ways. In the first place, the loose, open texture of the superstructure readily admits the water of rain and melting snow, and this water, passing quickly through the sieve-like material, still further softens the earth beneath. Then the weight of the stones themselves, added to that of heavy wagons which pass over the road, serves to press the loose, angular stones down into the soft earth beneath, while the dirt itself seems to permeate the body of the stone, and eventually to find its way to the surface, where it forms into puddles and hastens the disintegration of the entire structure. In this condition the passing of loaded wagons for a considerable time results in the disappearance of the Macadam stone into the soft dirt, and in such cases it too often happens that the remedy attempted results in the adding of new material in the same neglectful and slovenly way as marked the putting down of the first. The writer feels confident in saying that he can point out sections of Macadam highways in the United States where, by the wasteful process just described, enough stone has been sunk into the earth foundation of the road-bed to serve in the building of six times the same length of excellent Macadam road.

FIG. 5. CROSS-SECTION OF FILLED DRAIN WITH TILE BOTTOM.

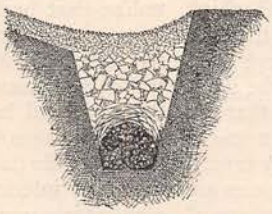
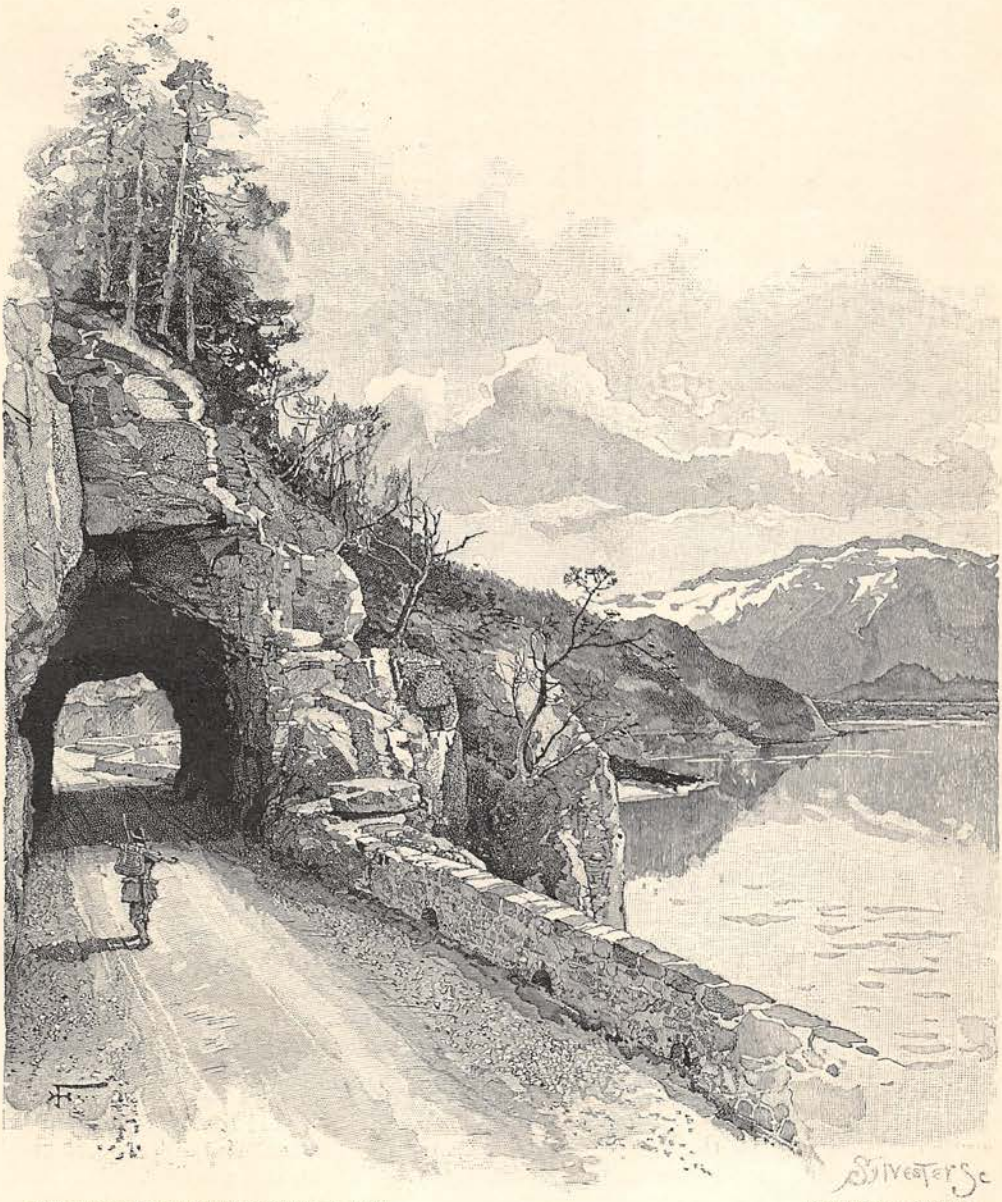


