

THE "YONAHLOSSEE" ROAD,

Between Blowing Rock and Linville, along the Southern slope of the Grand Father Mountain, which appears in the back-ground. [See page 45.]

NORTH CAROLINA GEOLOGICAL SURVEY.

J. A. HOLMES, STATE GEOLOGIST.

BULLETIN No. 4.

ROAD MATERIALS AND ROAD CONSTRUCTION IN
NORTH CAROLINA;

BY

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AND

WM. CAIN, CIVIL ENGINEER.

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NORTH CAROLINA GEOLOGICAL SURVEY,
RALEIGH, N. C., January 10, 1893.

To His Excellency HON. THOMAS M. HOLT,
Governor of North Carolina.

SIR:—I have the honor to submit herewith for publication as Bulletin No. 4 of the Geological Survey, a brief report on the character and distribution in North Carolina of materials suitable for the construction of highways and public roads; to which has been added a short discussion of the methods of using these materials, and of the tools and machinery used in modern road construction. And I beg leave to express my appreciation of the fact that the subject of better roads is one in which for many years you have shown an active and intelligent interest.

With great respect, I have the honor to be, sir,

Yours obediently,

J. A. HOLMES,
State Geologist.

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PREFACE.

It was originally intended that the notes on the character and distribution in the State of materials suitable for road construction given in this paper, should be published in the Bulletin on Building Stone.¹ But as they are intended for a different class of readers, it is thought best to publish them separately. And as there is at the present time a considerable amount of interest shown in relation to the subject of better public roads, it is thought best to supplement these notes on road materials by a brief discussion of the general subject of road improvement. Two chapters on this latter subject—Chapter III on Methods of Road Construction, and Chapter IV on the Machinery Used in Road Construction, have been prepared by Prof. Wm. Cain, of the State University, who is an engineer of large experience, and is familiar with the needs of the State in this direction.

It is not expected that this short paper will serve to any extent the purpose of a guide to road construction, but it is hoped that it may aid in stimulating a deeper and more intelligent interest in the subject among the people of the State, and may aid in bringing about a system of public roads more in accord with our civilization, with the needs of the community, and with common sense.

Those who wish to go more deeply into the subject of better public roads, and it is hoped that there may be many such, are advised to read, amongst the excellent books published recently, "Highway Construction,"² and "A Move for Better Roads,"³ both of which give lists of numerous other books and pamphlets relating to this subject. And every person interested should read "Good Roads,"⁴ the monthly journal published by the League of American Wheelmen, New York.

In the preparation of this Bulletin I have drawn freely from each of these publications, and have endeavored to give full credit at the proper places. I am especially indebted to Mr. I. B. Potter, editor of "Good Roads," who kindly had prepared for me electrotypes from a number of illustrations published originally in that journal. Proper acknowledgment is made in case of other contributed plates under each illustration.

J. A. HOLMES, *State Geologist.*

1. Bulletin No. 2, Building Stone in North Carolina; by J. A. Holmes and J. V. Lewis, 1893.

2. "Highway Construction"; by Austin T. Byrne, pp. 636. John Wiley & Sons, 1892. Price \$5.

3. "A Move for Better Roads"; Essays on Road-making and Maintenance and Road Laws. Henry Carey Baird & Co., Philadelphia. Price \$2.

4. "Good Roads," a monthly journal, edited by Isaac B. Potter, Potter Building, New York; \$2 a year.



From "GOOD ROADS."

Fig. 1.—MACADAMIZED ROAD IN NORMANDY, FRANCE.
THE BEST AND CHEAPEST PERMANENT ROAD FOR GENERAL USE.

INTRODUCTION.

HISTORICAL NOTES.—The use of stone in the construction of public highways, to the importance of which the American people are at last awakening, is by no means a modern invention. The Babylonians, the Carthagenians, the early Greeks in the Old World, and Incas of Peru in the New World recognized its importance, and some of their paved roads are well known in history, and their remnants still to be seen. And the Romans, starting with the Appian Way (312 B. C.), constructed a series of paved roads from Rome to the principal towns of the Empire and through many parts of Europe. Some of these splendid roads are still in use, and others form the foundations of modern roads.

It was not, however, until the close of the last century that modern European nations became aroused to the necessity of better roads. France and England took the lead in the matter, soon to be followed by Germany, Switzerland and other countries; each recognizing the fact that good roads are essential accompaniments and promoters of civilization, national prosperity, and even national existence. The progress in this direction has been constant, until at the present time France alone has not less than 130,000 miles of paved roads, unsurpassed in their excellence by those of any other country. And there is no doubt much of truth in the suggestion that the prosperity of her people, even under adverse circumstances, is due in no small degree to the fact that on her splendidly maintained system of highways the obstacles to "the movement of persons and exchange of commodities" have been reduced to a minimum.

In the introduction to his recent book on "Highway Construction," page 31, Byrne gives the following reasons why public roads have not improved as have other institutions in the United States: "(1) The excellence of the railroad systems and waterways; (2) the indifference of those in charge of highway maintenance; (3) the want of appreciation of the benefits of good roads and the fear of increased taxation on the part of the rural population; (4) the dispersion of the people over large areas in their search for desirable localities for residence; and (5) the ill effects of the system requiring the personal service of the rural population on the highways."

Various States of the Union adopted from the old English laws the provision that every citizen may work out his road-tax on the public highways, and by the continued existence of this law, the American

road is now a hundred years behind the demands of American civilization.

Early in the present century North Carolina statesmen, led by Judge Murphy, President Caldwell of the State University and others, devoted a large share of attention to the subject of internal improvements. It was their purpose to improve the facilities for navigation on all the principal rivers, and starting from the head of navigation on each stream to construct a series of public highways extending westward into the interior of the State.

In 1823 the Engineer of the Board, Hamilton Fulton, surveyed such a road from Fayetteville to Wilkesboro, and recommended its construction, at a total cost of \$63,200; and in his report of this survey he suggests the adoption of the following system of public roads,* dividing them into three classes: "The great principal and leading roads in one class to be denominated State roads; another of minor importance into county roads, and a third into private roads. The first of these to be made from a fund of which the State will contribute one moiety, and the counties through which the road passes their respective moieties of the expenses actually incurred in the county; when the road is once completed, to be kept in repair by the county. The second class to be made and kept in repair by the counties; and the third to be made and kept in repair by the private individuals who are benefitted by the same."

The public highway from Fayetteville to Wilkesboro was never built, as recommended by Mr. Fulton, but the plan bore fruit many years later when, in 1849, the citizens of Fayetteville (at the head of navigation on the Cape Fear river), with the co-operation of the State, undertook the construction of a series of plank roads. The Fayetteville and Western plank road, begun in 1849-'50, was built from Fayetteville to Salem. The Fayetteville and Centre plank road, begun in 1855, was to extend to Centre (now Norwood), in Stanly county. The Fayetteville and Warsaw plank road, also begun in 1855, was to extend eastward to Warsaw, on the Wilmington and Weldon Railroad. The construction of these plank roads was under the management of stock companies, three-fifths of the stock having been subscribed by the State and two-fifths by the citizens of the community. The average cost per mile on the Fayetteville and Western plank road was about \$1,300, and on the others it was probably the same.† During a few years after their construction these roads were highly satisfactory, but it was not long before the timber began to decay; and as the total receipts were not sufficient to make the investment a

* Annual Report of the Board of Internal Improvements of North Carolina, 1823, p. 45.

† The Fayetteville and Centre, and the Fayetteville and Warsaw roads were never completed; the former was built to near Little's Mills, and was continued thence to near Albemarle, as a dirt-road turnpike. There were also other short plank roads leading out from Fayetteville.

profitable one, they were not repaired, and have long since disappeared, and are now known only in the memories of the citizens and in the public records, which show them to have cost not less than three hundred thousand dollars.

As early as 1819,* and at intervals for forty years thereafter, the Board of Internal Improvements, as authorized by the General Assembly, co-operated on a small scale in having roads surveyed and constructed in several of the sparsely settled mountain counties; and in 1849-50 the General Assembly authorized a careful survey of the route, and the construction of the Western Turnpike Road, with various branches, to extend from Salisbury *via* Asheville, through Cherokee County to the State line, the cost to be borne out of funds arising from the sales of the Cherokee lands, and funds raised by private companies along the route. That part of the route between Salisbury and Asheville was abandoned in favor of the Western North Carolina Railroad. The road, with its tributary branches, was constructed from Asheville to its south-west terminus between 1850 and 1859.

All these western turnpike roads, in the building of which the State aided, were at best, fairly good dirt roads. Instead of constructing permanent stone roads, one of the chief aims of the builders was to get the stone out of the way. Nearly, if not quite all of them, were managed as toll-roads for several years after completion, but this feature has been generally abandoned, to the detriment of the traveller. They are still known as State roads, though the State has long since ceased to be interested in them, financially or otherwise.

During the past several decades plans for public improvement have turned in other directions. The railroads have penetrated many parts of the State; they have absorbed a considerable share of public attention; and there has been a growing belief among the people that they have in a large measure done away with the need for other public highways. But we are just now coming to a clearer understanding of the true relations existing between the railroads and good wagon roads. Both are so essential that we need not stop to compare their relative importance; neither can be extended so as to take the place of the other. It is true that railroads may have in large measure done away with the need for long turnpikes extending parallel to them through the same territory, but they have enhanced the importance of other public roads extending out on both sides of the railroad by greatly increasing the service that these public roads may render in the exchange of commodities and in the development of the natural resources of the country. A railroad at every man's door is out of

*Annual Report of the Board of Internal Improvements in North Carolina, 1823, pp. 12 and 13.

the question; but every community should be within easy reach, over a good public highway, of the railroad, the county seat, and the nearest market town. And he is, in an important sense and during a considerable part of the year, nearer to these when separated from them by ten miles of good macadam road than when separated by two miles of a winter-time dirt road.

SOME CONCLUSIONS.—I have introduced these brief historical notes to show: first, that other civilized countries have now a system of broken stone public roads, and find them an indispensable adjunct of national prosperity and progress; and, second, that in North Carolina the public road system, if indeed it may be called a system, of the present century has been an expensive failure. It would be an easy task to show also that our lack of good roads has greatly retarded the material growth and development of the State; and that it is a matter of paramount importance that we lose no time in adopting some different system of road construction and maintenance, such as has been found satisfactory in other countries.

So much for the past. The problem of better public roads, especially in the midland and western counties, perhaps outranks in importance all other industrial questions now before the people of the State. The most difficult part of the problem, as is so often the case, is that of revenue—how to raise the funds. This part of the problem demands the consideration of the General Assembly rather than that of the Geological Survey; but I venture to state in conclusion a few general propositions which have served as a basis of road improvement in other countries, and which I believe must be recognized in establishing a new system of public roads in North Carolina.

1. All public roads should be constructed and kept in repair as far as possible by men employed and trained for this special work; and if it is not deemed wise to abolish at once, as has been done in many other enlightened countries, the present system of having every voting citizen liable for work on the public roads, then it will be best to adopt such a modification of it as has been done in Mecklenburg County, where citizens are liable for four days of work, and are relieved of this obligation on the payment of the sum of fifty cents per day. The amount of this substitute money should be small—not greater than fifty cents per day—so that the great majority would pay it rather than work on the roads; and the few who prefer to work may be called out, not in a body, but individually at the discretion of the road supervisor, and thus forced to labor continuously and intelligently.

2. The cost of the construction of public roads should be paid out of funds raised by either of the following methods:

- (a) A State tax or County tax, or both;
- (b) The issuance of State bonds or County bonds, or both, or County bonds secured by State bonds so as to insure their sale at par and a low rate of interest.

The latter method possesses one decided advantage in that it provides a large sum for immediate expenditure in the construction of roads, and the existence of these improved roads will so enhance the value of property as to more than pay the interest on the bonds issued, a fact which has been demonstrated by actual experience in Virginia, New Jersey, Connecticut, Indiana, and in other countries. And it possesses a second advantage, that the people begin at once to realize the benefits of good roads; and the next generation of citizens who are to help pay for the bonds will be better able to do this, as they will have long enjoyed the full benefits of the roads and realized the increase in the value of property.

3. All criminals should, as far as possible, be used for work on the public roads, and thereby benefit the communities which have been injured by the commission of crime, and repay in part the cost of trial in the courts, and maintenance during confinement.

4. While it may be best under our form of government for the several counties to bear the main burden of constructing and maintaining good roads, yet in a work of such paramount importance to every citizen and so far-reaching in its consequences, where so large an expenditure is required demanding intelligent supervision, the State should co-operate with the counties in the construction of the principal highways, as it has done in educational matters, in the construction of railroads, canals and other internal improvements. If in no other way the State should co-operate with the counties to the extent (1) of allowing the use of convicts in such counties or groups of counties as agree to raise funds sufficient for the construction of better roads; and (2) by providing for the appointment of a road commission and the employment of a practical engineer of roads who can visit the various counties, give intelligent advice and direction to the work, and thus aid in the production of uniformly good results.

5. In the several counties the construction of better roads should begin at the county seats, and the work be done on the prominent roads radiating out from that point, first near the town, and gradually at greater distances out; except that where several counties co-operate in the construction of a trunk road extending through them, it may be wise first to complete the work on this road, and construct the other county roads thereafter.

6. While the granite block, brick and asphalt pavements are probably the best for city streets, and the plank road is perhaps the most satisfactory temporary good road which can be constructed in sandy and well timbered regions, the experience of a century has demonstrated the fact that for the public highways of the country the broken stone road as made by Macadam and Telford is by far the most durable, and in the long run by far the most economical.



FROM "GOOD ROADS."

Fig. 2.—HEAVY LOAD OF STONE BEING HAULED ON A MACADAM ROAD. IT SHOULD BE OBSERVED THAT THE WHEELS DO NOT SINK INTO THE SURFACE, AND THAT CONSEQUENTLY THE LOAD WHICH CAN BE HAULED IS GREATLY INCREASED.



FROM "GOOD ROADS."

Fig. 3.—AN EMPTY WAGON ON A WINTER-TIME DIRT ROAD, SUCH AS MAY OFTEN BE SEEN IN NORTH CAROLINA AND OTHER STATES.

CHAPTER ONE.

CHARACTER AND DISTRIBUTION OF ROAD MATERIALS.

In the following discussion of the character and distribution of road material in the State, it is thought best to avoid the use of technical terms as far as possible; and the names of rocks here used are those applied by the engineer rather than by the geologist. The character of the materials is discussed with a view to their fitness for use in the construction of broken-stone pavement, as used by Macadam and Telford on the public highways.

CHARACTER OF ROAD MATERIALS.

“In considering the relative fitness of the various materials,” says Byrne,* “the following physical and chemical qualities must be sought for:

“(1) Hardness, or that disposition of a solid which renders it difficult to displace its parts among themselves.

“(2) Toughness, or that quality which will endure light but rapid blows without breaking.

“(3) Ability to withstand the destructive action of the weather, and probably some organic acids produced by the decomposition of excretal matters, always present upon the roadways in use.

“(4) The porosity, or water-absorbing capacity, is of considerable importance. There is, perhaps, no more potent disintegrator in nature than frost, and it may be accepted as fact that of two rocks which are to be exposed to frost, the one most absorbent of water will be the least durable.”

The following table shows absorptive power of a few common stones: †

<i>Percentage of Water Absorbed.</i>		<i>Percentage of Water Absorbed.</i>	
Granites.....	0.06 to 0.155	Limestones	0.20 to 5.00
Marbles.....	0.08 to 0.16	Sandstones	0.41 to 5.48

Something of the quality and suitability of different materials for use in broken-stone pavements is shown in the following table: ‡

MATERIALS.	COEFFICIENTS OF WEAR.	COEFFICIENTS OF CRUSHING.
Basalt	12.5 to 24.2	12.1 to 16.
Porphyry	14.1 to 22.9	8.8 to 16.3
Gneiss	10.3 to 19.0	13.4 to 14.8
Granite	7.3 to 18.0	7.7 to 15.8
Syenite	11.6 to 12.7	12.4 to 13.0
Slag	14.5 to 15.3	7.2 to 11.1
Quartzite	18.8 to 30.0	12.3 to 21.6
Quartzose sandstone	14.3 to 26.2	9.9 to 16.6
Quartz	12.9 to 17.8	12.3 to 13.2
Limestone.....	6.6 to 15.7	6.5 to 13.5

* Highway Construction, p. 24. † *Ibid.*, p. 26. ‡ *Ibid.*, p. 172.

These "coefficients," showing the relative quality of various road materials, were obtained by French engineers as the result of an extended series of tests, and were found to agree fairly well with the results arrived at by actual observation of the wear of materials in the roads. The coefficient 20 is equivalent to "excellent," 10 to "sufficiently good," and 5 to "bad."

STONES NOT SUITABLE AS ROAD MATERIAL.—Before proceeding to the consideration of the stones found in North Carolina adapted to use as road material, it may be well to consider briefly some of those that are not suited to this purpose. In general, it may be said that all *schistose* and *slaty* rocks, *i. e.*, all rocks which split or break easily into layers or flakes, should be discarded. No rock of whatever species which is already in the advanced stages of decay, so as to become crumbly and soft or porous, should be used in macadamizing roads, as the result in all such cases will be that, under the action of the wheels and hoofs, these materials become ground into fine powder, which becomes mud when wet, and dust when dry. There are many places, however, where a decayed granite or gneiss rock, when highly siliceous, will make a good foundation for a Macadam road, and will be found useful as a covering on clay in the improvement of dirt roads. There are other materials, like quartz ("white flint"), which are hard enough, but which are quite brittle, and hence easily crushed to powder, and which, consequently, should not be used when better material is available. Sandstones, as a rule, are unfit for use in macadamizing roads, as they are easily crushed and usually porous.

STONES SUITABLE AS ROAD MATERIAL.—"The materials used for broken-stone pavements must of necessity vary very much according to the locality. Owing to the cost of haulage, local stone must generally be used, especially if the traffic be only moderate. If, however, the traffic is heavy, it will sometimes be found better and more economical to obtain a superior material, even at a higher cost, than the local stone; and in cases where the traffic is very great, the best material that can be obtained is the most economical."* In the middle and western counties of the State, in many places, stones now covering the cultivated fields will be found satisfactory for use on the roads, and in order to get rid of them farmers will haul and sell them for low prices.

Stones ordinarily used in the construction of Macadam and Telford roads are the following: trap, syenite, granite, gneiss, limestone, quartzite, gravel and sand. The first three of these names are used here in a very general sense, and include several species of rock which, in technical language, would be known by other names. In general,

* Byrne, Highway Construction, p. 170.

it may be said that they rank in importance about in the order named, but several of them, especially the granite, gneiss and limestone, vary so much in quality that this general statement is subject to modification accordingly.

The term *trap*, as here used, includes not only the black, rather fine-grained, igneous rock known as diabase, which occurs in long dykes in the sandstone basins of Deep and Dan rivers, but also the somewhat similar material which is to be found in the older crystalline rock of many other regions. In this State it is often known locally under the name of "nigger-head" rock. This rock does not usually split well into paving blocks, but when properly broken it is the most uniformly good material obtainable for macadamizing public highways, though sometimes it does not "bind" well.

Syenite, sometimes called *hornblende granite*, varies somewhat in quality and composition. It is a widely distributed rock in the midland and western counties of North Carolina, and is an excellent road material. The varieties which are finer in grain, and those having the larger proportion of the black mineral known as hornblende and are consequently of darker color, are best adapted for this purpose.

Granites vary considerably, both in quality and appearance, and in their value as road material. Those which are very coarse in grain, containing large and numerous crystals of feldspar, are, as a rule, more easily crushed and decay more rapidly, and should not be used in road construction when better materials are available. Those which contain a large proportion of mica split and crush more easily into thin flakes and grains, and for this reason, are also less valuable. Those varieties which are of fine grain and contain an admixture of hornblende are best for road purposes.

Gneiss, which has the same general composition as granite, also varies very greatly in its quality and adaptability to road building. It usually has the appearance of being somewhat laminated or bedded, and when the layers are thin and the rock shows a tendency to split along these layers it should be discarded for road purposes. In addition to this, the statements made above with reference to the granites will apply also to gneiss.

Limestone suitable for road purposes is not an abundant rock in North Carolina, but it is found in a few of the eastern and a few of the western counties. It is a rock which varies very greatly in character, from the hard, fine-grained, compact magnesium limestone, which is a most excellent material for the Macadam and Telford roads, to the porous, coarse and partially compact shell-rock of recent geological formation, which is less valuable material. Practically, all limestones

when used as road material possess one valuable qualification, that of "binding;" the surface material which becomes ground by the action of the wheels settles among the fragments below and consolidates the entire mass. For this reason, in many cases, it has been found to be good policy to mix a considerable quantity of limestone with some siliceous and igneous rocks, which though hard and tough do not consolidate readily.

Gravel and Sand are not used in the construction of stone roads as formed by Macadam and Telford, except as an excellent foundation, for which purpose they possess a very great value; and as a binding material, in small quantities, they are sometimes spread over the road surface between the layers of crushed stone. When used in this latter connection, however, the gravel must be quite free from round pebbles. Gravel is, however, used extensively in the construction of what are termed gravel roads; where there is no attempt at macadamizing the roads, but where the gravel itself is spread uniformly over the surface of a foundation road-bed which has been properly shaped and drained. Gravel like that which occurs so abundantly in many northern states, where glaciers existed, is not found in North Carolina. But river gravels are found in a number of our counties; and as suggested above, in the middle and western counties there are to be found in places decayed siliceous granite and gneiss which, though not suited for mixing with crushed stone in macadamizing roads, yet will be found to serve a useful purpose as a foundation for the broken stone on clay roads, and also as a top dressing on clayey dirt roads.