FIG. 6. CROSS-SECTION OF FILLED DRAIN WITH FASCINES AT BOTTOM.

In the proper construction of a Macadam road, then, rolling of the earth foundation is of prime importance, and it is essential also to give to the earth foundation a cross-section having a convex form, so as to quicken its draining qualities. The necessity for this rolling process may easily be gathered from what has been here written under the head of dirt roads, and the same reasons which have been urged in favor of rolling the earth foundation are found to exist in rolling the layers or courses of the Macadam superstructure. This superstructure is principally of broken stone, hard rock such as flint, granite, and the better qualities of limestone being in all cases preferred. In regard to size, the largest admissible stone should be small enough to pass through a ring two and one half inches in diameter, though Macadam himself specifies that the largest stone in this road should be determined by weight, and seemed to prefer a somewhat smaller stone as the maximum to be used. Theoretically, the stones of the Macadam road should be as nearly cubical in shape as possible, as indicated in fig. 10, where the largest of the three rough cube-shaped stones represents about the maximum size to be used in Macadam construction, and in the upper course of Telford roads, to which reference will be made elsewhere.

In a Macadam road the thickness of the road-covering need not in any case exceed nine or ten inches when completed, and in many locations, where the road has been subjected only to light traffic, even six inches have been found sufficient. Stone roads somewhat resembling the Macadam in form, and having a thickness of only six inches, are by no means uncommon in France, and have been successfully used in some of our New England States. Macadam mentions one case in which he declares that the road had been allowed to wear down to a thickness of only three inches, and that "this was found sufficient to prevent the water from penetrating, and thus to escape any injury from frost." It thus appears, as it will appear in all cases, that the efficiency of the



DRAWN BY HARRY FENN, AFTER A PHOTOGRAPH BY F. A. ELWELL. ENGRAVED BY H. E. SYLVESTER.

SCENE ALONG THE LAKE OF THUN, SWITZERLAND.

Macadam road, beyond a certain limit, does not depend so much upon the amount of material used in its construction as upon the manner in which that material is applied.

Drainage of Macadam roads, as of all roads, must be provided for, and the question of drainage admits of such extended scope in its treatment that it can be attempted here only in the briefest way. Suitable side-ditches should in all cases be provided, and center- and cross-drains may profitably be added wherever heavy water-holding clays and similar soils present the same conditions as have been referred to in recommending drainage of ordinary dirt roads. But some of the objections and dangers of open side-ditching have already been pointed out, and in the construction of Macadam and Telford roads it is infinitely better to avoid their use as much as possible. This can be done in many situations by substituting covered drains upon each side of the roadway; and these covered drains may be made in a variety of ways, depending for their cheapness and ease of construction upon the mate-

DRAWN BY H. D. NICHOLS. ENGRAVED BY J. H. E. WHITNEY.

MATTAPAN STREET, MILTON, MASSACHUSETTS, SEVEN MILES FROM BOSTON.

rials most conveniently at hand, and upon the ingenuity of the road-maker. Two forms in common use are shown in figs. 5 and 6.

In fig. 5 there appears in the shaded outline the ordinary form of an open ditch as constructed in stiff soils, where the sides may be cut with a steep incline without danger of caving in. The ditch so opened is made with a longitudinal grade at the bottom, corresponding with more or less exactness to the grade of the road-surface. Upon the graded bottom of the ditch is laid a succession of planks or flat stones, and upon this is placed a line of ordinary U tiling with ends set close together, so as to prevent, as much as possible, the introduction of foreign substances into the waterway of the tile. The tiling is then covered with straw, hay, coarse marsh-grass, or similar substance, still further to protect it from the introduction of dirt, and the ditch is afterward filled nearly to the top with coarse, irregular-shaped stones of various sizes, the work being completed by the addition of finer stones and sharp gravel, so laid as to invite the free passage of water from above. As these side-drains are generally located at about the lowest point in the cross-section of the finished roadway, the covering layer of the drain should be given a concave or gutter-shaped section as shown in the illustrations, so as to hold the water which runs off from the roadway and to carry it along in the line of the surface grade, depositing in adjacent culverts or watercourses such portions of the surface-water as fail to become absorbed by the porous material of the side-drains. Whenever it appears that natural waterways, culverts, or other artificial outlets occur at frequent intervals along the roadway, the expense of side-ditches and drains may be entirely saved by simply forming a concave-paved gutter, as shown in fig. 7, along which the surface-water may be carried by a proper grade to the nearest outlet; but in this form of construction it is essential that the earth foundation be properly shaped and rolled hard before the Macadam material is put on, and that the latter should be finished with great compactness, so as to resist the introduction of water, and the consequent softening of the earth foundation which is likely to follow. Fig. 6 represents another and somewhat cheaper form of side-drain, in which fascines are bound together in separate bundles and laid along the bottom of the drain, instead of the tiling. The fascines are covered with straw and coarse, porous material in the same manner as was shown in the description of fig. 5. Flat

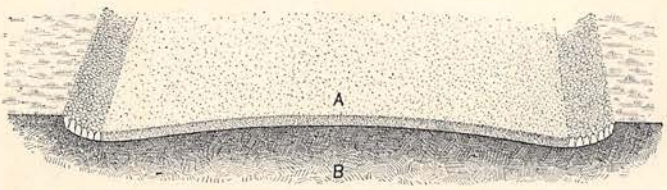


FIG. 7. CROSS-SECTION AND TOP VIEW OF COMPLETED MACADAM ROAD WITH PAVED SURFACE-GUTTERS AT SIDES.

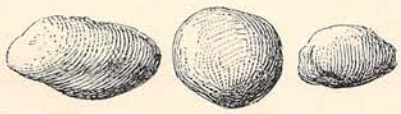


FIG. 8. ROUNDED PEBBLES AND SMALL COBBLESTONES TO BE CAREFULLY EXCLUDED FROM ALL MACADAM AND TELFORD ROAD-MATERIALS.

FIG. 9. SHOWING FORM AND SIZES OF STONE CHIPS COMMONLY USED FOR THE TOP LAYER IN CONSTRUCTION OF MACADAM AND TELFORD ROADS.

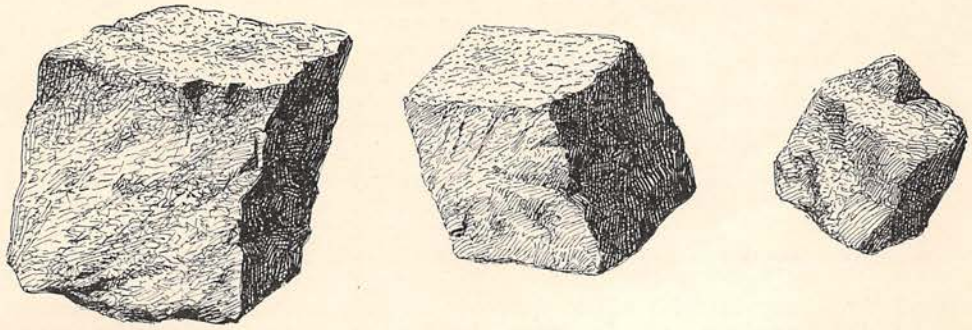


FIG. 10. SHOWING ROUGH CUBE-SHAPED STONES OF PROPER SIZE AND FORM TO BE USED IN MACADAM AND TELFORD ROADS. In the "intermediate" courses of either form of construction moderately larger sizes may be employed; but in top courses it is always best to restrict the workmen to a maximum-size stone not materially greater than that shown at the left of the figure.

stones or bricks are sometimes laid at the bottom of the side-drains, so as to form an open waterway with angular cross-section; and other methods are pursued, all leading to the same end and based upon the same principles of construction.