DISTRIBUTION OF ROAD MATERIALS.

A line drawn from Gaston to Smithfield, Smithfield to Cary, and from Cary to Wadesboro, separates the State into two general and well marked divisions, the eastern of which may be called the Coastal-Plain region, and the western may be termed Piedmont and Mountain regions.

IN THE COASTAL PLAIN REGION.—In the eastern counties, except along the western border of this Coastal Plain region at irregular intervals, we find none of the hard crystalline rocks suitable for broken stone roads. Over the larger part of the area we have sand, clays and loams, the sands becoming coarser and more gravelly along the western border and finer towards the eastern. At a number of points along some of the rivers and in some intervening areas is to be found a limestone rock which will serve a fairly good purpose in road building.

Gravel.—The gravel along this western border can be used successfully in making a fairly good road-bed, and should be used extensively where the hard crystalline rocks cannot be obtained. It may be found at many places in counties between the line mentioned above, extend-

ing from Gaston to Wadesboro, and a line drawn to the east of this from Franklin, Virginia, by way of Scotland Neck, Tarboro, LaGrange and Clinton, to Lumberton; and in a few places also considerably to the east of this latter line. The gravel is more generally distributed along the borders of the river basins, where it occurs in extensive beds, a few inches to twenty feet in thickness, though along the western edge of the Coastal Plain region it is often found on the hill-tops and divides between the rivers.

In many places the gravel is suitable for use on the road-bed just as it comes from the pit, containing pebbles of the right size, from an inch down to a coarse sand, and a small percentage of ferruginous clay, just enough to make it pack well in the road-bed without preventing proper drainage. In many cases, however, the proportion of clay and loam and sand is too large and must be reduced by the use of fine screens; and in other cases many of the pebbles are so large that they must be separated by means of a one-inch mesh screen, and those too large to pass through this screen broken before they are used.

The railroads passing through this region long since discovered the value of this gravel as a road material, and have used it extensively as a ballast on their road-beds. The small percentage of ferruginous clay soon cements the gravel into a hard compact mass.

Limestone.—In the south-eastern portion of this region limestone rock and calcareous shells from the oyster and from fossil mollusks from the marl beds constitute the only hard materials to be found there for road construction. In some places the limestone is fairly hard and compact, as at Rocky Point, on the Northeast Cape Fear river, at Castle Hayne and elsewhere, and this rock will make an excellent road. In other places it is made up of a mass of shells firmly cemented together, as on the Trent river, near Newbern, and elsewhere. At many other points beds of shells are so slightly cemented together that the material may hardly be called a rock, as the term is ordinarily used, and in this condition it is of less value as a road material, but may be used for this purpose to advantage. A careful search will show limestone of one of these grades to occur in considerable quantities at many points in these eastern counties, between the Tar river and the South Carolina line. The harder, the more compact, and finer grained this rock, the more valuable it is as a road material; but the loose shells from marl beds, when free from clay, and the oyster shells from the coast, when placed on a road surface and ground into fine fragments by travel, will solidify into a hard, compact road, as may be seen in the case of the excellent "shell road" between Wilmington and Wrightsville, which was built of oyster-shells

Clay and Sand.—The admixture of a small percentage of clay or loam with the sand on the surface of the road-bed will solidify it, and will thus very greatly improve the character of the road; and in this connection, and only in this connection, clay may be considered a useful road material. In whatever region the clay occurs in abundance, the road will be greatly improved by the proper admixture of sand from an adjoining region, and by proper drainage.

Granites and other crystalline rocks.—These are found outcropping at intervals along the western border of the Coastal Plain region, and wherever found accessible this material should be used in the construction of roads. Near the northern border of the State they are found exposed in considerable quantity; along the Roanoke river, between Gaston and Weldon, in Northampton and Halifax counties; near Whitaker's station, at Rocky Mount, just south of Wilson, and again a few miles north of Goldsboro on the Wilmington and Weldon railroad. Another isolated and interesting occurrence of granite is near the junction of Pitt, Wilson and Edgecombe counties, where it is exposed over a tract of several acres. West of the Wilmington and Weldon Railroad, in the counties of Halifax, Nash and Johnston, the streams have removed the surface sands and clay in narrow strips along their borders, and have exposed at intervals the crystalline rocks; and in many places these rocks will be found to make good road material. Further southwest, in Wake County, on the Cape Fear river, and Upper Little river, in Harnett County, and again along the banks of the Pee Dee river and tributaries in Richmond and Anson counties, granitic and slaty rocks occur in considerable quantities, the former especially suitable for road material.

In considering the materials for good roads in the counties of this Coastal Plain region, it must also be borne in mind that several large rivers connect this region with ample sources of granite and other good road materials which occur at the head of navigation on these streams and can be cheaply transported on flats; and further, that a number of railroads pass from the midland counties where the supply is abundant directly into and across the Coastal Plain region.

Plank Roads.—As suggested above, in deep sandy regions where timber is abundant, the plank road may prove the most economical good road that can be built for temporary use, and some of them last six to ten years. But the greatest objection to them lies in the fact that when the timbers decay, whether this be at the end of four or ten years, the road is gone; and the entire cost in labor and money must be repeated.

IN THE MIDLAND AND PIEDMONT COUNTIES.—Throughout the midland and Piedmont counties of the State, west of the Coastal Plain region, rocks suitable for road purposes are abundant and widely dis-

tributed, so that no one can claim as an excuse for *bad* roads that the materials are not at hand for making *good* roads. It will serve our present purpose to discuss these in the order of their geographic distribution, with but little regard to their geologic relations.

Trap Rock in the Sandstone Areas.—As stated above, sandstones possess very little value as road material, especially when broken into small fragments, as is necessary in making Macadam and Telford roads, but fortunately in this respect, the sandstones of North Carolina are quite limited in their distribution. The larger of the two areas begins near Oxford, in Granville County, and extends southwestward, passing into South Carolina below Wadesboro. It has its maximum width of about sixteen miles between Chapel Hill and Cary, and its average width is less than ten miles. It occupies the southern portion of Granville County, the southern half of Durham, the western border of Wake, the southeastern border of Chatham, and portions of Moore, Montgomery, Anson and Richmond counties. The other sandstone area is much more limited in extent. It lies mainly in Stokes and Rockingham counties, along the Dan river, between Germantown and the Virginia line, a length of not more than thirty miles, and a maximum width of not more than five miles.

Fortunately for the roads leading through these sandstone areas, there is an abundance of a hard, black, tough, fine-grained rock, known as diabase, or trap, occurring in dykes which have broken through the sandstone and now appear on the surface in lines of more or less rounded black masses of rock running nearly north and south. These dykes vary in width from a few feet to more than one hundred feet, and are separated from one another by distances varying from a few yards to two or three miles. A dozen or more of these dykes are crossed by the wagon road between Chapel Hill and Morrisville. Several dykes occur at and near Durham, and the rock has been used upon roads leading out from Durham, but unfortunately it has not been crushed into small fragments, as should have been done, and hence the result has not been altogether satisfactory.

There is, probably, in both these sandstone areas a sufficient amount of trap rock to properly macadamize every prominent road that crosses them, and, after this has been done, to furnish a top dressing for all public roads which are likely to be macadamized in the adjacent counties.

Trap Rock in Other Areas.—Fortunately, this excellent road material is, in its occurrence, not limited to the sandstone regions. Dykes quite similar to those which abound in the areas just described are also found extending across the country in many of the midland and Piedmont counties, and also the region west of the Blue Ridge.

Heretofore this black, "nigger-head" rock, as it is frequently called, has been regarded as a useless encumbrance of the ground; now, in connection with the move for better roads, it must be regarded as one of our most valuable rocks. The city of Winston has already made extensive use of it in macadamizing its streets, with excellent results.

The Eastern Granite Belts.—Granitic rocks are abundant over considerable areas in the midland and Piedmont counties, and especially in the former. One of these important areas may be called, as a matter of convenience, the Raleigh granite belt; which, in a general way, may be described as enclosed by lines drawn from Gaston to Smithfield, thence to a point midway between Raleigh and Cary, and thence a little east of north to the Virginia line. This belt occupies a considerable part of Wake, including the region about Raleigh, of Franklin, and practically the whole of Warren and Vance counties. The principal rocks of this belt are a light-colored gray, comparatively fine-grained, granite and gneiss; on the whole, a fairly good material for road construction. The rocks vary in composition and in appearance at different localities, but are fairly uniform in character over considerable areas. In some places the black or biotite mica is largely wanting, and the rock assumes a whitish feldspathic character; at other points the mica becomes abundant, and the rock assumes a dark gray color. In places the mica is so abundant that the gneiss becomes somewhat schistose, or laminated, and in this condition crushes easily, hence should not be used on the roads. Dykes of trap rock are occasionally met with, and these should be used in preference to the gneiss and granite wherever accessible.

The somewhat isolated patches of granite lying east of this belt in Halifax, Nash, Edgecombe and Wilson counties have already been referred to.

West of the Raleigh belt there is another granite area of limited extent which occupies the extreme northeastern portion of Durham county and the larger part of Granville county. This may be called the Oxford granite belt. The rocks of this area resemble to some extent those of the Raleigh belt, but there is a larger proportion of syenitic and trap rocks, which make excellent road material.

The Central Granite Belt.—This belt extends obliquely across the State from near Roxboro, in Person county, to the South Carolina line along the southern border of Mecklenburg. Its width varies from ten to thirty miles, and it occupies a total area of about three thousand square miles in the following counties: western half of Person, including the region about Roxboro; the southeastern portion

of Caswell, the northwestern half of Alamance, the larger part of Guilford and Davidson, southeastern portions of Davie and Iredell, Lincoln and Gaston and the larger part of Rowan, Cabarrus and Mecklenburg. In this belt throughout its entire extent road material of most excellent quality is abundant. The prevailing characteristic rocks are syenite, dolerite (trap), greenstone, amphibolite, granite and porphyry; and, as will be seen from this list, the tough hornblende and angite rocks predominate. Dykes of trap rock, some of them of considerable extent, are to be found in almost every portion of the belt. So uniformly tough and durable are these materials, that one could hardly go amiss in making selections for road construction.

The Central State Belt.—This region lies just east of the central granite belt, and extends obliquely across the State from Virginia to South Carolina. Its eastern border lies against the Deep river sandstone basin described above (p. 23). It varies from twenty to forty miles in width and includes all or portions of the following counties: the eastern half of Person, the northwestern part of Durham, the southeastern part of Alamance, nearly all of Orange, Chatham, Randolph, Montgomery, Stanly and Union; the eastern part of Davidson and Rowan, and the northwestern part of Anson. A considerable portion of this area is rich in other mineral products, but the entire belt as compared with the central granite belt, is poor in road materials. The rocks are mostly siliceous and clay slates, with a considerable admixture of chloritic and hydromicaceous schists; all of which are at best inferior for road construction. Here and there, however, trap dykes are found in this belt; and in places the siliceous slates become somewhat massive, passing into hornstone and a quartzite, which, when crushed, will answer fairly well for macadamizing purposes. In other places the chloritic schists become somewhat massive and tough and can be used in the same way. In still other places, as about the State University, and along the eastern border of Orange County, the rock is a fine-grained, tough syenite, accompanied by trap dykes, and is eminently suited for road purposes; and again, as near Hillsboro, granite occurs in a limited area. Vein quartz ("white flint") is abundant in many parts of the belt; and, though not usually recommended as road material, is worthy of consideration. While then, on the whole the rocks of this belt are not suitable for use as road material, yet a careful search will show the existence of a sufficient quantity of material of fair quality to macadamize all the public roads. And should this supply ever prove insufficient, excellent materials are to be found in abundance in the granite belt along the western border of this region, and in the trap dykes of the sandstone on the eastern border.

The Gneisses and Other Rocks of the Piedmont Counties.—West of the central granite belt as described above, and extending back to the foot-hills of the Blue Ridge, is the region occupied by the Piedmont counties—Rockingham, Stokes, Forsyth, Yadkin, Surry, Wilkes, Davie, Iredell, Alexander, Caldwell, Burke, McDowell, Rutherford, Polk, Cleveland, Catawba, Lincoln and Gaston. The rocks of this region resemble in many respects those of the Raleigh granite belt. They consist of a succession of gneisses, schists and slates, more hornblendic toward the east and more micaceous toward the west, with here and there masses and dykes of syenite, trap and other eruptive rocks. In places, as at Mount Airy, the true granite occurs in considerable abundance. The granites and gneisses, except where the latter tend to split into thin layers and crush, are fairly good materials for road construction, improving as they become finer in grain and as the percentage of hornblende increases; but the best material for road construction is to be found in the trap dykes and syenite ledges which at intervals traverse this region, more especially its eastern half.

The Gneisses and Other Rocks of the Mountain Counties.—The rocks of this region are not greatly unlike those of the Piedmont counties just described. Over much the larger part of the area rock fairly well adapted to road construction is abundant, indeed so abundant that the laborers on the public roads in that region during the past half century have expended the larger part of their time and energy in endeavoring to get this rock out of the way. Had they expended this time and energy in crushing the rock and spreading it over a well-formed foundation, this region would possess at the present time a number of excellent macadamized highways.

In the more northern counties—Alleghany, Ashe and Watauga—the predominating rocks are hornblende gneiss and slate, but massive syenites are abundant, especially between Rich mountain in Watauga and Negro mountain in Ashe county, and elsewhere. Further southwest, through Mitchell, Yancey, Madison and Buncombe counties, hornblende schists still continue, but they are more massive, and the gneisses predominate. These are, on the whole, compact and sufficiently tough for use in the construction of good Macadam roads. And the statement just made concerning these counties is also applicable to Henderson, Transylvania and Haywood counties, and in a measure to Jackson, Swain and Macon counties and the eastern half of Clay county, in all of which the supply of good road material is ample; but in these last three counties mica schist partially replaces the hornblende slate. In the western part of Swain, in Graham, Cherokee

and the western part of Clay county good road material is not so abundant as in the other counties named, but nevertheless is to be found in considerable quantities. The rocks over a considerable portion of this last-named area are micaceous and hydro-micaceous in character, and are practically worthless for the purposes of road building, but the quartzite ledges and beds of limestone in these counties will furnish ample and suitable material.

In conclusion, it may be said that in the middle and western counties of North Carolina material suitable for macadamizing the public highways is abundant and generally accessible. It will be the exception, rather than the rule, that this material will have to be transported for any considerable distance. In the eastern counties materials suitable for this purpose are inferior in quality and only moderately abundant in quantity, but the extensive and intelligent use of even these materials would very greatly improve the public roads and thereby increase the prosperity of the people. And in many places where the Macadam road is at present out of the question on account of the lack of stone, other materials, gravel, clay, loam and plank will be found in sufficient abundance to make the construction of better roads practicable, at reasonable cost.

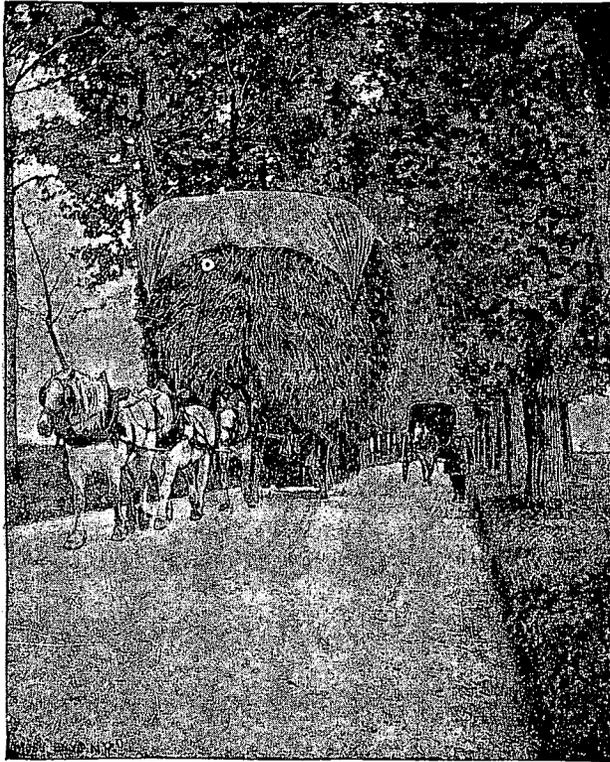


Fig. 4.—AN ENGLISH COUNTRY ROAD OF TO-DAY, MACADAMIZED.
(FROM "GOOD ROADS.")

CHAPTER TWO.

THE PUBLIC ROAD PROBLEM IN NORTH CAROLINA.

It has been well said that * "Every member of society is interested in the public road. At birth, at death, and at all intermediate points during life it is used, to a greater or less degree, by or for every individual member of society. It carries the doctor to the bedside of the sick, the minister to administer consolation to the dying, friends to the



From "GOOD ROADS."

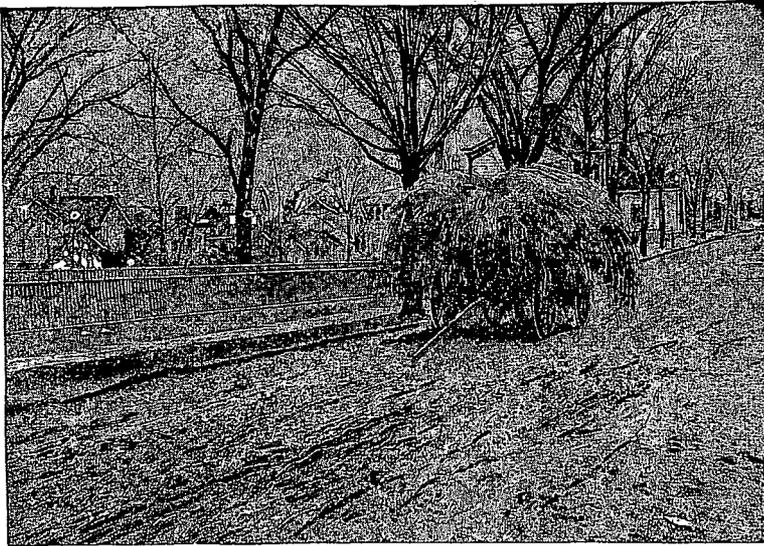
Fig. 5.—A LOAD OF HAY SUCH AS IS ORDINARILY HAULED ON A MACADAMIZED FRENCH ROAD.

house of mourning, and the dead to their graves. It brings purchaser and consumer together. It is the avenue alike of pleasure and of traffic. The farmer seeking his market, the commercial traveller looking for customers, the millionaire in search of enjoyment with his coach-

* Ex-Governor Beaver, of Pennsylvania, in the *Forum*, Vol. XIII, 1892, p. 773.

and-four, the wheelman in the pursuit of health, the few seeking pleasure and profit on wheels, and the many in like pursuits on foot—all are interested in the public roads. And yet, direct and immediate as these interests are, we are content to follow the methods of half a century or more ago, to submit to inconvenience, to discomfort, and to the immense waste of money and patience.”

The greatest obstacle in the way of the move for better roads among the American people, who are always loth to increase the “burdens of taxation,” is the item of cost; and this will continue to be the case until the people come to realize the fact that *bad roads cost more than good roads*. But the campaign of education has already begun, and in the hope of aiding in this work I have introduced the few following facts concerning certain items of cost.



From "GOOD ROADS."

Fig. 6.—A LOAD OF HAY WHICH TWO LARGE HORSES WERE UNABLE TO PULL ON A MUDDY AMERICAN DIRT ROAD.

*Cost of Wagon Transportation.**—“It is apparent that but few people comprehend the cost of transportation by horses and wagons, or realize the amount of money annually wasted by the ill condition of the roadways.”

The following table “shows from actual observation the cost of moving a load of one ton a distance of one mile on level roadways with different pavements in the usual condition in which they are maintained. The excessive amount of these charges is seen, when it is

* Byrne, p. 2.

remembered that the same goods using the roadways are now carried by the railroads at an average cost of $\frac{1}{16}$ of a cent" per ton per mile:

COST OF TRANSPORTATION BY HORSES AND WAGONS, HAULING ONE TON A DISTANCE OF ONE MILE ON DIFFERENT ROAD-COVERINGS.

On iron rails.....	1.28 cents.
" asphalt.....	2.70 "
" stone, paving, dry, and in good order.....	5.33 "
" " " ordinary condition.....	12.00 "
" " " covered with mud.....	21.30 "
" broken stone road, dry, and in good order.....	8.00 "
" " " " moist and in good order.....	10.30 "
" " " " ordinary condition.....	11.90 "
" " " " covered with mud.....	14.30 "
" " " " with ruts and mud.....	26.00 "
" earth, dry and hard.....	18.00 "
" " with ruts and mud.....	39.00 "
" gravel, loose.....	51.60 "
" " compacted.....	12.80 "
" plank, good condition.....	8.80 "
" sand, wet.....	32.60 "
" sand, dry.....	64.00 "

It will be seen from the above table that in hauling a load of one ton over one mile of level road, it costs more than twice as much to haul this load over the best dry dirt road, about five times as much to haul it over a moderately muddy dirt road, and eight times as much on a dry, deep-sandy road, as it does to haul the same load the same distance on the best dry, broken-stone or macadamized road. These facts, and others given below in this and the following chapter, will serve to show that better roads are needed in every section of the State—in the east as well as in the west—and that our bad roads in every section are a heavy and expensive burden.