After the road-bed has been properly excavated, the drainage provided for, and the earth foundation properly rolled and shaped, a layer of broken stone from four to six inches in thickness, and never exceeding the latter figure, should be spread evenly upon the surface of the earth foundation, and rolled until it has become thoroughly compact. In this process of rolling, a sharp, clean binding material in moderate quantities may be added to advantage, but on no account should loam, dirt, or other soft material be used, since these soon turn to mud by the addition of water. After the first layer is thoroughly consolidated, the second layer may be added, being spread evenly and smoothly over the surface of the finished course, and in its turn rolled until firmly compacted. In rolling these Macadam layers into a compact form, it is frequently found best to sprinkle the surface with water, as is recommended elsewhere in the construction of Telford roads. After the completion of the second course of macadam, a top or finishing layer of clean gravel or fine stone chips not exceeding two inches in depth should be spread evenly over the whole surface and thoroughly consolidated by rolling. For this top layer perhaps nothing is better than the fine chips and gritty material which may be found in every quarry where the breaking of stone is carried on, and if this cannot be otherwise obtained, it may be broken from the larger stones by a crusher specially adjusted for that purpose. The small stones used in this finishing layer are usually in size and shape somewhat like those represented in fig. 9, and the largest stone used for this purpose should not exceed three quarters of an inch in its greatest dimension. The completion of the top surface just described marks the finished work of the construction of a Macadam road, and it is then ready for use. A partial cross-section of a completed Macadam road is shown in fig. 3, in which A represents the consolidated stones resting upon the rolled and compacted earth foundation B. The top view and cross-section of the finished Macadam road are shown on a small scale in fig. 7, where A again represents the finished superstructure and B the compact earth foundation.

An important thing to be kept in view in the construction of roadways of the Macadam, Telford, and kindred types is the necessity of excluding from the road-material all rounded stones of whatever size. Such stones are most damaging in their effects when incorporated in the structure of any of these roads, and the greatest care should be taken to prevent their use. On many occasions mere pebbles of the

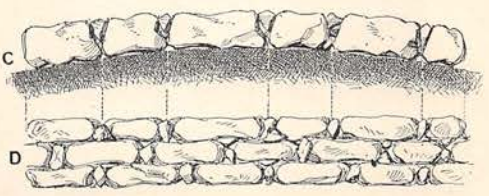


FIG. 11.

Cross-section (C) of portion of Telford sub-pavement laid on rolled earth foundation, and top view (D) of three partial courses of same, showing method of breaking joints of larger stones and wedging and packing of stone chips into voids and interstices.

EAST BROAD STREET AND MAGNOLIA AVENUE, ELIZABETH, NEW JERSEY, APRIL 14, 1891.

size and form shown in fig. 8 will in some manner find their way between the flat and angular stones of the superstructure, destroying the compactness of the roadway and preventing that snug settling and wedging of the angular stones which are so essential to the proper completion of the road.

TELFORD ROADS.

THE system of Thomas Telford, whose name for many years has been used to designate the kind of road which he advocated, differs from the Macadam system in many particulars, the most important of which prescribes the use of a sub-pavement of large stones set in in courses upon the earth foundation.

Since the time of Telford, and indeed in his own day, road-builders have modified his rules without in any way detracting from the excellent quality of their work. For example, in some cases it has been found better not to prepare a level bed for the road-materials as Telford advised, but rather to give to the earth foundation a downward slope from the center-line to each side of the roadway, so as to insure a convexity of cross-section parallel to the cross-section designed for the road-surface when completed. According to the original Telford specifications the convex form of the finished surface was obtained by varying the size of the stones used in the sub-pavement, and by placing the deeper stones in the center of the road, while those of less depth were placed in the order of their decreasing size from the center to the sides of the roadway. This method, while possessing excellent features, appears in some cases to have the disadvantage of requiring a careful assortment of the sub-pavement stones, and it may also be questioned whether the leveled earth foundation is as well suited to insure sub-drainage as is the rounded earth

ENGRAVED BY F. W. SUTHERLAND.

A STONY ROAD IN BAD REPAIR.

(CODMAN STREET, DORCHESTER, MASSACHUSETTS, NEAR STABLE OF THE MUNICIPAL PAVING DEPARTMENT.)

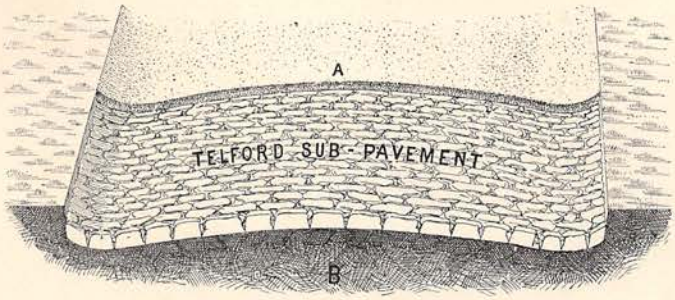
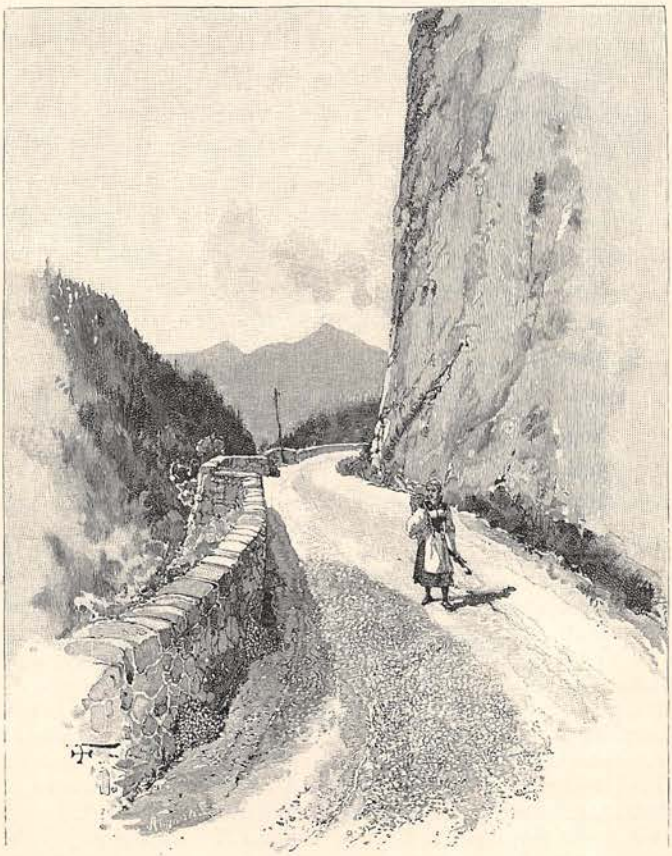


FIG. 12. TOP VIEW AND CROSS-SECTION SHOWING METHOD OF CONSTRUCTING TELFORD ROADWAY.