The following table,* showing the load which a horse can draw on different grades, will serve to illustrate the fact that the many steep hills on the roads through the middle and western counties of the State are a serious drawback to travel, and a heavy item of expense. The fact that such is the case will be all the more apparent when we remember that the weight of a load which a team can haul is limited, not to what it can pull over the larger part of the road, but to what it can pull up a certain hill over which the road passes, or across a certain muddy flat through which the road may lead.

* Byrne, p. 270.

LOAD A HORSE CAN DRAW ON DIFFERENT GRADES ON THE VERY BEST MACADAM ROAD.

Rate of Grade, Feet per 100 Feet.	Equivalent Length of Level Road—Miles.	Maximum Load in Pounds which a horse can haul.
Level surface, very best Macadam road	1.000	6,270
1 foot rise in 100 feet, "	1.500	4,145
2 feet rise in 100 feet, "	2.000	3,114
3 feet rise in 100 feet, "	2.484	2,486
5 feet rise in 100 feet, "	3.444	1,800
7 feet rise in 100 feet, "	4.844	1,367
10 feet rise in 100 feet, "	5.977	1,080

It will be seen from this table that an average horse weighing 1,200 pounds can pull six times as much on a good level road as he can pull up a hill which rises 10 feet in a distance of 100 feet (and such hills are numerous in the middle and western counties of North Carolina); and it also shows that on such a good road it requires as much force to haul a given load up a mile of such steep grades as it does to haul the same load over 6 miles (5.977) on a level surface. In the following chapter of this report it is shown still more clearly that a single steep hill may double, or even quadruple, the cost of hauling over a given section of road.

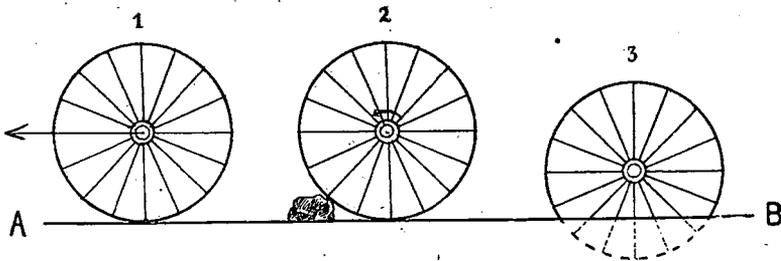


Fig. 7.—ILLUSTRATING THE DISADVANTAGES OF BAD ROADS. NO. 1 REPRESENTS A WHEEL ON THE SMOOTH HARD SURFACE OF A GOOD ROAD WHICH OFFERS VERY LITTLE RESISTANCE TO THE FORWARD MOVEMENT OF THE LOADED VEHICLE. NO. 2 IS A WHEEL RESTING ON THE HARD SURFACE OF A ROAD COVERED WITH LOOSE OR PERMANENT FRAGMENTS OF STONE. NO. 3 IS A WHEEL PARTLY SUNK INTO THE SURFACE OF A MUDDY ROAD.

The accompanying figure will serve to illustrate some of the obstacles in the way of hauling heavy loads over the ordinary dirt highways. Wheel No. 1 of the figure is supposed to rest on the smooth hard surface of a good Macadam road. It does not sink into the surface and has no obstacles in front of it; consequently it is easily pulled forward whatever weight it may bear. Wheel No. 2 also rests upon a smooth hard surface, but there is a stone in front of it; and before it can

move forward the horse must not only pull the load but must also actually lift one-fourth of the entire weight of the load and vehicle to the top of the stone—supposing that the vehicle has four wheels; if it has two wheels he must lift half of the total weight. Wheel No. 3 is supposed to be on (or in) a winter-time dirt road and has sunk in mud half-way to the hub. Before going forward the horse must either lift this wheel out of the mud, in which case he must not only lift the entire weight of the load—supposing all of the wheels to be in the mud—but he must also lift an indefinite weight of mud and overcome a considerable amount of friction between the sides of the rim of the wheel and the mud into which the wheel has sunk before he can raise the vehicle on to a hard road surface again.

Other Items in the Cost of Bad Roads.—In estimating further the cost of bad roads, we should take into consideration the loss of time by horses and men, the cost of maintaining the same during such lost time, the injuries and the wear and tear to the horses, vehicles and harness caused by the bad roads. We should also take into consideration the small loads that must be hauled over these roads, frequently not one-fourth of a full load, and we must bear in mind the fact that during the winter months, when ordinary farm work cannot be carried on, is the time when wagons and teams should be mostly used on the roads in going back and forth to markets, etc., but this is just the season when many of the public highways become well-nigh impassable, even with light loads. It must also be remembered that bad roads keep down the selling and taxable value of lands and all other real estate, while good roads raise these values, as will be brought out more clearly below.

In the eastern counties there are many places where the soil is clayey or marshy, and where the roads become impassable for loaded vehicles during wet weather; but in the sandy regions, while the roads are always bad and make wagon transportation costly, hauling over them is less costly when the sand is wet than when it is dry. In the middle and western counties, however, it is during the wet weather that the roads become so bad as to be practically impassable for loaded vehicles for from four to twelve weeks of each year.

In order to determine approximately how much our bad roads cost the people of the State, let us see first how much four weeks of impassable roads cost in the middle and western counties, and then how much the bad roads of the whole State cost us during other portions of the year by increasing the number of horses and mules which must be purchased and fed, the number of teamsters who must be paid, and

the number of wagons and harness which must be purchased and kept in repair, because in travelling and hauling we use these bad roads instead of good roads. We have now in the State, in round numbers, 260,000 horses and mules.* We may deduct from this number 50,000 which, in the cities and towns, can be used during the entire year, and there remain 210,000 horses and mules which, for our present purpose, may be designated country horses and mules.

Adopting the line of geographical division described on page 20, we may credit 134,000 of these to the fifty-six middle and western counties, and 76,000 to the forty eastern counties. These 134,000 country horses and mules credited to the middle and western counties cannot be used during four weeks of the year on account of bad roads. The cost of feeding them per day, at twenty cents each is \$26,800, which for the four weeks amounts to \$750,400. Now let us add to this the item of the loss of time for these animals. Putting this at twenty-five cents per day (twenty-four days), we see another source of loss amounting to \$804,000. These two items give us a total of \$1,554,400 per annum which may be charged against the impassable public roads. Let us add to this the cost of the following items which will amount in the aggregate to certainly not less than \$50,000: (1) Value of the service of ox-teams and the cost of feeding them during the four weeks; (2) and the loss farmers sustain by not being able to carry farm produce, tobacco, cotton, etc., to markets at times when prices are highest; and the result presents at a reasonable estimate, a total loss of more than \$1,600,000 per annum to be charged against, excessively bad public roads in North Carolina during these four weeks.

We may suppose that one man was employed in the management of each pair of these 134,000 horses and mules of the midland and western counties. Of these 67,000 teamsters we may fairly suppose that one-half of their time during the four weeks lost by the horses and mules was profitably employed in other ways about the farms; but we may also fairly consider the other half of their time as lost on account of bad roads. Valuing the services of these men at fifty cents per day and charging one-half of this as lost, owing to bad roads, we have 67,000 men at twenty-five cents, equal to \$16,750 per day; and for four weeks \$402,000. While this is believed to be a real loss due to bad roads it will not be included in the final estimates of the total loss, because

*The number of horses and mules in North Carolina during 1891, as given in the Auditor's Report for 1892, p. 107, is 253,614. The increase from 1890 to 1891 was 13,046, hence the number for 1893 may be safely estimated at 260,000; and supposing that these additional horses and mules to be distributed among the several counties in the same proportions as existed in 1891, we may estimate, after deducting the 50,000 town horses and mules, the remaining number of country horses and mules now in the fifty-six middle and western counties as 134,000, and the number in the eastern counties as 76,000.

there is a reasonable doubt as to the amount of actual loss from this source.

But then there is another large item that must be taken into consideration. I have estimated that this \$1,600,000 per annum is lost during four weeks when the roads are so bad as to practically prevent all hauling. But it must be remembered that even when the dirt road is in good average condition, the loads hauled are not more than one-third those hauled on good Macadam highways. The average load for one horse on a macadamized country road in France is said to be two or three tons, and on the paved streets of a French city one horse often pulls three to five tons; whereas, taken month in and month out, the load for one horse on the average American dirt road is less than half a ton. It can therefore be safely claimed that if we had good macadamized roads, the hauling we now do in two months could be done in less than half the time; or if extended over two months, it could be done by less than half the teams and teamsters and wagons now employed.

Of our 210,000 country horses and mules, including the eastern as well as the western counties, of course many of them do but little hauling on the public roads at any time; but there are also quite a number that spend the larger part of the year on the road; and there are others which go on the road at irregular intervals as there is extra hauling to be done. It is probably safe to estimate that all the hauling over the public roads during the year would require the constant employment of the entire 210,000 horses and mules and 105,000 teamsters and wagons during at least two months, with the roads in their present average condition, and would require their employment during one month on good Macadam roads. Here, then, is an important item of loss on account of bad roads, *i. e.*, the services and cost of maintenance of these horses and mules, teamsters, wagons and harness during one month. In this case it is manifestly proper to include in the estimate the wages of teamsters, who spend all of their time with the teams and are paid full wages, while the teams are pulling half loads, and hence losing half of the time. Valuing the services of these 210,000 horses and mules at twenty-five cents per day each (twenty-four days), we have an item of \$1,260,000; estimating their feed per day at twenty cents each,* twenty-eight days, we have another item of \$1,176,000; and these combined show a loss of \$2,436,000 for the

* It is generally estimated that to feed a horse or mule while regularly at work costs twenty-five cents per day; and while this is probably correct for horses where the feed has to be bought at the average market prices, where the corn, fodder and oats are grown on the farm and hence are to be valued at prices for which they can be sold on the farm, I have estimated the cost of feeding a horse while at work at twenty cents per day.

month. The pay of 105,000 teamsters, estimated at fifty cents per day each, gives an item of \$52,500 per day and \$1,260,000 for the four weeks. The wear and tear on the 105,000 wagons and harness, if placed at ten cents per day while in constant use, gives an item of \$10,500 per day and \$252,600 for the four weeks. Add these several items and we have a sum of \$3,948,000 annually lost to the people of the State by having poorly laid out and constructed dirt roads instead of good Macadam roads, not including the loss during the four weeks when the roads are impassable. That this is an actual loss will be seen more clearly when we understand that the amount of hauling which could be done at a profit will greatly increase as we make good roads, and thus reduce the cost of wagon transportation.

But there is yet another item which must be included in this general estimate before the grand total is reached. In the beginning of this discussion we left out of consideration fifty thousand of the horses and mules in the State as being approximately the number about the cities and towns which can be used throughout the entire year. The suburban roads and many of the streets of these towns, however, are kept in such poor condition that we may safely estimate that if these streets and suburban roads were properly macadamized, these 50,000 horses and mules and their drivers could do twice the work they now do, or one-half of them could easily do all the hauling now done, and the other half might thus be easily dispensed with, and the cost of horse feed, wagons, harness and teamsters saved. Let us see what this saving would amount to if the latter plan were adopted. It costs to feed these 25,000 horses and mules, at twenty-five cents* per day each for the year, in round numbers, the sum of \$2,281,000; and for these horses 12,500 teamsters are required, which, at fifty cents per day, cost for 300 days \$1,875,000; and 12,500 wagons and harness, at ten cents per day (for 300 days), \$375,000; making a total of about \$4,531,000 per annum from these sources, which may fairly be charged against our inferior roads and streets.

If we now estimate that there are in the State 220,000 citizens† who are liable to work on the public roads four days of each year, and value their services at fifty cents per day, we have the sum of \$440,000, which, whether expended in money or muscle, may be considered an annual tax for public roads. But, in spite of this large expenditure, year after

* See note on page 34.

† The poll-list for 1891, which is supposed to include all male citizens between the ages of twenty-one and fifty years, shows 221,530 individuals. The general road law makes all male citizens between the ages of eighteen and forty-five years liable for work on public roads, and the total number of such persons is hardly smaller than the poll-list.

year and decade after decade, we have not in the State to-day a public highway worthy of the name.

Let us now bring together the results of these several estimates :

Loss on account of the cost of feeding, and loss of time by the 134,000 country horses and mules in the middle and western counties, during four weeks of impassable roads, etc., (p. 33).....	\$ 1,600,000
Loss, on account of bad roads, of the time and expenses of maintenance of 210,000 country horses and mules, 105,000 wagons and harness, and wages of 105,000 teamsters, during one month (p. 34).....	3,948,000
Loss, on account of bad roads, of the services and expense of feeding 25,000 town horses, and services of 12,500 teamsters, and wear and tear on 12,500 wagons and harness, all of which could be saved by having good roads and streets (p. 35).....	4,531,000
Wasted in working public roads in taxes and labor (p. 35).....	440,000
Total	\$10,519,000

The aggregate of these several items gives a grand total of over ten million dollars, which sum the people of the State lose annually on account of bad roads, and which sum might be saved annually to the State by a system of good macadamized roads.

I am aware that many will question these astonishing figures, but they are careful estimates—not random guesses. And while admitting that there are many sources of possible error, I am satisfied that whoever examines the estimates candidly will be profoundly impressed with the fact that on account of these bad roads the people of North Carolina are suffering yearly enormous losses without any compensating return, and of the magnitude of which they seem to be hardly conscious; and it must be remembered that every year, as trade increases, and with it the number of horses and wagons and teamsters, we must use these bad roads more and more, and the losses they entail thus increase annually. These losses are, in an important sense, equivalent to an annual tax on the people of the State of ten million dollars, paid largely by the farmers who own the stock and wagons, but paid also in part by every man, woman and child in the State.

England and France each expend eighteen million or more dollars annually in the maintenance and extension of their splendid systems of macadamized highways, and regard the investment a good one; but the people of North Carolina, too poor, as they claim, to build good roads, nevertheless bear annually this enormous burden for the privilege, as it were, of doing without them.

And what do we get in return for this large drain upon the wealth of our people? A system of dirt roads, sandy in one region and clayey in another, which, as compared with macadamized highways, retard or prevent travel; diminish or prevent investment of capital;

keep intelligent settlers away; retard and greatly increase the expense of all transportation and exchange of commodities between farms and markets; decrease the profits of farming; interfere in the country with proper attendance at the schools and at churches; prevent proper social intercourse among people in the country, and between those living in the country and those in towns; make young people and old people dissatisfied with living in the country and anxious to move to towns and cities, where they can walk, ride or drive with some degree of comfort; keep down the value of all lands and other real estate; prevent the inauguration of many mining, manufacturing and other enterprises, by making wagon transportation too expensive. In a word: in exchange for this heavy annual burden we have an expensive system of bad roads which greatly retards the material, social and intellectual development of our people, and is a standing discredit to our civilization.

And how long will this continue to be the case? What are we waiting for? How long will it be before the intelligent men of the State join earnestly in this move for better roads? How long will it be before our people, instead of asking for a "reduction of the burdens of taxation," already exceptionally light, will come to understand that it will pay to expend a considerably larger portion of our labor and money in the development of such internal improvements as the construction of better public roads? How long will it be before we all come to realize the imperative need of better roads sufficiently to determine to have them, whatever sacrifice may be necessary in order to pay for them? If we wait until the country increases in wealth we may expect to "make haste slowly," for certain it is that bad roads tend to perpetuate our poverty, and as equally certain it is that good roads tend to increase the wealth and prosperity of the people.

Farming lands in many parts of the United States during the past few years have decreased in value. Ex-Governor Campbell stated recently that this decrease in value of farming lands amounts in Ohio to \$220,000,000 in ten years. The abandoned farms in many States are numerous. The mortgage indebtedness of American farms during the past few years has increased at the rate of \$2,500,000 per annum.

After mentioning these facts in a recent article in the *Forum*, Mr. I. B. Potter continues: *

"It is of course no easy task to charge these sluggish conditions and shifting fortunes of agriculture to any certain cause; but, in searching for a solution, certain facts appear with such conspicuous prominence as to make them worthy of mention; viz., that with the same physical conditions, the same market, and unchanged prices of

*Vol. XII, 1891-'92, p. 380.

farm produce, the American farm has in late years substantially declined in the market value; that the value of farm-produce in a given locality is, in general, determined by the price offered in the local market; that the farmer pays the same for all that he buys, and gets no more for what he sells, whether his farm be near or distant from the market-town; that under these conditions the most immediate means of relief is to diminish the total cost of placing this produce in the market-town; that an amazing share of this cost is made up by the difficulties of wagon-road transportation, necessitating scant loads, long delays, mud blockades, breakdowns, and extra trips; that these or similar hampering conditions are tolerated by no other industrial class within the nation; and finally, that the quickening means for work, travel, and transportation adopted within and between the mercantile industries of the different towns have added to the attractiveness and profits of these pursuits, and by force of contrast have detracted from the commercial value of the neighboring farms."

The depression among agricultural interests during recent years is indeed a complicated question, and concerning its causes and remedies there are grave differences of opinion; but there is among the thoughtful statesmen of to-day a striking unanimity of belief that bad roads are a large factor in causing this depression, and that good roads will greatly aid in relieving it.

The cost of good roads.—I have endeavored to show above approximately how much our present system of bad roads costs the people of the State; and in stating this at \$10,000,000 per annum, I believe that this estimate is below rather than above the actual loss. It must be apparent to every one that at any reasonable cost per mile, the annual expenditure of a small portion of this sum in road improvement would give us a system of public highways, which in a short time would much more than pay for themselves.

The cost per mile of the improved public roads will be discussed more fully in the next chapter, in connection with the treatment of the methods of construction. Of course the cost will depend largely upon the kind of road to be made, but it may as well be clearly understood that the construction of any public highway which is to be worthy of the name, and which is to be of any real and lasting benefit to the communities through which it passes is an expensive undertaking. The re-surveying, grading, proper drainage and other work in improving a good dirt road, may cost under different conditions from \$100 to \$500 per mile. Macadamizing these dirt roads, already graded and drained, with different widths of road, different thicknesses of broken stone and other varying conditions, may cost from \$1,000 to \$10,000 per mile.

Does it pay to build good roads?—In view of this large outlay necessary for the construction of good roads, let us face the issue squarely and ask ourselves the question: Does the investment pay? Are the disadvantages of bad roads on the one hand and the advantages of

good roads on the other, sufficient to warrant the large expenditures necessary for the construction of better public highways? In view of the fact that most of us have had but little opportunity to become acquainted with good roads and their advantages, it is clear that we must, in large measure, look to the experience of other States and other countries for a full answer to this question. In doing so, however, let us understand clearly our present position. We stand between the two horns of a dilemma, and we must accept one or the other. We may let our public roads remain as they now are, and continue to bear for this privilege a burden amounting to several millions a year without any compensating return; or by a smaller additional annual expenditure, in a few years we may in large measure rid ourselves of this burden, and meantime build a system of public highways which will bring unnumbered blessings to the people of the State.

England and Wales are said to expend annually \$20,000,000 in the maintenance of their public highways; and Scotland and Ireland expend large additional sums. The people of each of these countries regard the investment as a good one, and are even extending their costly roads.

France expends on her highways not less than eighteen million dollars per annum; and referring to the economic worth of these roads to the French people, Mr. Francis B. Loomis, commercial agent at St. Etienne, France, reports to the United States Department of State as follows:*

"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 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."

And if it be claimed that we should not look to these wealthy countries for our examples, we may turn to Australia and Canada, both of which have a system of public roads far superior to our own, even in regions more thinly settled and less wealthy.

In our own country, limited sections of macadamized roads have been built in portions of Massachusetts, Connecticut, Rhode Island, New Jersey, Pennsylvania, Indiana, Kentucky, Tennessee, Virginia

*Streets and Highways of Foreign Countries, Consular Reports, United States Department of State, Government Printing Office, 1891, p. 51.

and other States. And in every case where a sufficient amount of money has been raised for the construction of really good roads, whether by tax levy or sale of bonds, the people generally have regarded the investment as a good one, and have been more than satisfied with the result.

For example, Union county, New Jersey, in 1889 issued \$300,000 worth of four per cent. bonds, and raised by taxation \$25,000 each for 1889 and 1890, making a total of \$350,000, which was expended in the construction of good Macadam roads, beginning in 1889 and completing the work early in 1891.* Before the improvement work began "the roads were dusty, sandy, stony, or so muddy that they were impassable, and so dangerous that the road authorities were indicted year after year by grand juries. All the land was *simply out of the market*; nobody wanted it." One piece of property of twenty acres, with house and other buildings, within a mile of Elizabeth, was a drug in the market for years at \$6,500, and was finally sold at \$6,000, before the Macadam roads were built. Within a year after the roads were completed the owner refused \$30,000 for it, without having invested a dollar in improvements.

"The accretion of new wealth, induced to come to the county by the good roads, aggregates several times the cost of the roads. Farmers say that under no consideration would they return to the old system. Some of them say that the new roads have raised the value of property as a whole along them, from fifty to one hundred per cent. Others declare that the saving in harness, wagons, horses, etc., is equal to the amount paid for the roads." One of the new macadamized roads runs parallel with the Central Railroad of New Jersey, and along this line four new stations have been erected and promising towns started. Notwithstanding the payment of the interest on the bonds and special tax for two years, the rate of taxation was not appreciably increased; but on the contrary, was one cent less on the one hundred dollars in 1892 than it was before the construction of the new roads was begun. This is to be explained by the fact that from the beginning of 1889 to end of 1892 the increase in the value of property of the county amounted to nearly \$4,000,000. In every way these roads "have been a splendid success. They have far more than fulfilled every expectation and every promise made for them."

Along the line of the Shenandoah Turnpike, in the Valley of Virginia, the president of the company says that the construction of this

*The results of this liberal investment in road construction will be stated in "Good Roads" for March (1893), in a paper by Mr. Charles C. McBride, of Elizabeth, Union county, New Jersey, chairman of the New Jersey committee on good roads of the League of American Wheelmen. Through his kindness I am permitted to publish in advance the accompanying facts and extracts contained in a private letter to the writer.—J. A. H.

macadamized turnpike years ago raised the value of the property along its line more than twenty-five per cent.; and a like result is said to have attended the construction of similar turnpikes in other parts of this region.

In Wake, one of the larger and wealthier counties of our own State, Macadam roads are being constructed, and are giving general satisfaction. Here 100 miles of Macadam roads would be equivalent to six such roads averaging each 16.6 miles in length leading in different directions from Raleigh to near the county boundaries. That it would pay the people of Wake county to build these and other roads, even should they cost a large sum, and that this would raise the selling value of land and other real estate in the county 10 to 30 per cent. no one who has studied the question can doubt.

In Mecklenburg county, which has done more toward improving its public roads than any other of the counties of our own State, there has been an increase in the value of property along the macadamized roads, and the people are so well satisfied that the investment is a good one that they continue cheerfully to tax themselves to extend the work. And so it is in all countries, and so it will be in every county in our own State; wherever a sufficient extent of good roads has been constructed to enable people living along the line to realize their advantages they become satisfied that good roads are indispensable, and that it pays to build them, whatever sacrifice may be necessary in order to do so.

Mileage of Public Roads in North Carolina.—It is of course impossible to give accurately the total mileage of public roads in the State owing to the fact that the majority of these roads have never been carefully surveyed and measured. But an approximate estimate based upon the best maps obtainable and extended observations in many counties shows a total for the State of (1) about 10,000 miles of prominent public roads radiating from the county seats to the borders of the counties, and (2) about 10,000 miles of cross-roads leading through various portions of the several counties. (3) In addition to these there is a considerable mileage of roads—probably 20,000 miles in all, some of them public and some private—of comparatively little importance, which are not included in this estimate. This would give an average of about 200 miles of prominent public roads for each county in the State, *i. e.*, 100 miles of roads leading from the county seat out through the country, and 100 miles of cross-roads; and an average of 200 miles of lesser public and private roads for each county. In many of the larger counties the mileage is greater, and in many of the smaller counties it is less than this average.

A few Practical Suggestions.—Admitted that our present inferior roads tend to perpetuate our poverty and retard the development of the State; admitted that it will pay to build better roads, whatever reasonable sacrifice may be necessary in order to do so—it may not be out of place in concluding this chapter to offer a few suggestions relative to certain phases of the road problem in North Carolina.

In the introduction to this Report (pp. 14–16), I have stated some general conclusions which need not be repeated here. In Chapter I. I have endeavored to show that in the midland and western counties the materials out of which to construct good roads are abundant; and that even in the eastern counties, while stone is less abundant, or entirely wanting, the intelligent use of such materials as can be found in these counties will result in greatly improving the public roads.

The raising of funds sufficient for the work is the most urgent and difficult phase of the public road problem which now awaits solution. But there is everywhere in the State a growing recognition of the principle that in building and maintaining public roads, property should coöperate with labor; and hence that it is right and wise to raise funds for this purpose by taxation. In wealthier counties like Mecklenburg, Wake, Guilford, Forsyth, Cabarrus, Buncombe, Alamance and others, which are already entering upon the work of road improvement, the demand for better roads is becoming so urgent that the funds will be raised by taxation or bonds with increasing ease as the work progresses; but in the smaller and more thinly settled counties the raising of funds ample for this as well as other purposes becomes a serious problem.

Take, for example, the counties west of the Blue Ridge. From all that beautiful and interesting region between the Virginia line and Georgia, through which thousands of visitors would be delighted to drive every year—travel is practically excluded except along the railroads by the absence of good highways. The people living in these counties are becoming aroused to this fact; they see that good roads mean for them not only great saving in convenience, time and money in their own travel, but also great gain in the many thousands of dimes and dollars which these travellers would leave in every section through which they passed, and the addition of larger sums which many of them would invest in lands and homes. But how to raise in these sparsely settled communities money sufficient to build a costly system of highways is a problem not easily solved. It will never do to say that this cannot be done; for better public roads are an essential preliminary step in the development of this region. And what cannot be accomplished in a year for lack of sufficient means must be

accomplished by the united efforts of all classes of citizens during several years. In the achievement of this end in the sparsely settled and less wealthy counties, the following suggestions may be found of service:

Each county should raise by tax or bonds as large a fund as possible for use in road improvement; and the present general road law continuing in force, let property and labor (as should be the case) cooperate in this important work.

The money raised should be expended in the purchase of improved road machinery, and in the constant employment of a limited number of men who thus become trained in road building; and let the citizens living along the roads liable for road work be called out for this purpose, not all at once, but in limited numbers and at intervals (as suggested on p. 14).

The Boards of County Commissioners of the several counties should designate one or more prominent roads which shall be first improved, and add other important roads to this special list as rapidly as circumstances may permit. These special or "tax roads," as they are often called, should be selected both with reference to the convenience to the best markets for the people of the county, and to the attractions for the travelling public. The County Commissioners of each county should select an officer to be known as the Road Supervisor or Road Engineer who should personally superintend all the work of improving and maintaining these special roads. This officer should be selected with special care, and whenever possible the person selected should be a practical road engineer.

In the betterment of the main public thoroughfares, the several counties through which they pass should cooperate upon some plan arranged by the Boards of Commissioners of the several counties, in the working of their convicts on the road, in the purchase and use of improved road machinery, and in such other ways as may be deemed advisable.

In endeavoring to accomplish the greatest good with the least expenditure of money in this work, it will be found wise as described more fully in the next chapter: (1) To have the line of the entire road surveyed by a competent engineer, and the location changed in all places where the grade or road-bed can be greatly improved thereby; (2) the road should then be carefully graded, drained and rolled; (3) special sections of the road, where the soil in wet weather becomes quickly cut up into deep ruts, should be macadamized as rapidly as the funds will allow. After a few of the most important roads in each county have been treated in this way, the leading highway, on

which the work was first begun, may be macadamized throughout its entire length, and other important roads may be treated similarly, as circumstances permit or require. As illustrating the class of roads which it is here intended to designate as leading highways or roads of first importance in their communities, I may mention in the northwestern section of the State such roads as those from Sparta to Elkin, from Jefferson to Wilkesboro, from Wilkesboro to Lenoir, and from this latter road at Patterson a road *via* Blowing Rock to Boone; from Cranberry *via* Bakersville and Burnsville to Asheville, and from Bakersville to Marion. These roads with a few other connecting links—such as a road from Sparta *via* Jefferson and Boone to Cranberry—would open up this section of country and lead to its much more rapid development. Similar illustrations of leading highways can be supplied by the reader for every portion of the State with which he may be familiar.

In this connection it may also be wise to encourage the building of turnpikes by private companies. Many object to these roads because they have to pay toll-gate charges, but it is far cheaper to pay these nominal charges for the privilege of driving on a good road than it is to haul half loads and be severely jolted on a bad road for the privilege of traveling free. And if in our efforts to build good roads in thinly settled regions private companies are willing to coöperate in this way, their fair proposals should be welcomed. Subsequently, as the wealth of the community increases and the people are better able to do so, they can construct other roads or purchase these turnpikes on reasonable terms and open them to the public.

We have now in the State two striking illustrations, on a small scale, of the value of private enterprise in this connection. One is the "Shell road," extending from Wilmington to Wrightsville, which has for a number of years supplied a hard, smooth, excellent road both for those who drive in search of pleasure and those who with carts and wagons transfer various commodities between Wilmington and the sea-coast at Wrightsville sound. It is eight miles long, and in width averages about twenty-one feet. It extends through a level region, sandy and marshy at intervals. Ditches were dug on both sides two to four feet deep for the purpose of drainage, the soil removed from the ditches being used to raise the road-bed. In the center of this road-bed a space twelve to sixteen feet wide was covered six inches deep with oyster shells taken from Wrightsville sound. Traffic soon ground the uppermost shells to a powder, which cemented the whole mass and gave a smooth surface on top. The attractiveness of the driveway has been increased by the planting of trees on both sides. The road was built

as a private enterprise by Wilmington gentlemen between 1875 and 1881 at a total cost of nearly \$40,000.

The other of the two roads mentioned as built by private enterprise is the "Yonahlossee" road from Blowing Rock to Linville, which passes through the beautifully picturesque region along the southern slope of the Grandfather mountain, with a branch road extending to the top of this mountain. The main road is about twenty miles long, ten to fourteen feet in width, and was built at a total cost of about \$10,000 by the Linville Improvement Company, on the plan projected by Mr. Hugh MacRae, then president and treasurer of the Company. Its route was surveyed and the road constructed under the supervision of Mr. S. T. Kelsey during 1890 and 1891. The larger part of the road surface is of loam and gravel (decayed siliceous gneiss); but along the steep slope of the mountain a considerable amount of excavation was necessary, the materials dug out of the mountain side being used to build up the lower half of the road; and in many places considerable quantities of rock had to be blasted out of the way and then used in the construction of culverts and supports for the road on the lower side. The road is an excellent one for summer travel and leads through one of the most beautiful and interesting portions of the mountain region of North Carolina. A somewhat similar turnpike is now being built from Boone to Cranberry by a private company; and it is to be hoped that others may be constructed in the near future.

Societies should be organized in the State for the collection and distribution of information with reference to the improvement of public roads; and agricultural societies already in existence should cooperate in this work. Institutions for higher education should give instruction as to the modern methods of locating and constructing roads. And it is gratifying to know that this is already being done by the State University and a few of the colleges.

CHAPTER THREE.

NOTES ON COMMON ROAD CONSTRUCTION.*

The subject of highways is naturally divided into their location, construction, and maintenance; but the first is so peculiarly the province of the civil engineer that it is not treated, save incidentally, in what follows. An instrumental survey of a proposed line is absolutely necessary to insure the lightest grades with (as far as possible) the shortest distance that can economically be allowed.

It will be seen from facts given below that the economy resulting from reducing grades is much more marked than that in saving distance. A very little calculation will show the enormous reduction, for the entire State, of the annual cost of hauling by wagons which may be made by a proper revision of the location of most of our roads by simply reducing grades on portions of the line, as a single steep grade on a long line limits the load which may be hauled over the entire distance. And those who have these matters in charge cannot appreciate too soon nor too clearly the fact that the proper laying out and construction of a good wagon road requires well-nigh as much good judgment and engineering skill as do the surveying and building of a railroad.

Assuming that this work will be entrusted to experts, and that the lines of road will be properly located, there follows in order the grading, proper construction of the road-bed, its drainage, and the improvement of its surface—all to be accomplished before the road can be thrown open for travel. As the subject of grading is sufficiently well understood, it was thought best to confine attention to the proper drainage of the road-bed, its proper shape, and the improvement of its surface, with remarks on maintenance, which subjects are not so well known and are generally ignored by the average road overseer.

The subjects thus chosen will be grouped under the following headings:

- Drainage;*
- Earth Roads;*
- Telford and Macadam Roads;*
- Repairs of Broken-stone Roads;*
- Cost of Broken-stone Roads, and Repairs;*
- Gravel and Plank Roads;*
- Traction;*
- Grades.*

* Prepared by Wm. Cain, Mem. Am. Soc. C. E.; University of North Carolina.

The most important of these subjects, especially for the heavier clayey soils, is drainage, and to this attention will first be directed.

DRAINAGE.

In Sandy Regions.—The first principle of successful road construction is proper drainage. In the "sand hills" this is not so evident, as the porosity of the sand effects the purpose which drains are required to do elsewhere; and as a rule, except in long, rainy spells, too much water passes through the pores of the sand, leaving it a loose, pulverulent mass, on which horses have to exert about double the pull required on an ordinary earth road, and about seven to eight times the pull required on a good Macadam or a plank road. The sandy road is really better when moist, unless it has a covering of stone or other material, as it generally accomplishes of itself more than is required for proper drainage.

But the principle is brought home at once, even in sandy regions, when a low, miry bottom or morass has to be crossed. Here "the first principle" is to dig deep and wide ditches on either side of the road, and raise an embankment with the excavated material as much above the natural surface as is necessary to ensure a dry road-bed. These ditches should discharge into natural channels ultimately, and it is preferable to have them, as well as the embankment, on a grade, when practicable.

In Clayey Regions.—The principle is the same on grades throughout the clayey lands. Ditches from two to three feet deep should be dug on either side of the road, whenever the material is a tenacious clay, but as there is danger of vehicles getting into these ditches and upsetting, they should either be separated from the roadway by a fence as shown in Fig. 10, or covered as is shown in Fig. 11, B, or what is better still, by the use of road machines the road surface should be graded from the center gradually down to the gutter, as shown in Figs. 9, 12, 16 and 21; and *in all cases* the centre of the road should be higher than the sides, so that the water will discharge readily into the drains. This rise at the centre, for earth roads, should be at least one-fortieth the width of road surface proper, and it should be increased on grades one or more inches, so that the water will not run along the road, but quickly reach the gutter by a diagonal path. In clayey soils the rise in the center should be as much as one-thirtieth of the width of the road; and where there is no center drain the elevation is sometimes as much as one-twenty-fifth of the width.

Central Covered Drains.—Where the sub-soil is wet and full of springs, stone or tile drains are put in trenches, say eighteen to thirty inches deep, along the centre of the road (Fig. 9), connecting with cross drains at intervals of two hundred, three hundred, etc., feet, as the case may require. The drains may be made of any material, such as stone or brick, as well as tile, but the latter is preferable. Round tile is best, and if three inches in diameter is said not to cost (labor and materials included) more than twenty-two to thirty-five cents per foot. The

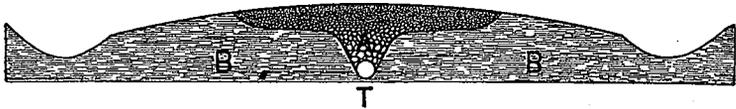


Fig. 9.—SHOWING CROSS SECTION OF DIRT-ROAD (B) WITH TILE DRAIN (T) IN THE CENTER FOR AIDING IN THE DRAINAGE OF THE SURFACE OF THE ROAD-BED IN CLAYEY SOILS.

A small quantity of straw may be placed just above the tile, and above this should be placed a quantity of coarse gravel or broken stone (A) and above this latter should be filled in with sandy loam or gravel as far as practicable. The depressions on both sides show the gutters or shallow ditches.

fall should be about two inches in ten feet, and not more than four inches in ten feet. The tile is made in lengths of one to two feet, and pieces of larger pipe fit on over the ends and connect the different lengths. The tile and covers should be carefully bedded in the earth throughout their entire length, to avoid breaking, and stones should be carefully packed around and over them to the top of the trench to relieve them of as much weight as possible. All "connections" should be made with Y branches, and silt basins are preferable at all junctions.

Diagonal Covered Drains.—These sub-drains are sometimes put diagonally across the road, meeting at a point at the centre, so as to form a V, with the point up hill. They should be placed twenty or thirty feet apart along the road in wet places.

Side Ditches.—In Europe, the ditches on either side of the road and running parallel with it, are often placed outside of the foot-paths (which are three to six feet wide), and a fence is built between the path proper and the ditch to keep the unwary from tumbling in. (See Fig. 10). In this case, the edge of the foot-path, which is about six inches above the gutter, is sodded, so that water falling on the road is conducted first to the open gutters, along which it runs without damage to the foot-path, and finally discharges by tile drains, about fifty feet apart, passing under the foot-path directly to the ditches. Where economy is desirable, the foot-paths may be omitted, and in fact the deep ditches are not necessary on grades as a rule, as

we see from analogy to the efficient drainage of railroad cuts. The common road may be drained in the same manner as a railway, by gutters or ditches on either edge of the road-bed, a foot to a foot and a half deep, the side of the cut forming one edge of the ditch. In very bad places, covered tile drains will be required under these gut-

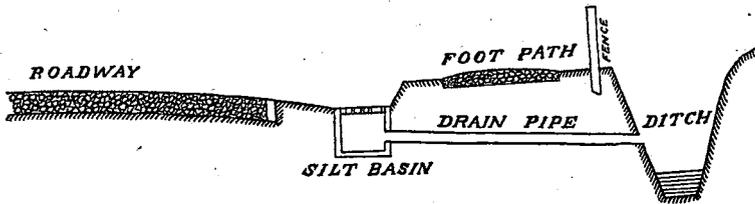


Fig. 10.—SHOWING CROSS SECTION OF A MACADAM ROAD WITH FOOT PATH PROVIDED, AS IN MANY PARTS OF EUROPE, FOR THE EXCLUSIVE USE OF PEDESTRIANS.

ters, say two or three feet deep. (See Fig. 11, B, page 50.) Where water is liable to run over the top edge of a cut, catch-water drains are made, running a few feet from the edge of the cut and parallel to the road, which should turn the running water away from the cut altogether to other channels or into the fields.

Culverts.—For culverts underneath embankments, large tile or stone drains are best. Wood should not be used for any kind of a drain, except temporarily, as it rots and invariably causes some accident. French drains, made by throwing in rocks into a trench in any order, are recommended by many, but the writer has found them a complete failure as a drain across an embankment, from silting up. It may take longer for the drain to close up or seal itself, in the case of sub-drains of common roads, as the water in them never runs with sufficient force to carry much silt, but in the end they will choke up and have to be replaced. Channels can sometimes be constructed in loose rock drains by selecting the rock for the covering of the little channel, but the tile drain is superior in every way and costs less than the stone drain.

The character of the road surface will often determine whether subsoil drains are required. Thus with a compact macadam covering the rain-water is conducted quickly to the gutters and comparatively little soaks through to form mud beneath the surface. A sand covering even is an aid, as it improves with moisture and protects the clay to a certain extent, as any excess of water can flow through it as well as over it to the gutters. On a clay road, however, the rain that falls is only in part carried to the gutters, even with a well formed surface. Much of the water soaks into the clay and is retained there and on

the surface together, especially when the road is cut up into ruts and holes, and no amount of side ditching under these circumstances can make a dry road-bed. As vehicles move over the soaked road, the tires cut into the wet clay and churn it up, so that it becomes worse and worse under travel and finally impassable from the mud, which can only dry off during a prolonged dry spell. The drains mentioned as running *under* the road are serviceable, but a good earth road can only be made in such clay soils by excavating a large part of the soil above and to either side of the subsoil drains and filling in with gravel or other material (as seen in Fig. 9), which will readily drain the water falling on it into the subdrains.

EARTH ROADS.

The common earth road containing much clay, can never be made satisfactory in wet weather; but by strict attention to the principles of drainage outlined above, it can be much improved and rendered a pleasant road to drive over during the larger part of the year. The usual method of constructing and repairing such roads in this State is an excellent example of how "not to do it." The road is worn or washed concave, so that water runs down its middle or remains upon the surface and soaks in, forming mud, and the repairs often consist of pine brush, sods, turf, or other perishable material, thrown into the holes and covered with earth; or, perhaps, rocks are thrown in when convenient, the result being a non-homogeneous surface, which is bound to wear into holes again. The road surface should be *homogeneous*, of

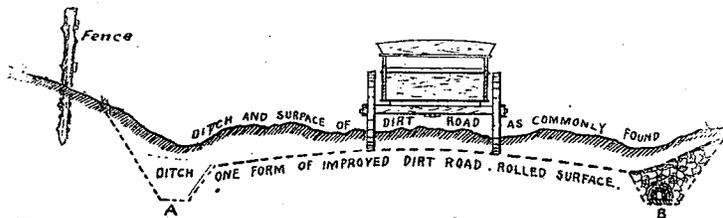


Fig. 11.—CROSS SECTION OF DIRT ROAD SHOWING COMMON FORM OF BADLY SHAPED SURFACE, TENDING TO BAD DRAINAGE AND PERMITTING WAGON WHEELS TO SINK INTO THE SOFT SURFACE. ALSO SHOWING FORM OF IMPROVED DIRT ROAD SURFACE WITH PLAN (A) OF AN OPEN DITCH ON ONE SIDE, AND PLAN (B) OF A COVERED TILE DRAIN ON THE OTHER SIDE. [From *Good Roads*.]

earth, or preferably of sand, gravel, shells, ashes, slag, &c., to render it as dry as possible, if the material of the road is clayey. In this case four inches of sand or gravel, well rolled, over only half the road, if there is not enough of it to cover the whole road surface, will make a wet weather road, the other half being suitable for dry weather.

If none of these materials are obtainable for covering the clay, Byrne recommends* the burning of the clay and spreading it on the road surface, which he estimates can be done at a cost for labor of about twenty or twenty-five cents per cubic yard; and he claims that when thus burnt, spread over the road surface and rolled, this clay makes a porous and serviceable road covering, easily drained. In clayey regions it is also well to keep all trees and shrubs large enough and near enough to shade the road cut away sufficiently to allow full access of sunlight for drying the road surface.

On sandy roads, clay may be added to the surface. The sand roads should have very light ditches—only enough to carry off the rain water—or none at all on the sand hills proper. The clay roads will need ditches from one to four feet deep on either side, as above explained, but with every precaution, in prolonged wet spells they are cut to pieces by the narrow tires of wagon wheels, and are barely passable. In the sandy regions of eastern counties it is possible in many places by deep plowing or ditching to bring up along the roadside a sufficient quantity of clay or loam which when mixed with the sand will pack and greatly improve the character of the road surface.