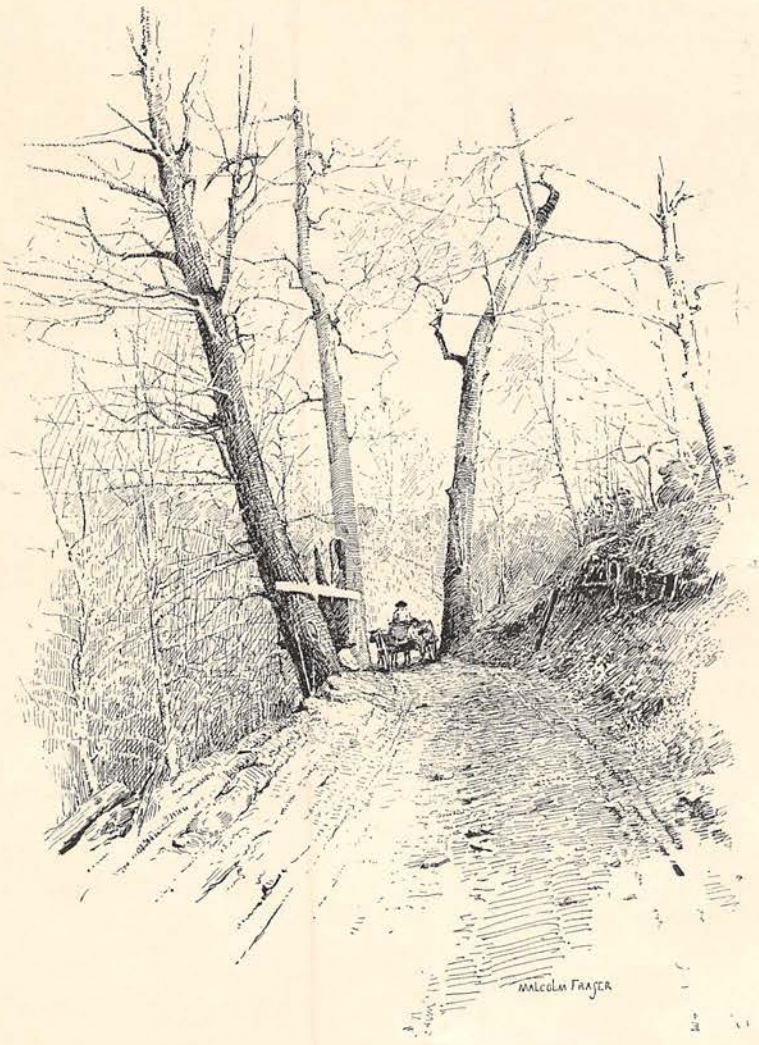
B is the rolled earth foundation on which is laid the sub-pavement as shown in fig. 11. At A have been laid the upper courses of broken stone rolled into compact form, similar to that shown in the broken-stone layer of fig. 3.

foundation which in late years has come to be more commonly used. The construction of the Telford road may be better understood by reference to some of the accompanying figures. In fig. 11 C represents a portion of cross-section, or end view, of the Telford sub-pavement laid on a well-rolled earth foundation, with the broadest edges of the stone laid lengthwise across the road. In the interstices between these larger stones of the sub-pavement are wedged and firmly packed the smaller stone chips. At D in the same figure is shown a top view of portions of three successive layers, or courses, of sub-pavement stones, in which may be seen the rough, irregular upper edges of the large stones, and the chips and smaller fragments which have been wedged and packed into the interstices. This wedging and packing should be most carefully and thoroughly done, as it insures the solidity of the sub-pavement, and serves to prevent the dropping or settling of all materials which are subsequently put on. When finished, the sub-pavement should present a general uniformity of outline, with a moderately roughened surface caused by the irregular upper edges of the pavement stones and chips — an irregularity which serves well to prevent the shifting and sloping of the



DRAWN BY HARRY FENN, AFTER A PHOTOGRAPH BY F. A. ELWELL. ENGRAVED BY K. C. ATWOOD.

SWISS MOUNTAIN ROAD IN PROCESS OF REPAIR.



DRAWN BY MALCOLM FRASER, AFTER A PHOTOGRAPH BY JOHN CARBUTT.

A ROAD NEAR TRYON CITY, NORTH CAROLINA.

smaller stones above, and to insure the compact binding together of the entire structure. In the making of a Telford road it is important to remember that the stones used in the sub-pavement need not be selected with regard to their hardness, and that stones may be used in this part of the work which would be wholly unsuited to situations where they might be exposed to direct contact with heavy vehicles. Another practical point to be remembered in the laying of the sub-pavement is that the driving and wedging of chips and smaller stones into the interstices of the sub-pavement must not be permitted near the face of the unfinished work, as this practice would result in the loosening and forcing apart of the larger stones of the sub-pavement.

After the completion of the sub-pavement at least two separate layers of broken stone are generally put on to form the upper and finishing course of the roadway. The intermediate course next to the sub-pavement is made of broken stones somewhat after the manner of Macadam material, although these need not be, and in practical work generally are not, of the same uniform size and quality as are required for the finishing layer. The stones used in the intermediate course may vary in size from one inch to three inches in their largest diameter, and this course should be at least four inches thick, free from dirt, and laid in a bed of uniform thickness to preserve the regular contour of the roadway. In putting down this course, the heavy roller should again be employed to compact and consolidate the stones, so that the repeated passing of the roller over its surface will produce no settling, hollows, or uneven places. Before

completing the rolling, a quantity of clean, sharp sand should be laid on the surface of the intermediate course, evenly and in sufficient amount, and over this the roller should be passed repeatedly, after having first sprinkled the sand with a sufficient quantity of water to prevent its sticking to the surface of the roller.