In these sandy regions, further, it is well to leave trees growing close by the road, with their limbs overhanging it, so that the shade may retard the drying of the surface and the leaves and twigs which fall upon the road may improve the surface by preventing the movement of sand by the wheels. As an aid in the accomplishment of the same purpose, the growth of grass and other small plants on the unused parts of the roadway should be encouraged. And, according to Byrne,† “A coating of four inches of loose straw will, in a few days travel, grind into the sand and become as hard and firm a dry clay road.”

Advantages of Wide Tires.—These tires should be two inches in width for the very lightest vehicle, up to six inches for those carrying the heaviest load per wheel. In France, “the freight and market wagons have tires from three to ten inches in width, usually from four to six inches. The four-wheeled freight wagons have tires rarely less than six inches, and the rear axle is about fourteen inches longer than the fore, so that the rear wheels run on a line about an inch outside of the line of the fore wheels. The varied gauge is also usually observed with cabs, hacks and other four-wheeled vehicles.” In many other countries the width of tire is limited by law, and in the interest of good roads, the restriction should be imposed in this State, or a

* Highway Construction, p. 451. † *Ibid.*, p. 453.

bonus should be offered, or exemption from payment of road tax granted for a time to all persons who use these wide tire wheels.

"Foreseeing the objection which might be raised to the great cost of supplying vehicles now in use with wide-tired wheels, an ingenious inventor has placed upon the market an adjustable wide tire, which may be made of any desired width and so constructed as to fit any of the wagon wheels now in common use. These tires are made by the Richardson Manufacturing Company, at Bath, N. Y. Both iron and steel are used in their construction (as may be desired by the purchaser), and they seem to have given much satisfaction during the brief time they have been in the market."*

Width of the Road.—As to the *width* of roadway or the space traversed by vehicles, 12 feet is barely sufficient for two vehicles to pass, but 16 feet is ample and is the usual width macadamized in this country, though sometimes only half this width is so treated, the other half remaining an earth road. For three vehicles abreast, 22 feet is a minimum common width; whilst 30 feet is ample for four vehicles, and is rarely exceeded except on thoroughfares leading into very large cities.

Bad Location of our Common Roads.—Our common clayey roads are in their best condition, say six months in the year; they are tolerable three more months, and are wretched or impassable during the remainder of the year. They will never be improved without proper supervision of men trained to the business, and this fact is especially evident when we consider the bad location of most of them. Only a trained engineer can properly re-locate these roads on ground and grade suitable for the traffic. As to the great yearly loss from steep grades, which are often easily avoided, see the latter part of this chapter.

TELFORD AND MACADAM ROADS.

The movement for better roads was placed on an intelligent basis in England when in 1816 Macadam introduced the system of broken stone pavements which now goes by his name. In the construction of these roads the stones were broken by hand by men, women and children to sizes not larger than two inches diameter, and laid on a convex earth surface in layers of about three inches each, to a total depth of six to ten inches. In a few years 25,000 miles of such roads were constructed, the effect of which was to open up a great area of country, increase values enormously, lessen very materially the cost

* *Good Roads*, Vol. II., No. 2 (Aug., 1892), p. 92.

of transportation, and incidentally tend to the enlightenment and increased civilization of the people.



Fig. 12.—CROSS-SECTION AND TOP VIEW OF COMPLETED MACADAM ROAD WITH PAVED SURFACE GUTTERS AT SIDES. [From the *Century Magazine*.*]

Macadam was followed by Telford, whose construction differed from his in adding generally a course of stones on a level earth foundation, seven inches in depth at the center and diminishing to three inches fifteen feet from the center (for a thirty-foot road), the stones to be set on their broadest edges and lengthwise across the road, the breadth of the upper edge not to exceed four inches in any case. All the

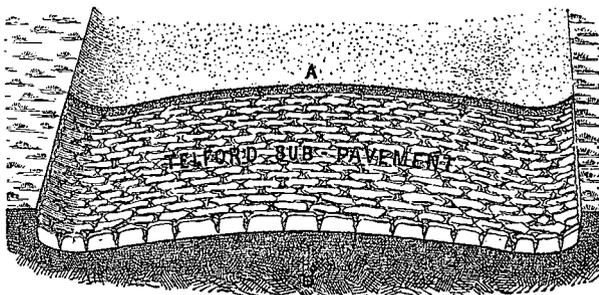


Fig. 13.—TOP VIEW AND CROSS-SECTION SHOWING METHOD OF CONSTRUCTING TELFORD ROADWAY. [From the *Century Magazine*.]

B is the rolled earth foundation on which is laid the sub-pavement as shown in Fig. 14. 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. 12.

irregularities of the upper part of this Telford pavement are to be broken off by the hammer and the interstices filled with stone chips firmly wedged or packed by hand with a light hammer. On this foundation of large stones a covering of six inches of macadam, or stones of one and a half to two inches or less in diameter, is placed and rolled in layers as usual, so as to form a smooth, tight surface which will be agreeable to traffic and shed water readily. The object of the founda-

* Plates for Figs. 12, 13, 14, 18, 19 and 20, used originally in the *Century Magazine*, were supplied for this bulletin by the O. S. Kelly Co., of Springfield, Ohio.

tion is to distribute the pressure over as large an area as possible, so that the surface covering will not sink anywhere, and which should insure a smoother road surface than where no foundation course is laid. Telford also allowed that this foundation might be of gravel or sand when stone could not be easily obtained.

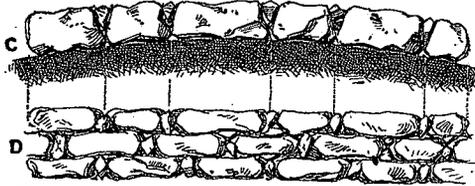


Fig. 14.—CROSS-SECTION (C) OF PORTION OF TELFORD SUB-PAVEMENT LAID ON ROLLED EARTH FOUNDATION, AND TOP VIEW (D) OF THREE PARTIAL COURSES OF SAME, SHOWING METHOD OF BREAKING JOINTS OF LARGER STONES AND WEDGING AND PACKING OF STONE CHIPS INTO VOIDS AND INTERSTICES. [From the *Century Magazine*.]

Macadam claimed that his roads of broken stone, made of small stones laid directly on the earth in layers aggregating from six to ten inches thick, made as good a surface as the Telford road, *when the earthen road-bed is well drained and well rolled*; and on this point experience has sustained his position.

Macadam versus Telford Roads.—The controversy over the relative merits of Telford and Macadam roads has waged continuously to this day. The opinions of the most experienced men in this country on the subject may be summed up as follows:

- (1) Generally, either system makes a good road when faithfully carried out;
- (2) The Telford system has a decided advantage in northern latitudes, where the frost penetrates the ground for several feet;
- (3) On a road-bed which cannot be drained thoroughly, the Telford should be used;
- (4) Where the soil is hard and gravelly, and not retentive of moisture, the Macadam pavement is a success anywhere; in fact, as far north as Bridgeport, Conn., a macadamized road only four inches thick on a dry foundation, has proved a great success;
- (5) The Telford pavement generally costs more than a simple macadamized road, though the difference for equally good roads is not great, since the foundation course of the Telford road can be made of inferior and softer stones and the hard metalling reserved for the top. This surface metalling can be thinner than for a Macadam road;

(6) If the roads are kept in good repair, there is little difference in their wearing quality, but if not repaired, the thinner Telford coating will sooner wear out, and then the foundation course will make one of the worst stone roads imaginable, whilst the Macadam road, if properly constructed, will be good nearly as long as it lasts. The Telford foundation in this case is so much loss and is a useless expense.

(7) Wherever the drainage is not good, the Macadam wears into ruts more readily than a Telford road.

I have recently measured the depth of frost at Chapel Hill during the prolonged cold weather of January, 1893, when the thermometer fell to 0° F., and find it to be 8½ inches. At and below this limit, it has been suggested that Macadam roads when properly drained, may be safely used, especially on steep grades where the water flows off quickly; hence for this State, it would seem that a Telford foundation is superfluous except in badly-drained soils. However, the proper construction of both systems will be given in what follows.

Cross Section.—It is now universally conceded by all, that the earthen road-bed on which the stone is laid, should not be level, as Telford recommended, but should be made parallel to the final stone surface which should always be higher at the middle than at the sides. The natural soil should be cut away to this curved form and all perishable matter removed and replaced with good earth.

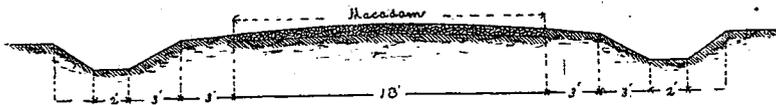


Fig. 15.—CROSS-SECTION OF MACADAM ROAD ON LEVEL GROUND, WITH SIDE GUTTERS OR DITCHES NOT PAVED. [From *Good Roads*.]

The middle of the road-bed, as consolidated by rolling and traffic, should be made higher than the sides in the following proportions of the width of the carriage-way from gutter to gutter:

Earth road, rise at centre	$\frac{1}{10}$ to $\frac{1}{40}$
Gravel road, rise at centre	$\frac{1}{50}$
Broken stone road, rise at centre	$\frac{1}{60}$
Stone blocks, rise at centre	$\frac{1}{80}$
Wood, rise at centre	$\frac{1}{100}$
Brick, rise at centre	$\frac{1}{20}$
Asphalt, rise at centre	$\frac{1}{80}$

For country roads, it will suffice to make the rise half-way from the inner edge of the gutter to the crown or middle of the road $\frac{1}{8}$, and at $\frac{1}{2}$ this half width of road from the gutter $\frac{1}{2}$ of the rise before given.

Thus for a finished broken stone covering for a road 16 feet wide, the centre rise is 3.2 inches, the rise at 2 feet from the centre is 2.8 inches and at 4 feet, 1.2 inches. This transverse section gives a slightly steeper slope nearer the centre than for the usual circular or parabolic section and is therefore preferable.

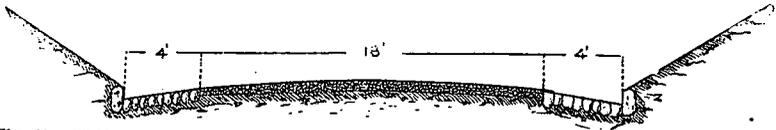


Fig. 16.—CROSS-SECTION OF MACADAM ROAD IN AN EXCAVATED ROADWAY AND ON A GRADE, WITH STONE PAVED GUTTER. [From *Good Roads*.]

Before the stone is rolled and consolidated by traffic, for a 16 foot roadway it is best to add at least 2 inches to the rise at the centre to allow for subsequent settlement; and further, on grades of over 5 feet in 100, an extra allowance of at least an inch is made to prevent the

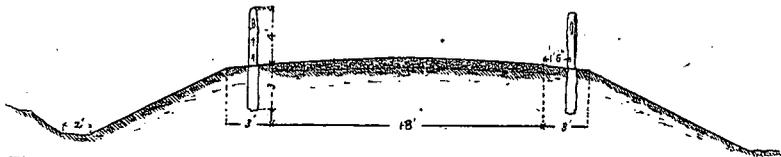


Fig. 17.—CROSS-SECTION OF MACADAM ROAD, ON AN EMBANKMENT OR FILL, BUILT UP WITH EARTH TAKEN FROM THE EXCAVATIONS, SO AS TO IMPROVE THE GRADE. THE FENCES ON THE SIDES PREVENT THE OCCURRENCE OF ACCIDENTS. [From *Good Roads*.]

water running along the centre of the road and washing the material away. A proportionate increase is to be made for other widths of roadway. On steep grades too, breaks in the grade are sometimes made every four or five hundred feet to give a rest to the horses.

Foundation.—The road-bed should be *thoroughly drained*, as already explained, and then *thoroughly rolled* to a firm surface. If beds of gravel or sand are convenient, it is well to use these on a clayey foundation, or if these are not to be had, to put a layer even of sandy loam 4 to 6 inches deep on the clay surface and roll it thoroughly. Sand makes a good foundation when confined, as it helps to distribute the pressure brought on a portion of it over a large area; besides it never makes mud and it prevents the mud below from working up among the stones. In country practice it is rarely used owing to the expense of obtaining it.

The Broken Stone Covering.—To build a Macadam road, about 4 inches of stone, broken by a crusher, so that the largest pieces have only a diameter of, say $1\frac{1}{2}$ inches for trap rock, is spread uniformly

over the surface, just as it comes from the crusher, spawls, chips and dust included. This is rolled with a 2- to 5-ton horse roller or a 10- to 15-ton steam roller, so as to make the entire covering as tight and solid as possible, approximating to solid stone. If a light horse roller has been used, it is well to invite travel on the road for a while, as the wagon wheels consolidate a road better than the roller, though they do

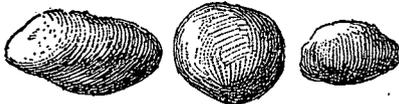


FIG. 18 ROUNDED PEBBLES AND SMALL COBBLESTONES TO BE CAREFULLY EXCLUDED FROM ALL MACADAM AND TELFORD ROAD-MATERIALS.



FIG. 19 SHOWING FORM AND SIZES OF STONE CHIPS COMMONLY USED FOR THE TOP LAYER IN CONSTRUCTION OF MACADAM AND TELFORD ROADS.

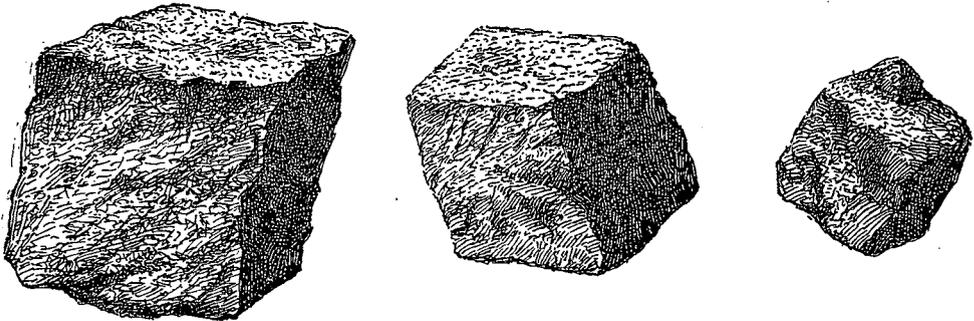


Fig. 20.—SHOWING ROUGH CUBE-SHAPED STONES OF PROPER SIZE AND FORM TO BE USED IN MACADAM AND TELFORD ROADS.—[From the *Century Magazine*].

In the "intermediate" courses of either form of construction slightly 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 in the left of the figure.

so unequally and are apt to cause ruts unless the tires are wide. These ruts are to be worked out by the roller; then a thin coating of sand, gravel or screenings is laid and rolled, and another 4 inches of broken stone laid as before. It is advised to water each layer, add screenings and more water and roll until the water flushes the top. We have now a uniform depth of, say 6 inches of broken stone, as when rolled thoroughly the 8 inches original depth of stone is reduced to 6. Similarly we proceed for other depths.

It has been found by experience that a final depth of macadam of 6 to 8 inches is ample for light traffic and even 4 inches has been successful on a gravelly soil. To make a smooth road at once, a last top coat of screenings is used, but it costs \$200 to \$400 per mile and may be omitted if necessary, as the travel will eventually smooth and consolidate the surface.

Use of Binding Material.—Some engineers advocate the use of thin layers of clay or loam taken from the sides of the road as a substitute for the screenings for packing. It is put on each 4-inch layer of stone in turn, watered and rolled as before, and undoubtedly consolidates and brings the stones to a bearing very soon, as it fills the voids between the stones better than any other material. A light roller can consolidate the road with this packing, whereas it takes a 10- to 15-ton steam roller to consolidate a road packed with spawls, screenings or sand alone.

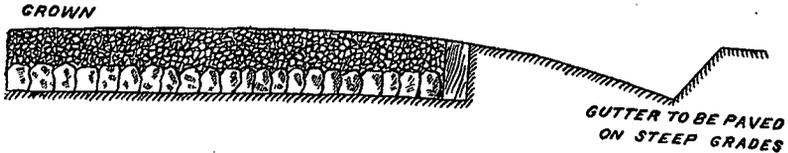
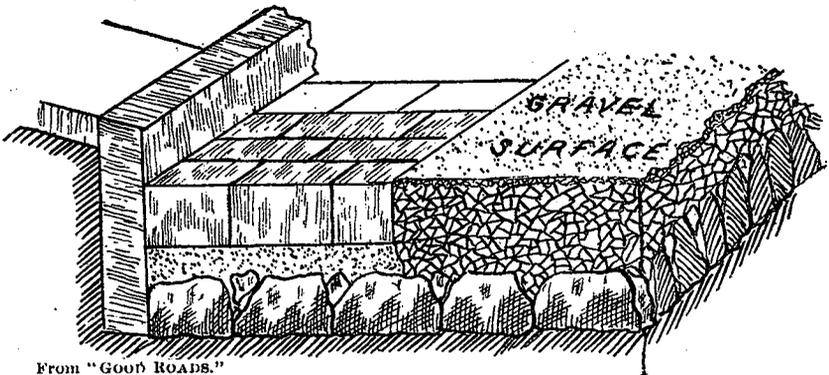


Fig. 21.—SHOWING CROSS SECTION OF ONE-HALF OF TELFORD ROAD FROM THE CENTER OR CROWN TO THE GUTTER ON ONE SIDE; THE LARGER STONES BELOW SHOW THE TELFORD FOUNDATION WITH THE CRUSHED STONE ABOVE. TO THE RIGHT OF THE STONE IS THE ORDINARY SOIL WHICH ON A LEVEL SURFACE OR GENTLE GRADES NEED NOT BE PAVED.

The French engineers have long used this earth packing, and it has recently been used by Mr. J. Owen on the New Jersey roads with success, though the general sentiment is against it, as it is claimed that heavy rains will wash it out and cause looseness in the mass. As the voids in broken stone are about one-half, and no amount of rolling can reduce them to less than one-fourth the total volume, some packing is essential, and if the screenings from the crusher are insufficient, clay or loam may be judiciously used in thin layers. Sand is said to be inefficient as a binder.



From "Good Roads."

Fig. 22.—TELFORD ROAD SHOWING A FOUNDATION OF LARGER STONES WITH SMALLER STONES WEDGED BETWEEN THEIR TOPS; ON THE LEFT IS A PORTION OF CURBSTONE AND GUTTER AS USED IN CITIES, AND ON THE RIGHT A PORTION OF THE BROKEN STONE COVERING OF THE ROADWAY WITH SURFACE GRAVEL. THE CURBSTONE AND GUTTER HERE SHOWN ARE TOO EXPENSIVE FOR USE ON COUNTRY ROADS.

The Telford Road.—In building a Telford road, the top surface of ground is made parallel to the final surface of roadway as with the Macadam road. On this, the foundation is made of large stones that may be of inferior quality to that used for the covering, as before described. On this foundation one-half to three-fourths inch of screenings of stone (or loam if necessary) is put on and rolled to prevent spawls working up; then the layers of macadam are put on as usual.

Use of both Macadam and Telford plans on same road.—An experienced engineer in road construction recommends on a grade of one in one hundred, six inches Telford foundation and four inches macadam on top; on grades of one foot in one hundred to five in one hundred, five inches Telford foundation and three inches macadam, and for grades of over five feet in one hundred he advises six inches macadam without any Telford foundation. Such thicknesses have given success even in bad soils. It is hardly advisable generally to build roads with only four inches of macadam covering alone, for although they have succeeded at Bridgeport, Connecticut, where the soil is sufficiently dry, yet in another case after doing good service for three years, a severe winter broke up miles of them; still they may be tried as an experiment in favored localities, on dry and gravelly earth beds, where they should prove the most economical of all good roads.

Misuse of Stone on Roads.—It should be clearly understood that broken stone of all sizes up to four or five inches, dumped in any way on an old road whose surface has not been prepared properly does not make a “macadamized road.” It is a complete waste of money, and if such a system is pursued, will bring discredit upon this “move

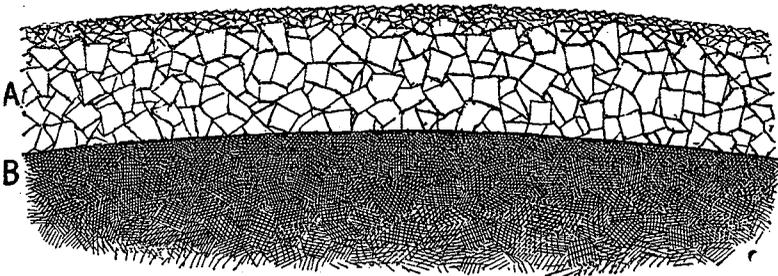


Fig. 23.—CROSS SECTION OF MACADAM ROADWAY (A) LAID ON COMPACT EARTH (B), MADE SOLID AND PERMANENT BY HEAVY ROLLING.

for better roads.” Instead of the transverse section of the earth road being made convex as above explained, I have seen it made concave and dug into holes and the stone wastefully thrown in the holes and not consolidated or brought to shape, so that possibly much more

material was used and the road cost more than if an engineer had graded it properly and built a superior Macadam road.

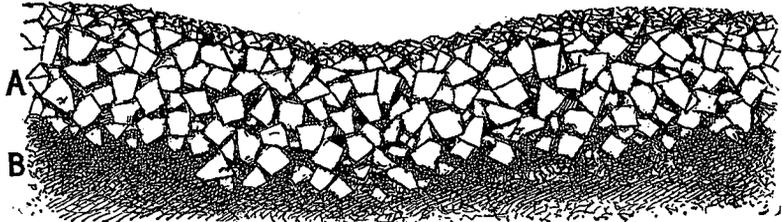


Fig. 24.—CROSS SECTION SHOWING WASTEFUL USE OF MACADAM MATERIAL (A) ON A ROAD SURFACE (B) NOT PROPERLY COMPACTED BY ROLLING, NOR THOROUGHLY DRAINED.