The top or surface course is the finishing work in the building of a Telford road; and in the making of this course great care must be had both in selecting the material to be used and in the method of laying it down. All the stones of this course should be of uniform size, and all stones should be rejected from this material which are too large to pass through a ring having an inner diameter of two inches. If trap-rock can be obtained for this course, it can be used with the assurance that a better material is scarcely obtainable; but if trap-rock cannot be had, there are several varieties of hard granite and limestone which make excellent substitutes, and which are frequently used with success.

The top or surface course should be laid with a uniform depth of not less than three inches, and after being compactly rolled it should show a thickness of at least three inches above the intermediate course. After the loose stones for the top course have been evenly laid over the surface of the intermediate course, so as to show the form of the completed roadway, the roller should be run over the new surface just enough to render it moderately compact, and for this purpose a light roller will be sufficient. Then a light coat of clean, sharp sand should be put on, and sprinkled as in the case of the intermediate course, after which, by the use of splint brooms, the sand may be worked in between the stones of the surface, while the heavy roller is made to follow, pressing the small stones

DRAWN BY HARRY FENN.

A MOUNTAIN ROAD IN NORWAY.

firmly into a compact mass. The rolling should proceed backward and forward in line with the direction of the road, beginning at the side or gutter of the roadway, and working toward the center. The process of rolling and adding moist sand should continue until each stone becomes so firmly bedded, and the finished surface so hard, that more sand cannot be pressed into the surface, after which all loose material remaining on top of the road may be removed, so as to leave the surface smooth and complete. This process of rolling the top sur-

DRAWN BY MALCOLM FRASER, AFTER A PHOTOGRAPH BY F. A. ELWELL.

A FRENCH NATIONAL ROAD.

ENGRAVED BY P. AITKEN.

VIEW OF BLUE HILL AVENUE, MATTAPAN, MASSACHUSETTS.
(AN IMPORTANT BUT BADLY KEPT ROAD, SHOWING DEEP RUTS CAUSED BY THE USE OF NARROW WHEEL-TIRES.)

face can hardly be continued too long or done too thoroughly. In France it is no uncommon thing for engineers to require that this rolling shall be continued until a cubic inch of hard Macadam material laid on the finished surface of the road shall be crushed by the roller without being pressed into the finished surface or marring its compactness.

Macadam himself declaimed most loudly against binding material; but the methods of both Macadam and Telford were anticipated by Trésaguet, a French engineer, whose methods have been followed with eminent success by the road-builders of France. The system of Trésaguet involved the use of a binding material, and it is now generally adopted in the construction of roads both in England and America. Every stone road comes eventually to be supplied with a binding material into which its component parts are bedded and by which its voids are filled. This may easily be seen by the examination of any of the old Macadam roads which were originally laid without a binding material, and which, after a long term of years, are found to contain a gritty substance which completely fills all the voids between the original stones. The use of binding material in the first instance insures and hastens the compacting of the roadway, and, if the materials be of proper quality, in no way detracts from the character of the work.

In fig. 12 is shown a cross-section and top view of a Telford road in process of construction after the manner here described. The portion at A represents the finished surface of the broken-stone layer or course after the completion of the rolling, and the portion at B is the compact earth foundation upon which the sub-pavement has been set. The concave portion on each side of the road serves as a gutter to carry surface-water lengthwise in the direction of the roadway into the nearest watercourse or culvert; and where no watercourse is conveniently near, it is best to introduce side-ditches or -drains as described in that portion of the text which refers to Macadam roads. It may briefly be said that this form of concave gutter is not so commonly used as curb gutters, in which the curbstone is set nearly vertical, inclining slightly outward from the roadway, and forming an angle with the road-surface at its lowest point, somewhat after the manner of the street gutter seen in cities and towns. Such a form of construction permits of a more thorough use of the roller on the entire road-surface, but in districts where suitable stone for curbing cannot be had cheaply, the concave gutter may be well substituted.

Isaac B. Potter.