Let it be borne in mind that only experts in road making should have charge of the construction of our roads, and that there is no economy in employing a cheap man. Such a policy will certainly cost tens of thousands of dollars in the end and has proved a failure whenever tried.

REPAIRS OF BROKEN STONE ROADS.

As to *repairs*, the thick coverings last longest. An average road will last four or five years (unless very narrow) and for our country roads, should not cost for repairs over \$100 to \$150 per mile per year.

A road properly constructed should wear equally along its length and should be repaired by a coating of broken stone throughout, put on as before described. When ruts or holes are formed, it is proper to repair at once, but the daily tinkering and breaking up of a road in places for repairs, so universally followed by some, is not recommended by others. A good road of hard materials, well compacted, needs but few repairs for some years; but a road of soft materials can only be kept in good order by constant repairs.

COST OF BROKEN STONE ROADS AND REPAIRS.

The following table of cost of Macadam roads is taken from Byrne's "Highway Construction," (page 186):

LOCALITY.	Thickness of stone. Inches.	Width of Pavement. Feet.	Method.	Cost per mile.
Bridgeport, Connecticut . . .	4	18 to 20	Macadam.	\$ 3,000 00
Fairfield, Connecticut	4	20	Macadam.	5,000 00
Franklin Township, N. J	4	15	Macadam.	4,700 00
Plainfield, New Jersey	4 to 6	16	Macadam.	3,000 00
Kingston, Rhode Island	8	16 to 20	Macadam.	5,500 00

The cost is seen to vary with the depth of stone covering and the width of the road. Thus, for a depth of stone of four to six inches, the cost for a sixteen foot road is at least \$3,000 per mile; whereas, for the same width, but with eight inches of stone, the cost is \$5,500. The proximity of the stone of course largely influences the cost. If in places the plan be adopted of having only one half of the sixteen foot road macadamized, leaving the remaining half to serve as a dirt road, the cost per mile of the four inch Macadam road might be reduced to \$1,500 or \$2,000 per mile.

The Most Economical Width of Macadam Road.—As stated on page 52, and as indicated in the above table, the width of the macadamized part of the road, as generally adopted in the United States, is 16 feet, but varies from 15 to 20 feet. In Austria the macadamized space ranges from 14 1-2 to 26 1-4 feet, in France from 16 to 22 feet, while in Belgium the regular width is only 8 1-4 feet. The full width of the roads, however, in different countries, and even in the same country, ranges from 26 to 66 feet, portions of this space being occupied by the foot-path, ditches and the macadamized wagon-way—and in some cases a dirt road by the side of the latter. As the cost of the Macadam road varies with the width and thickness of the broken stone covering, this should be as narrow and thin as may be consistent with the usefulness and durability of the road. The 8-foot Macadam road has proved fairly satisfactory in Belgium, and in Mecklenburg county of our own State, where it is now being tried. But on account of its narrowness the wagon wheels must always run in the same places, and with our narrow American tires ruts are cut with comparative rapidity. This road is too narrow for vehicles to pass without one of them leaving the macadamized part, and in so doing there is always a tendency to break down the latter on its edges, to bring quantities of mud on to the road surface; and in wet weather leaving the macadamized part with a loaded wagon often means to sink into the mud on the roadside. Consequently, as far as possible, the Macadam road should have a width of not less than 14 feet, so as to allow two vehicles to pass, and especially is it important to do this on roads on which the soil is rotten and becomes easily cut up in bad weather; also on mountain roads, where the tendency to wash away the dirt road is so strong, it is better to macadamize the full width of the road (14 or 16 feet). And it should be borne in mind in deciding as to the width of space to be macadamized, that a Macadam road 14 feet wide and 5 inches deep costs very little more than one 8 feet wide and 8 inches deep, and is far more satisfactory.

Cost of Repairs.—The cost of keeping the road in repair per year varies with many conditions, the traffic being the principal. Thus in London the cost of maintenance varies from 6 to 62 cents per square yard; in Paris it is about 45 cents, and in Boston 50 cents.* It must be borne in mind that the cost of labor in Europe is less than in the United States. The country roads cost less for repairs; thus in Belgium it is 6 to 10 cents per square yard; in France 1 to 10 cents; in Bavaria \$116 per mile. From the experience in this country it would seem that repairs for highways should not cost more than 3 cents per square yard, or for a road-bed of 16 feet in width, \$176 per mile. It has been given lower than that by some and higher by others, but experience in New Jersey would indicate about \$150 per mile per year including renewals every 5 years. An average estimate, therefore, for a macadamized road 16 feet in width and 6 to 8 inches thick would be about \$4,000 to \$5,000 per mile for construction and about \$150 per year for maintenance—the interest of \$2,500 at 6 per cent. For roads of less width, the cost is proportionately decreased, though not in a direct ratio.

Where the stone is near at hand and the other conditions favorable, roads 16 feet wide have been built at \$3,000 to \$4,000 per mile, and it is to be hoped that with cheaper labor most of our roads can be built at the lower rate; but it is safer to take the larger figures in making our preliminary estimates.

Some memoranda of average cost of various items, etc., may be of interest here. They are taken from Byrne and other sources.

Rollers.—A 2-horse roller weighing 2 tons will cost \$175; a 10-ton steam roller costs \$3,500 to \$4,000. The yearly maintenance of the latter runs from \$1,300 to \$2,000, when it is used constantly.

A steam roller finds difficulty in surmounting a grade of 1:6, but none on a grade of 1:14. It can roll 500 to 3,000 square yards per day; average in England of 42 towns, 1,105 square yards. In England the cost of rolling is from 1 to 2 cents per square yard (\$60 to \$120 per mile for a 16 foot road-bed); in the United States, 1 up to 14 cents per square yard.

Loam put on and rolled will cost from \$30 to \$50 per mile. The rolling of the stone covering should start from the sides and be continued "until the stones cease to creep in front or sink under the rolls, and the surface has become smooth and firm."

Stone Crushers.—These cost, average size, and including engine, boiler, etc., \$2,500; expenses of operating, per day, \$15 to \$27.

* A road 16 feet wide contains 5,867 square yards of surface in one mile.

Cost of Quarrying and Crushing Stone.—The following gives the cost of quarrying and crushing, etc., per cubic yard at Hartford, Conn.: Quarrying 70c., crushing 35c., carting to breaker 25c.; total cost crushed at quarry \$1.30, and delivered on streets, \$1.80. The haul was not over two miles.

Amount of Crushed Stone Required.—A well rolled road covering contains from 70 to 80 per cent. of stone. Adding 25 per cent. for compression, we have the number of cubic yards of broken stone required in a mile as follows:

DEPTH IN INCHES.	WIDTH OF PAVEMENT.		
	8 Feet.	16 Feet.	24 Feet.
Four inches.....	645	1290	1935
Six inches.....	968	1935	2908
Eight inches.....	1290	2580	3870

GRAVEL ROADS.

Macadam is said to have deduced his principles of construction of broken stone roads from noticing how wheels sunk in and ploughed up a gravel road in consequence of the roundness of the pebbles.

Rounded pebbles should never be used for gravel roads except from necessity, but where an abundance of angular stones can be found near the line of the proposed road, a good and cheap gravel road can be made exactly in the manner hitherto detailed for broken stone roads. As a rule pit gravel contains too much earth, from which it should be partially screened; but a certain amount of ferruginous clay is desirable and causes the gravel to set and become hard as soon as it is exposed to the action of the atmosphere. The gravel and clay mixed are put on in layers of say three inches, then watered and rolled by a 2- to 5-ton horse roller, when other layers can be added in a similar manner. No gravel larger than two inches diameter should be used, all larger stone should be broken. Such roads are good in dry or slightly damp weather, but in rainy periods or very dry weather the clay loses its hold and the road becomes muddy or dusty, as the case may be, and loses its coherence. Such roads, however, are vastly superior to earth roads and should be constructed where suitable gravel is abundant.

Cost of Gravel Roads.—They have been constructed at Richmond, Virginia, for fifteen to twenty cents a square yard, and at Haverhill,

Massachusetts, for twenty-five cents per square yard, or say from \$900 to \$1,500 per mile for a roadway sixteen feet wide.

In Illinois, for a roadway twelve feet wide, the gravel being twelve inches deep at the middle and nine inches at the sides, the cost was \$900 per mile; in Boston, Massachusetts, the cost was seventy-five cents a square yard, or say \$1,500 per mile for a sixteen foot roadway.

Plank Roads.—The construction of plank roads in the timber regions of our State is well understood. The track is usually made eight feet wide, with a dirt road of eight to twelve feet alongside; sills four by twelve inches and fifteen to twenty feet long are laid parallel to the centre line of the road and about four feet apart. They are laid flat-wise and firmly embedded in the ground and "break joints." The plank covering, laid at right angles to the sills, consists of boards eight feet long, nine to twelve inches in width and three inches thick. They are placed on the sills, but are not spiked to them and are so arranged that every three or four project alternately on each side three or four inches beyond those next to them, so that vehicles can readily pass from the earth road to the plank road. The slope of the planks should be three inches in eight feet towards the ditches.

The cost per mile varies from \$1,000 to \$2,400 exclusive of extra earth work, bridges, culverts, etc., and the planking lasts about eight years when well built and cared for.

Possibly, in the long leaf pine regions where timber is plenty and rock scarce, plank roads are the cheapest and best that can be constructed.

Tractive Force.—The pull of the horse on the vehicle or force required to overcome the resistance to motion, is called the tractive force and is expressed in the following table as a part of the gross weights of wagon and load for various road surfaces, at velocities corresponding generally to a pace or a trot. The table is taken from one compiled by Mr. Rudolf Hering.

Sand	$\frac{1}{8}$
Sandy road	$\frac{1}{8}$
Loose gravel	$\frac{1}{7}$
Common gravel road	$\frac{1}{6}$
Hard rolled gravel	$\frac{1}{5}$
Ordinary earth road	$\frac{1}{4}$
Hard clay	$\frac{1}{3}$
Hard and dry earth road	$\frac{1}{2}$ to $\frac{1}{3}$
Cobble stone	$\frac{1}{2}$ to $\frac{1}{3}$
Macadam, little used	$\frac{1}{2}$ to $\frac{1}{3}$
Macadam, ordinary	$\frac{1}{3}$ to $\frac{1}{4}$
Macadam, best	$\frac{1}{4}$ to $\frac{1}{5}$

Good Belgian block	$\frac{1}{30}$ to $\frac{1}{24}$
Planked roadway	$\frac{1}{46}$ to $\frac{1}{37}$
Asphalt	$\frac{1}{33}$
Granite tramway	$\frac{1}{28}$
Iron	$\frac{1}{10}$

Load a Horse can Draw on Different Surfaces.—Hence, if we call the load a horse can draw on an iron track 100, the loads he can pull on other road surfaces (taking average results) will be represented as follows:

Iron track	100
Granite tramway	83
Asphalt	67
Plank road	30
Best stone blocks	30
Macadam, good	18
Cobble stone	10
Gravel road	8
Earth road, common	6
Sand	3

Cost of Transportation.—So many elements enter into the cost of transportation on various road surfaces that it is impossible to estimate the saving in improving the surface except very approximately. As an illustration, however, let us take a level earth road twenty-five miles long on which an average horse, moving at two and one-half miles per hour, will make a day's journey in ten hours. The horse can easily exert a horizontal pull of one hundred pounds on the wagon for this rate and time.

Let us suppose that the traction on the earth (hard clay) road is one-twentieth the gross weight of wagon and load; whereas, if the surface is macadamized, the traction will be just half or one-fortieth of the total load. Further, we shall suppose that fifty two-horse wagons go over the road daily for three hundred days in the year, the yearly cost of one hundred horses and fifty drivers being as follows:

One hundred horses at 50 cents per day	\$ 50 00
Fifty drivers at \$1.00 per day	50 00
	\$ 100 00

For one year (of three hundred working days) this would amount to $300 \times \$100 = \$30,000$.

As the traction on the earth road is $\frac{1}{20}$, and one horse exerts a pull of 100 pounds all the time, the gross load carried by two horses on the earth road is $20 \times 200 = 4,000$ pounds = 2 tons. Assuming the two

horse wagon to weigh half a ton,* this leaves the net or paying load carried as a ton and a half. With a Macadam surface, however, (the traction being $\frac{1}{16}$) the two horses attached to the wagon can drag a gross load of $40 \times 200 = 8,000$ pounds = 4 tons. Subtracting from this the weight of wagon ($\frac{1}{2}$ ton), we have the net load = $3\frac{1}{2}$ tons or $\frac{7}{8}$ times the net load carried on the earth road. Therefore $\frac{7}{8}$ of the wagons originally employed can haul the same tonnage. Thus 50 wagons at $1\frac{1}{2}$ tons (net load) = 75 tons daily; $\frac{7}{8} \times 50$ wagons at $3\frac{1}{2}$ tons (net load) = 75 tons daily. We thus find that to haul the same tonnage over the Macadam road, only $\frac{7}{8}$ of the horses, drivers, etc., used on the earth road are required, so that the yearly saving on this 25 miles of road by macadamizing it would be $\frac{7}{8}$ of \$30,000 = \$17,143—interest on \$285,717 at 6 per cent. Clearly it would pay the people who travel over this road to borrow the sum of, say \$100,000, and with this macadamize the 25 miles at once; and in nine years the annual savings will have paid the interest and paid off the principal.

The saving is even greater than has been estimated on account of extra wear and tear of wagons and harness on the earth road and its impassable condition during a part of the year, as to which, see Chapter II.

GRADES.

Where *grades* are encountered, the ratio of the relative resistance due to gravity to the resistance on a level road is greater the smoother the road. The writer has computed the following table to show this. The load which can be hauled on a level, for the kinds of road given, being called 100, the loads which may be hauled on various grades are as follows:

GRADE.	Ordinary Earth Road, Traction one-tenth.	Very good Earth Road, Traction one-twentieth.	Good Macadam Road, Traction one-fortieth.
Level	100	100	100
1 foot in 100 feet.....	91	83	71
2 feet in 100 feet.....	83	71	55
3 feet in 100 feet.....	77	63	45
4 feet in 100 feet.....	71	55	38
5 feet in 100 feet.....	66	50	33
10 feet in 100 feet.....	50	33	20
15 feet in 100 feet.....	40	25	14.

*The two-horse wagons used in the hilly country around Chapel Hill weigh from 800 to 1,400 pounds, the average of 20 weighings being 1,075 pounds. The net load carried varies from 478 to 2,020 pounds, the average being 968 pounds. The one-horse wagons weigh from 400 to 640 pounds, average 551 pounds, and carry net loads of 180 to 630 pounds, average 416 pounds. These figures were kindly furnished me by Mr. A. S. Barbee.

Thus on a rise of 10 in 100, a horse can pull on an ordinary earth road $\frac{1}{10}$ or $\frac{1}{2}$ the load he can draw on a level; but on a good macadamized road he can only draw on this grade, $\frac{1}{20}$ or $\frac{1}{4}$ the load he can draw on the level. It follows from this example, or generally from the table, that it is much more important to reduce grades on any road that is to be macadamized than it is to lighten the grades on a common earth road whose surface is not to be improved.

It was assumed in the table above that a horse can exert the same pull on a grade as on a level, which is not true, especially for the steeper grades; so that for the latter, the above figures should be somewhat less. This is due to a horse's anatomical formation and great weight, for although a horse on a level is equal to 5 men, on a rise of 15 feet in 100 he is not as strong as 3 men, and finally the grade may become so steep that he can barely pull his own weight up it.

A horse can, however, for a short time exert double his usual force (or even more for very short distances), which will take him over hills giving double the resistance on a level. His tractive force also varies with the velocity, being for an average horse working 10 hours a day at 4 miles per hour 60 pounds, at $2\frac{1}{2}$ miles per hour 100 pounds, and at 1 mile per hour 250 pounds. It is also proportionately greater when he works a less number of hours each day.

On a macadamized road where the traction is $\frac{1}{4}$ of the load on a level, the horse will have to exert double his force to overcome a grade of one foot in thirty-five, which he is supposed to be capable of doing. This grade likewise being "the grade of repose," a vehicle can be driven down it at a good rate, say twelve miles per hour, without increased speed due to gravity. Hence, whether viewed as an ascent or a descent, this grade should be the *maximum* (when practicable) under the conditions assumed. Similarly a grade of one in forty is the maximum when the traction on a level is $\frac{1}{5}$ of the load.

The *minimum* grade should not be less than half a foot in a hundred, or better, one in a hundred, for purposes of drainage, giving a full and free flow to water in the gutters and ditches.

Steep Grades add Greatly to Cost of Transportation.—As grades are frequently much greater than one foot in thirty-five, it is well to give an example showing the loss a *single steep grade, on a line say twenty-five miles long, or a day's journey, will entail.* To take an extreme case, suppose the hill to rise one foot in ten, when traction on a level is $\frac{1}{4}$ of the load or 57 pounds per ton of 2,000 pounds, corresponding to an average macadamized road. The extra force required on the grade is of

2,000 pounds—200 pounds, which added to 57 gives 257 pounds, the horse must exert on the grade for each ton hauled. Half of this is 127, so that if the hill is not too long for the horse to exert double his usual force in overcoming it, the ratio of the gross load he can draw on the grade to that he can draw on a level is 57:127.

Let us suppose (as in a previous example) that 50 two-horse wagons pass over the hilly road 300 days in the year at a cost of \$30,000 per year. If a horse can exert a pull of 100 pounds at $2\frac{1}{2}$ miles per hour for ten hours, then as we have taken the traction at 1:35, the horse can pull a gross load of $35 \times 100 = 3,500$ pounds on the level portion of the road. Therefore,

Two horses can pull a gross load of	7,000 pounds.
Weight of wagon assumed to be	1,000 pounds.
Net load on a level	6,000 pounds.

On a grade of ten feet rise in one hundred feet, the two horses exerting double their usual strength can draw, as we have seen,

$\frac{57}{127} \times 7,000$	3,142 lbs.
Weight of wagon	1,000 lbs.
Net load on grade	2,142 lbs.

This is but little over a third the net load (6,000 lbs.) drawn by two horses on a level. For convenience, take it as one-third.

We thus see that it will take three teams on the grade to haul the same *net* load as one team on the level portion of the road. The *extra cost* in one year, due to the grade limiting the load over the whole twenty-five miles of road is thus two-thirds of the cost over the line with the hill on it, or $\frac{2}{3} \times \$30,000 = \$20,000$ —the interest on \$333,333 at six per cent. Any amount less than this can be economically expended in getting a level route around the hill if the length or cost is not greatly increased.

It is supposed here that the hill is at least 400 to 600 feet long (as a horse can exert more than double his strength on less lengths) but not over a mile, so that the horse can continually exert double his usual strength over the entire grade. The net tonnage is taken very small—only $50 \times 2142 = 107,100$ pounds or about 54 tons a day at a cost of \$100 or \$4 per mile (wear and tear omitted) or 7.4 cents per ton per mile. On the perfectly level road, the cost is one-third of this, or 2.5 cents per ton per mile, certainly a very low estimate.

If the *distance* has to be increased 1 mile to avoid the hill, suppose the cost of this extra mile to be \$10,000 and the yearly maintenance

\$150 per mile, the interest of \$2,500 at 6 per cent; a total of \$12,500. As the cost of hauling the net load of 54 tons on the road with the grade is \$30,000 per year, the cost of hauling the same net tonnage on the level road is one-third of this, or \$10,000 per year on 25 miles, or \$400 per mile—the interest of \$6,666 at 6 per cent. Add to this the cost of building and maintaining the extra mile (\$12,500) and we have \$19,166 in all as the principal to provide for the first cost, maintenance and cost of operating the extra mile, against \$333,333 to expend in avoiding the hill. This example suffices to illustrate how a very large amount can often be judiciously expended in avoiding some steep hill, which limits considerably the loads carried over the rest of the line, even when the latter is not level, as was supposed to simplify the calculations. In most cases, however, the road line can be changed at moderate cost.

Many of our roads were originally only bridle trails, or at least were located without reference to economy in hauling heavy loads by wagons. Consequently most of them go directly over hills, without any attempt at securing a gentle grade even when one is perfectly practicable. As we have seen, the heaviest grade limits the load over the whole road to what can be hauled up the steep grade; besides this, all other hills giving lesser grades increase the cost of hauling; so that many changes in the location of our country roads, particularly if they are to be macadamized, are imperatively demanded. On such work only a trained engineer is competent and should be employed. Such a man can earn a hundred fold his salary in one year when the saving to all concerned is considered.

The endeavor has been made in what precedes to give some of the principles of highway construction which it seemed desirable should be *generally known*. Let the move for "better roads" be organized carefully and judiciously and attend first to a revision of the location of country roads, particularly in the hilly country; then must follow the improvement of the surface by macadamizing or otherwise, the *proper* construction of which should be *rigidly insisted on*.

CHAPTER FOUR.

TOOLS AND MACHINERY EMPLOYED IN ROAD CONSTRUCTION.

The following brief notes on the tools and machinery employed in the construction and repair of roads are intended only to give such general information as may be useful to county commissioners, road supervisors and others who may be interested in the subject. As new and improved types of tools are likely to be placed on the market at all times, and as prices change more or less every year, it will be well for all persons desiring to purchase such machinery and tools to correspond directly with several manufacturers or large dealers, and also with different road engineers about them before doing so. The facts here stated are taken in part from Byrne's "Highway Construction," and "Good Roads," in which there will be found a full and illustrated treatment of the subject. When a lot of tools and machinery is ordered at one time doubtless the manufacturers will cheerfully send along an agent to show how the machines are put together and operated.

Tools Used in Grading.—A large part of the work of road improvement, after the location has been settled, will be found to consist in the proper grading and drainage of the dirt road-bed. In connection with the building of railroads so large an amount of work of this kind has been done that improved machinery has been extensively and economically used, and in the treatment of our public roads it will be wise to adopt similar methods. The following list of tools will be found useful in clearing, grubbing, ditching and grading:

Axes, price per dozen	\$12.00 to \$15.50
Bush-hooks, handled, per dozen	17.00
Grub-hoes, per dozen	11.00 to 17.00
Mattocks, per dozen	15.50 to 18.00
Shovels, square-pointed, per dozen	7.00 to 13.00
Shovels, round-pointed, per dozen	7.25 to 13.50
Picks, per dozen	10.75 to 22.50
Spades, per dozen	13.25 to 14.50
Hoes, per dozen	13.50
Wheelbarrows, per dozen	20.00 to 52.50
Plows for road work, each	20.00 to 60.00
Scrapers, drag, each	12.00 to 15 00
Scrapers, wheel, each	50.00 to 70.00
Carts, each	65.00 to 75.00
Road machines, each	100.00 to 300.00

Plows.—Plows of special forms adapted to this work are used extensively in road improvement and are manufactured by several establishments. They are known under different names, such as “road-plows,” “grading-plows,” “township-plows,” etc., and vary in form according to the character of work they are intended to do.

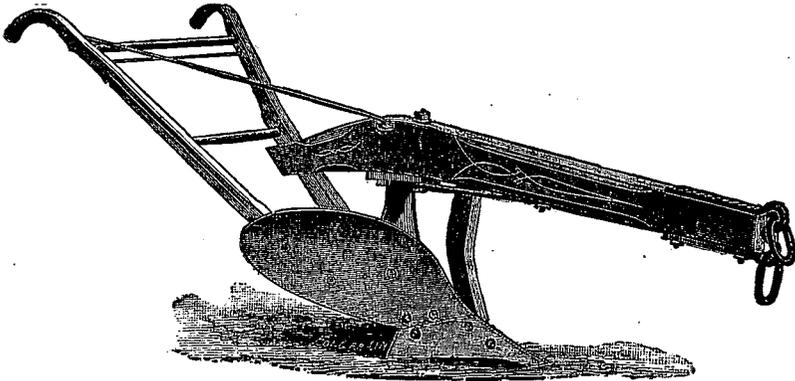


Fig. 25.—TOWNSHIP OR BREAKING PLOW.

They are made of the strongest wood and wrought iron, with steel points, and are pulled by two or four horses. They weigh from 100 to 300 pounds and cost from \$20 to \$60 each. The accompanying illustration of the “Township” or “Breaking-plow” shows their general characteristics. In rocky soil it will be found best to remove the knife to prevent its edge becoming dulled by the stone. This plow is

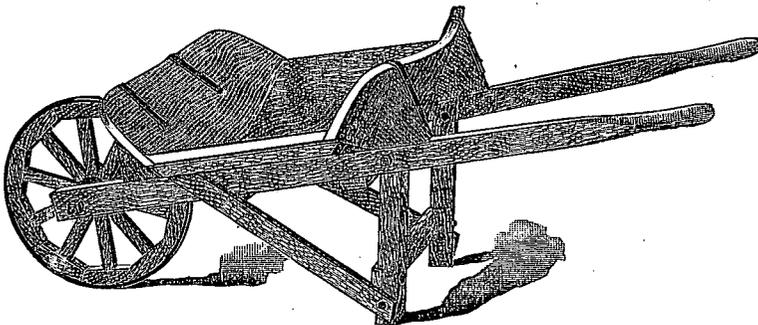


Fig. 26.—WHEELBARROW OF OAK WOOD.

of light draft, requiring two horses in loam soils and four horses in heavy clay soils. It is not intended for turning the soil but cuts a furrow 10 inches wide and 6 to 11 inches deep, and weighs about 120 pounds. These road-plows are manufactured by the American Road

Machine Company, Kennett Square, Pennsylvania; the Kilbourne & Jacobs Manufacturing Company, Columbus, Ohio, and other companies.

Wheelbarrows.—The wheelbarrow shown in Fig. 26, constructed of wood, is one of the forms most commonly used in earth work. Its capacity ranges from 2 to 2 1-2 cubic feet, its weight is about 50 pounds and its price is about \$20 per dozen. Fig. 27 shows another form

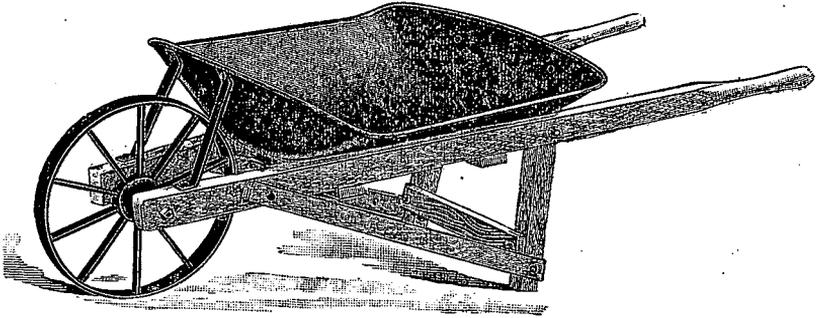


Fig. 27.—WHEELBARROW WITH IRON WHEEL AND PRESSED STEEL TRAY.

of wheelbarrow with frame of oak, wheel of iron and tray or bowl of pressed steel. Its capacity ranges from 3 1-2 to 5 cubic feet, and its price from \$5.50 to \$7.50 each. While costing more it will be found to be much more durable than the all-wood barrow.

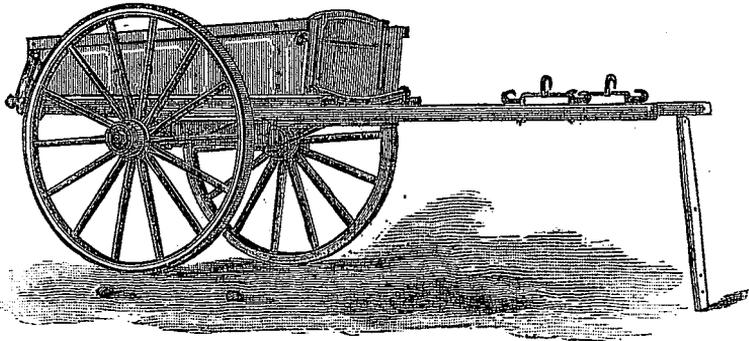


Fig. 28.—ORDINARY EARTH CART.

Carts.—Fig. 28 shows a form of cart ordinarily used in hauling earth and other materials. These carts have broad-tired wheels to prevent their sinking into soft earth, and the body is so balanced that when the load is evenly divided there should be no great pressure on the horse's back. The average capacity of these carts is 22 cubic feet,

but it is more convenient to have them large enough to hold an even cubic yard of earth. The average weight is about 800 pounds, and the price \$65 to \$75.

The Austin Dump Wagon (Fig. 29) is claimed to be a great improvement on the ordinary cart, as it can be dumped more quickly and easily. Its capacity is from 35 to 45 cubic feet. It is manufactured by the F. C. Austin Manufacturing Company, Chicago. It is an expen-

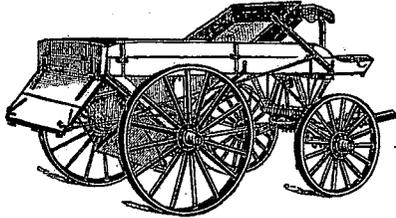


Fig. 29.—THE AUSTIN DUMP WAGON, DUMPED.

sive wagon, costing \$135; but being of iron throughout, it is quite durable, and those who have used it claim that it is an economical machine even at this price.

*Scrapers.**—“These are great labor savers in many places, and are made in a variety of forms. The best are of solid steel, being lightest, strongest and most durable, and in the end the cheapest. In many soils a good steel scraper can be used even though ploughing has not been done, but the plough is always an important aid in loosening the soil, no matter what method is adopted for its removal. The common solid steel drag scrapers will carry from three to seven cubic feet of

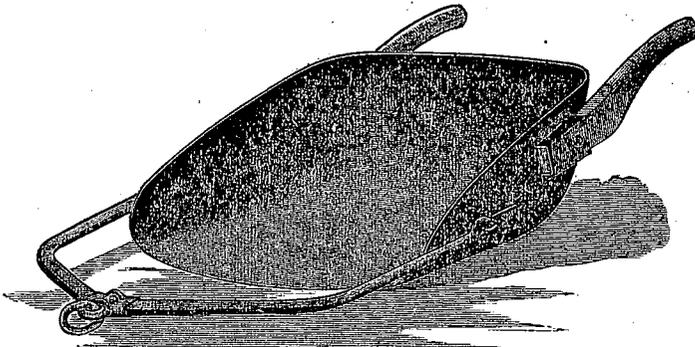


Fig. 30.—DRAG SCRAPER IN POSITION FOR LOADING.

earth, the largest size being generally employed for longer hauls and where the earth is to be carried away on a down grade. A scraper having a capacity for about five cubic feet is best for ordinary carting,

* I. B. Potter, in "Good Roads," Vol. I, (1892) pp. 333-'5.

while if only one horse is employed, and light work only is intended, the scraper carrying three feet will be sufficient." The scrapers with two strips or runners on the under surface, as shown in Fig. 31, have a lighter draft, and those with round edges on the bottom, like the one here illustrated, last longer.

"In the employment of a scraper you will find it necessary in most cases [in using scrapers having a capacity of 5 to 7 1-2 cubic feet] to

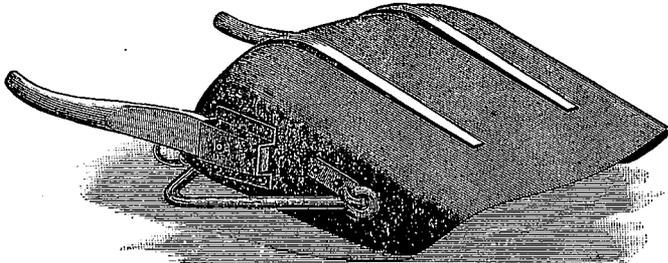


Fig. 31.—DRAG-SCRAPER WITH RUNNERS.

use a team of two horses, and if the haul is short the size of the scraper should be made correspondingly smaller, because the filling of the scraper will be more frequent, and this portion of the work will be very severe upon your team. Scrapers are largely used in the handling of earth where much work is to be done, and they have an advantage in cheapening the cost of the work. Trautwine computes that by the use of a drag scraper in light soils, the cost of handling earth per cubic

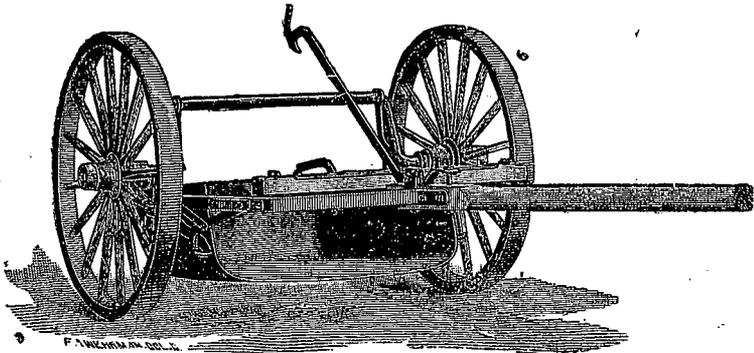


Fig. 32.—WHEEL SCRAPER IN CARRYING POSITION.

yard (not including contractor's profit) varies from 5 1-2 to 12 cents per cubic yard where the lengths of haul vary from 200 to 250 feet, including the spreading of the material in places, while the same cost under shorter lengths of haul, where the earth is 'wasted,' varies from 4 1/2 to 11 cents.

While drag scrapers are quite satisfactory on short hauls, for long hauls wheeled scrapers are coming into general use. "They are made to carry from about twelve to seventeen cubic feet of earth when 'even full,' and mounted on wheels having broad tires to prevent them from cutting into the soft earth. The bowl of the scraper is made so that it may be raised or lowered, and is operated by lowering the edge of the scraper into the earth until the bowl is filled, after which it is raised a distance of some inches above the ground and carried to the dump or embankment, when the bowl is emptied by revolving it upon an axis from which it is hung. The cost of removing earth by wheel

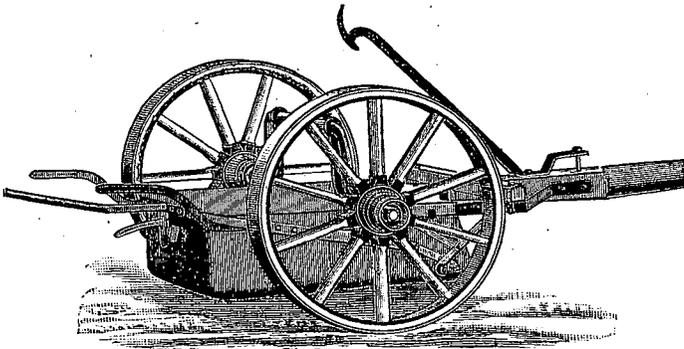


Fig. 33.—WHEEL SCRAPER IN POSITION FOR LOADING.

scrapers is somewhat less than that involved in the use of the drag scraper. * * * * * A wheel scraper of medium size will weigh about 450 pounds, will carry a little less than one-half a cubic yard, and will cost from \$50 to \$70. A drag scraper weighing about 100 pounds will cost from \$12 to \$15."

Mechanical Graders.—†"Within the last few years several machines have been devised for the purpose of handling earth more expeditiously and economically than can be done by hand; they are called by various names, such as 'road machines,' 'graders,' 'road hones,' etc. Their general form is shown in Figs. 34 and 35.

"Briefly described, they consist of a large blade made entirely of steel or of iron, or wood shod with steel, which is so arranged by mechanism attached to the frame from which it is suspended that it can be adjusted and fixed in any direction by the operator. In their action they combine the work of excavating and transporting the earth. They have been chiefly employed in the forming and maintenance of earth roads, but may be also advantageously used in preparing the subgrade surface of roads for the reception of broken stone or other improved covering.

†Byrne, page 580.

A large variety of such machines is on the market, and the price ranges from \$100 to \$300."

The accompanying illustration (Fig. 34) shows the "Champion" reversible road machine, manufactured by the American Road Machine

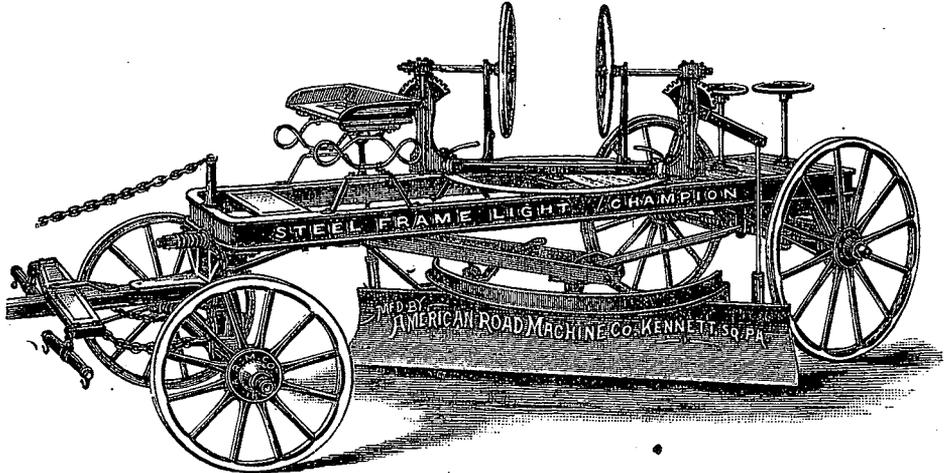


Fig. 34.—THE STEEL FRAME LIGHT CHAMPION REVERSIBLE ROAD MACHINE.

Company, Kennett Square, Pennsylvania, which can be had with either iron or wooden wheels—the latter being probably preferable. It can be easily pulled by four good mules and is said to be capable of doing as much work as 40 or 50 men, under favorable conditions. By tilting the blade it will cut the side ditches or gutters, as well as grade the road when the blade is properly adjusted. The price of it is \$250.

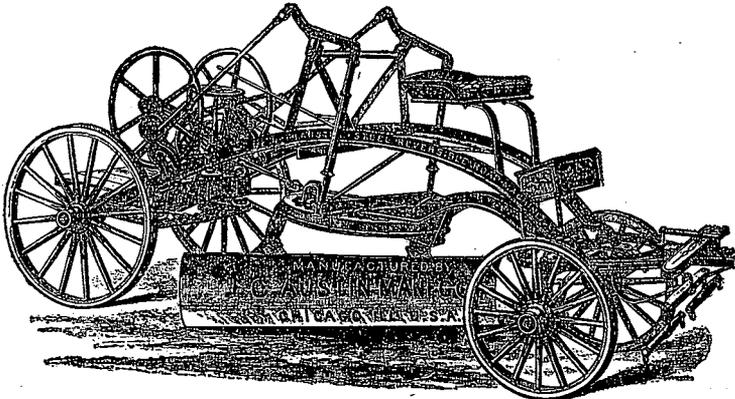


Fig. 35.—THE AUSTIN REVERSIBLE ROAD MACHINE.

Fig. 35 shows another form of road machine made by the F. C. Austin Manufacturing Company of Chicago.

"The New Era Grader," a machine recently introduced by the F. C. Austin Company, seems to be well adapted to the rapid handling of large quantities of earth at a comparatively low cost; and it promises to mark a considerable step in advance in the grading for railroads and wagon roads in comparatively level regions where the soils are fairly loose. But its adaptability for use on public roads in hilly regions and stony soils like those of midland and western North Carolina does not appear to have been demonstrated as yet. Persons desiring further information concerning the nature and work of this machine should correspond with the manufacturer in Chicago.*

Rolling.†—"Let us suppose that drains have been put in, culverts laid, banks sloped and the road surface given its proper shape. It is by no means a finished road even now, for in many parts the earth will be loosely compacted and in others scarcely settled at all. Rains will wash it, wagon wheels will sink into the surface and in a short time the earth will settle unevenly and take on a shape that will make you look upon it as a mortifying failure. You may obviate many if not all of these bad results by the thorough and proper use of a good roller. Every dirt road that is subjected to wagon traffic becomes hard by the process of rolling. Every wagon wheel acts as a roller, and when you consider the millions of wagons in use you may see the force of my statement when I tell you that if wagon tires were made of a width fairly proportioned to the heavy loads which they are required to sustain, our country roads would be vastly smoother and always in better condition than we find them today.

"You are familiar with the soft and cloggy condition of the ordinary country road in springtime, and know how the summer sun gradually evaporates the water and leaves the road surface roughened and cut by deep ruts and marred by occasional mud-holes where the deep water has not fully evaporated. To hasten the escape of the water I have advised thorough drainage, but to destroy ruts and preserve the road surface in good passable condition, rolling should be resorted to, and the more constant your rolling the smoother and more satisfactory will your road become.

"Great differences of opinion exist regarding the proper weight of roller to be used in the different kinds of road-making, but it is reasonably well settled that a roller of any given weight cannot be used to the same advantage on all kinds of roads, and that the weight of the roller in each case should, if possible, be adjusted to answer the condition presented. A comparatively light roller of large diameter may be used to advantage where the ground is soft and yielding, but the same

* For an illustrated description of this machine, see Byrne's Highway Construction, p. 580.

† *Good Roads*, Vol. II., No. 2, pp. 85, 86 and 90.

roller would hardly answer to consolidate heavy and moderately firm materials. It is therefore best, when possible, to use a roller which may be loaded and lightened at will to answer these several conditions, remembering, however, that the final work of the roller can hardly be done by too heavy a machine, and that the process of rolling is more likely to be discontinued too quickly than unduly prolonged, which latter is indeed hardly possible in ordinary conditions."

Horse Rollers.—Admitting the importance of using a roller in all road work, the question arises as to what kind of roller will be found most satisfactory for the work in hand. It is perhaps generally conceded that for work on city streets and on country roads where there are no weak bridges which might be broken down by the weight of

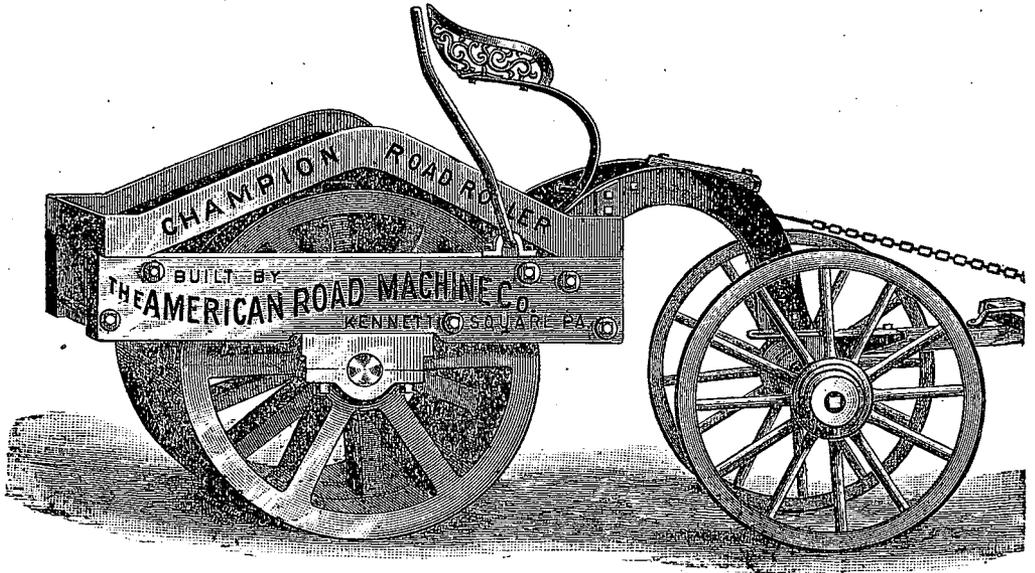


Fig. 36.—THE CHAMPION ROAD ROLLER.

the roller, and no especially steep grades to ascend, that the heavy steam rollers are preferable. But for the ordinary country road work a good horse roller answers the purpose fairly well and costs considerably less than the steam roller, though the expense of operating the latter is but little if any more than that of a large-sized horse roller. In the choice of a horse roller it is better to select one which does not bear heavily on the necks of the horses, and one the weight of which can be considerably increased by the use of bars of iron, masses of stone, or otherwise. In the Champion road roller shown in Fig. 36, the weight, which normally is three tons, can be quickly increased to five tons by the addition of two tons of railroad iron cut into 4-foot

pieces, or by adding masses of stone when the iron cannot be secured easily. The advantage of thus being able to increase the load will be apparent when it is understood that whereas over a rough and somewhat soft road surface it requires four strong mules to pull the 3-ton roller, after this roller has passed over the road several times and has begun to pack down the surface, the four mules can as easily pull the roller with its weight increased to five tons. And furthermore, it is often better for the road surface that when passing over it for the first few times the unweighted roller be used and that subsequently the weight be increased.

Other horse rollers are made by R. C. Pope, St. Louis; the F. C. Austin Manufacturing Company, Chicago, and the Gates Iron Works, Chicago.

Steam Rollers.—A steam roller may be described as a kind of locomotive mounted on broad heavy wheels, and used for compacting the road surface. They vary in weight from eight to thirty tons, the sizes

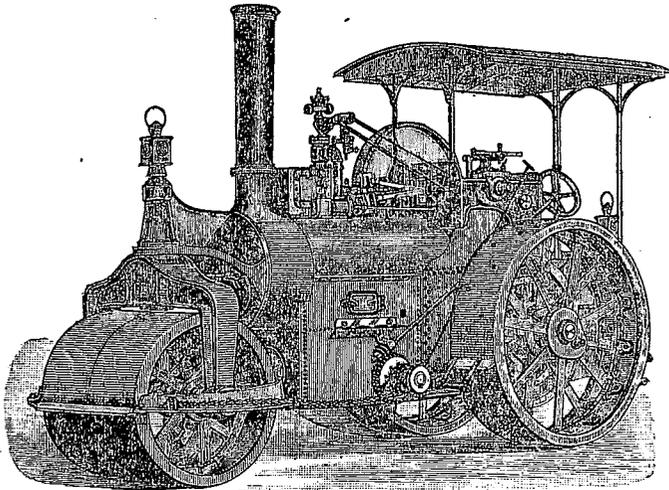


Fig. 37.—SPRINGFIELD STEAM ROAD ROLLER.

generally used weighing from eight to fifteen tons. The advantages of steam rollers are stated by Byrne as follows:*

“(1) They shorten the time of construction.

“(2) A saving of road metal, (*a*) because there are no loose stones to be kicked about and worn; (*b*) because there is no abrasion of the stones, only one surface of the stone being exposed to wear; (*c*) because a thinner coating of stone can be employed; (*d*) because no ruts can be formed in which water can lie to rot the stone.

“(3) Steam-rolled roads are easier to travel on account of their even surface and superior hardness, and have a better appearance.

*“Highway Construction,” p. 183.

"(4) The roads can be repaired at any season of the year.

"(5) Saving both in materials and manual labor."

The Springfield steam roller manufactured by the O. S. Kelly Company, Springfield, Ohio (shown in Fig. 37), has been found quite satisfactory. The following information concerning this roller can be given best in tabulated form:

SPRINGFIELD ROLLER.

	10-TON.	12½-TON.	15-TON.
Front roll, diameter.....	4 feet.	4 feet.	4 feet.
Front roll, width.....	44 inches.	48 inches.	48 inches.
Driving wheels, diameter.....	6 feet.	6 feet.	6 feet.
Driving wheels, width.....	18 inches.	20 inches.	22½ inches.
Extreme width of machine.....	75 inches.	85 inches.	90 inches.
Pressure per inch of width.....	500 pounds.	570 pounds.	600 pounds.
Coal capacity.....	450 pounds.	500 pounds.	550 pounds.
Water capacity.....	153 gallons.	175 gallons.	200 gallons.
Maximum grade ascended with 100 lbs. stone.	16 per cent.	16 per cent.	16 per cent.
Price.....	\$3,500.	\$4,000.	\$4,500.

Other steam rollers on the American market are the Aveling and Porter roller, an English machine and probably the first of its kind on the market, now used largely in both England and America; and the Harrisburg patented double-engine roller, an American machine and used at many places in this country. Both these rollers are made in three sizes having different weights; the former 10, 15 and 20 tons and the latter 10, 12 and 15 tons in weight.

Tools for the Construction and Repair of Macadam Roads.—The following list gives the more important tools and machines which have been found useful in the construction and repair of Macadam roads:

Sledge hammers, 5 lbs. and over, for breaking masses of stone, \$		\$
per lb.....		.30
Hand hammers, 3 to 5 lbs., for breaking masses of stone, per lb.		.36
Hand hammers, 1½ to 2 lbs., for breaking masses of stone, per lb.		.45
Ring gauge, iron, 2 or 2½ in. in diameter for testing stone, each		.25
Tape lines, 100 feet long, in rolls.....	1.00 to	4.00
Straight-edge, wooden, made by any carpenter*.....		
Reel and stake, per dozen.....	6.00 to	9.50
Rakes, used for leveling stone, per dozen.....	14.00 to	16.00
Hand rammers, each.....	1.10 to	12.00
Levels, per dozen.....		48.00
Brooms, per dozen.....	8.50 to	9.00
Wheelbarrows, per dozen.....	20.00 to	52.50
Stone crusher, each.....	600.00 to	1,250.00
Rollers, horse, 2 to 5 tons, each.....	150.00 to	500.00
Rollers, steam, 10 to 15 tons, each.....	3,500.00 to	4,500.00
Drilling outfit, work by hand, each.....	100.00 to	150.00

*A good design is shown in Byrne's "Highway Construction," p. 590.

Drilling outfit, work by steam, each	\$ 300.00 to \$ 600.00
Derricks, for use in quarrying, each	50.00 to 200.00
Engine for running crusher, etc., each	650.00 to 800.00

Stone Crushers.—Breaking stone by hand for road purposes, which was formerly so extensively practiced, has now been generally abandoned—notwithstanding the claim that stone broken in this way is more uniform in size, has sharper edges and hence packs better—because, as is generally conceded, the steam crushers do the work much

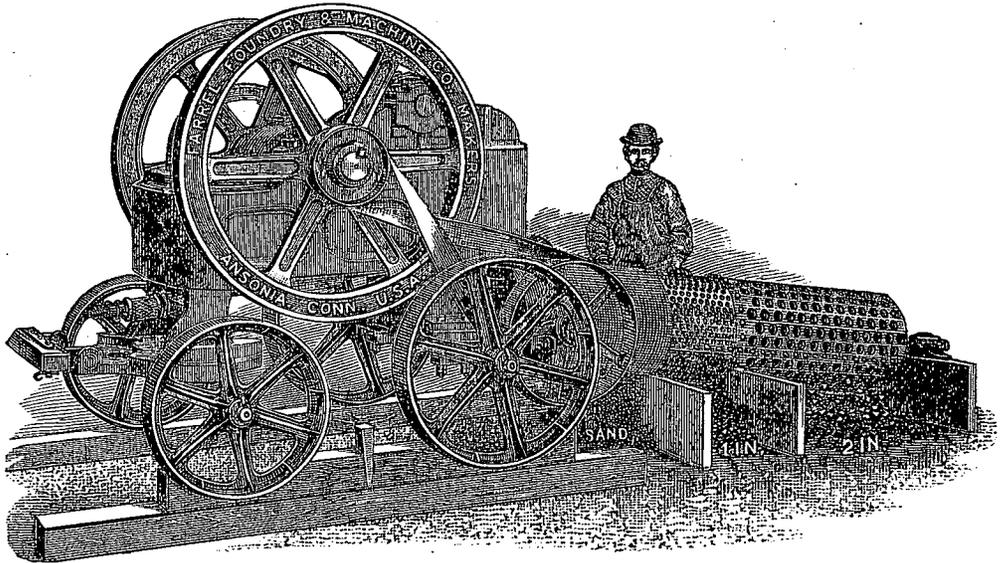


Fig. 38.—FARREL MARSDEN CRUSHER, MOUNTED ON WHEELS AND WITH SCREEN ATTACHMENT.

more rapidly and cheaply. At the present time a good stone crusher is regarded as an essential part of an outfit for macadamizing roads. The following are among the leading crushers now on the American market:

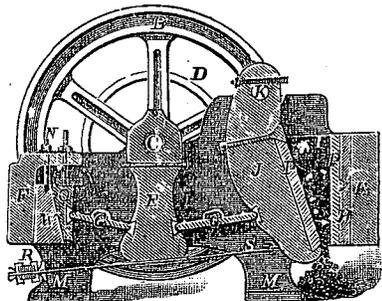


Fig. 39.—FARREL MARSDEN CRUSHER, SECTIONAL VIEW.

The Farrel Marsden crusher, manufactured by the Farrel Foundry and Machine Company, Ansonia, Conn., and by the Mecklenburg Iron

Works, Charlotte, N. C., is being used extensively. The accompanying illustration (Fig. 38) shows this crusher mounted on wheels, thus making it portable, and with attached screen for separating the different sizes of broken stone. When it is preferred not to separate these different sizes the screen can be removed. Fig. 39 shows a sectional view of the Farrel Marsden crusher.

FARREL MARSDEN CRUSHER: DIMENSIONS, CAPACITY, ETC. (as published.)

NO.	RECEIVING CAPACITY.	APPROXIMATE PRODUCT OF 2-INCH STONE PER HOUR.	APPROXIMATE WEIGHT.	HORSE POWER.	PRICE.*
3	10x4 inches.	3 cubic yards.	4,500 pounds.	6	\$275.00
4	10x7 inches.	5 cubic yards.	7,600 pounds.	10	500.00
5	15x9 inches.	8 cubic yards.	16,200 pounds.	20	750.00

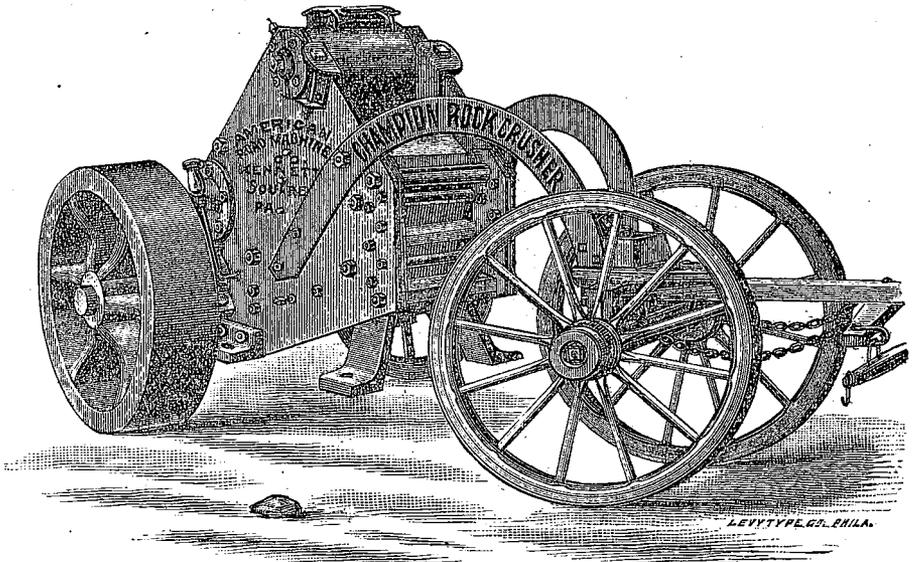


Fig. 40.—CHAMPION ROCK CRUSHER, PORTABLE VIEW.

The Champion rock crusher, made by the American Road Machine Company, Kennett Square, Pennsylvania, is shown in Fig. 40 in its portable form, and in Fig. 41 when stationary and at work with elevator and screen attachment. The front wheels and tongue shown in Fig. 40 when the crusher is stationary can be removed and used on the road roller shown in Fig. 36 (page 78). The elevator, 9 to 12 feet long, can be so arranged that the broken stone will fall directly into bins from which it can run into carts without being handled. The elevator and screen cost \$400 additional to the price of the crusher.

* Price unmounted and without screen.

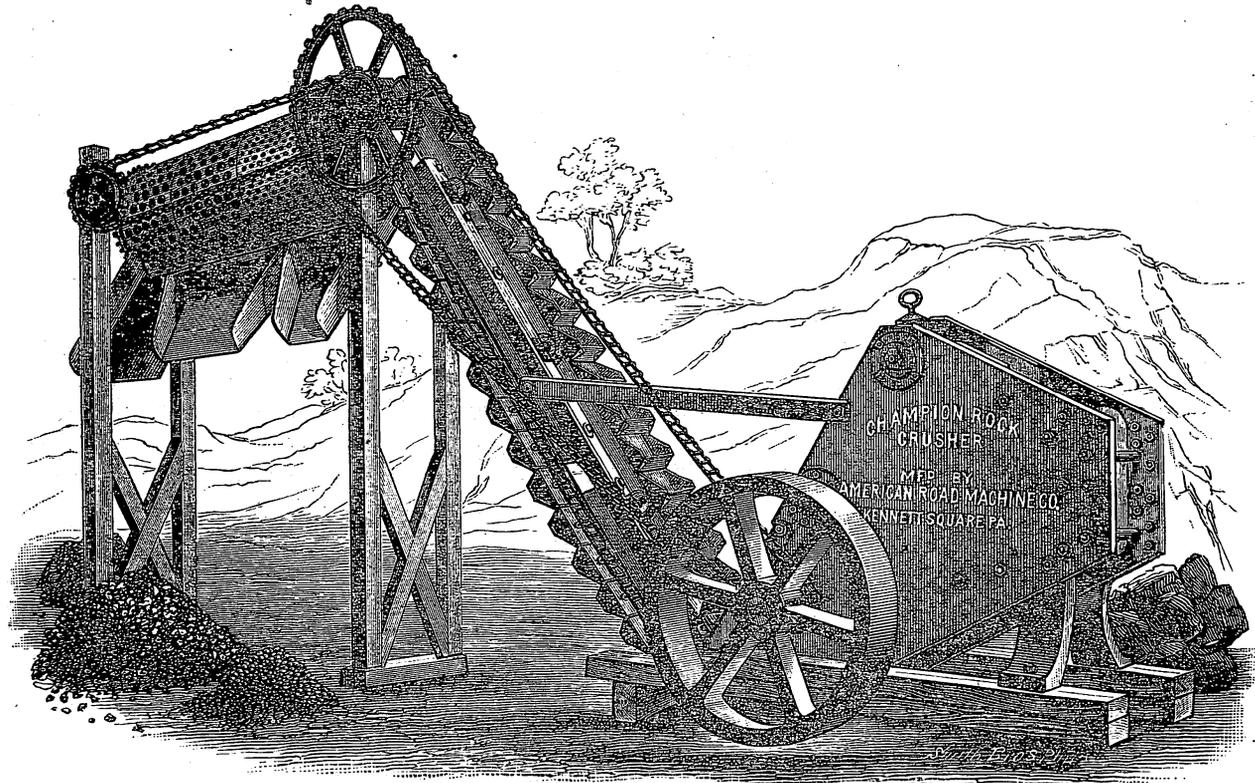


Fig. 41.—CHAMPION STEEL ROCK CRUSHER WITH ELEVATOR AND SCREEN ATTACHMENT.

CHAMPION CRUSHER: WEIGHT, CAPACITY, ETC. (as published.)

NO.	RECEIVING CAPACITY.	APPROX. PRODUCT STONE PER HR., 2 in	WEIGHT APPROXIMATE.	HORSE POWER.	PRICE.
3	7x13 inches.	10 to 15 tons.	5,000 pounds.	10	\$600
4	9x15 inches.	15 to 20 tons.	8,000 pounds.	12	800

Forster's crusher, the Brennan crusher, the Gates crusher and the Smith Hydraulic Safety crusher are also on the market and deserve to be considered in the purchase of stone crushing machinery.

Rock Drills.—The rock as it occurs in the quarry must first be blasted out and then broken into masses small enough—8 to 15 inches in diameter—to go into the crusher, where it is crushed into small fragments—2 inches and less in diameter—ready for distribution on the road surface. In the work of blasting out the rock at the quarry, until recently the hand-drill has been used exclusively, but during the past few years, where extensive operations are being carried on, it has been replaced by the steam drill, which does the work more rapidly and more cheaply. The crusher is generally located at the quarry, and the same engine which runs the crusher can also run the steam drill; and in the purchase of an engine for running the crusher one should be selected with several horse power more than what is claimed to be sufficient to run the crusher alone, so that extra work of this kind can be done without an extra engine becoming necessary. Where the stone used for macadamizing is picked up largely from the fields, and is already in fairly small masses and hence but little quarry work is to be done, it will be found cheaper to use the hand-drill; but where there is a considerable amount of regular quarry work to be done it will be cheaper to use the steam-drill notwithstanding the greater purchase cost of the drilling outfit.

Outfit for Hand Drilling.—The following list includes the more important articles used in hand drilling: *

Drill-steel, per pound.....	\$.25
Striking-hammers, 3 to 5 pounds, per pound.....		.36
Striking-hammers, 5 pounds and over, per pound.....		.30
Spoons, each.....		2.00
Wedges, per pound.....		.12½
Plug and feathers, per pound.....		.30
Crowbars, per pound.....		.10
Stone-sledges, per pound.....		.30
Blacksmith outfit.....	50.00 or more.	

Outfit for Steam Drilling.—The outfit for steam drilling includes† a steam drill, a set of drill-steels; a set of blacksmith's tools for sharp-

* Byrne, "Highway Construction," p. 586. † *Ibid.*, pp. 587-'9.

ening the drills; a sand pump; a band for centering the piston; extra drill parts; and a steam hose. The following table shows the approximate prices of such an outfit:

Drill and tripod complete.....	\$ 175.00 to \$350.00
Steam hose, per foot.....	.54 to .97
Drill steels, per set.....	25.00 to 115.00
Forge and hand tools.....	50.00 and upw'd
Sand pumps, each.....	\$ 3.00
Giant blasting powder, per pound.....	.15 to .60
Leading wires, per foot.....	.01 and upw'd
Magneto-electric blasting apparatus, each.....	25.00 to 50.00
Derricks, each.....	50.00 and upw'd

These drills and outfits are manufactured and for sale by the Rand Drill Company, New York, and by several other companies.

Engines or Boilers.—Almost any good portable engine and boiler of sufficient power will answer for running the rock crusher, rock drill, dump cars, etc. It is better in purchasing to select one which can give a greater power than is called for in advertising statements;

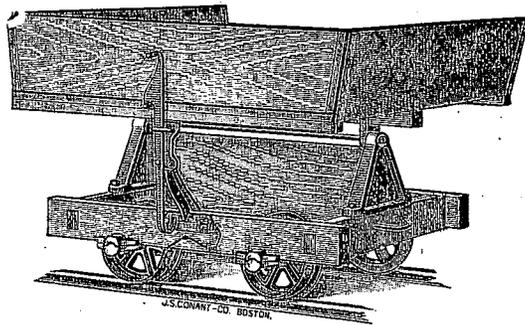
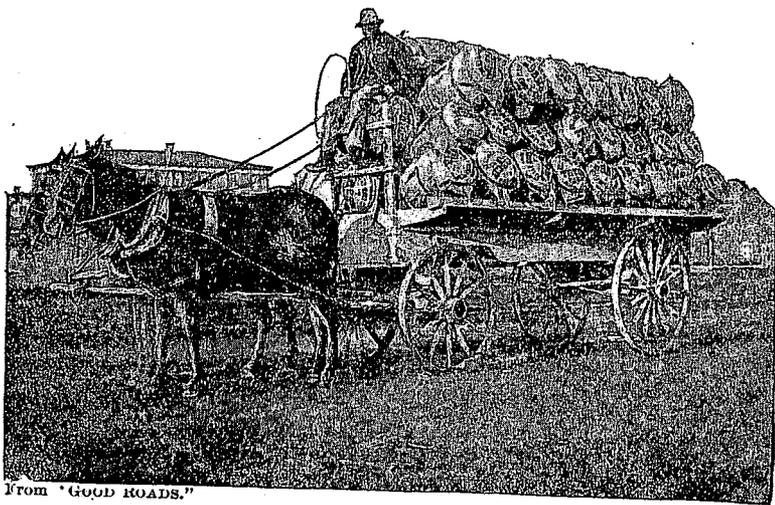


Fig. 12.—STEELE'S DUMP CAR.

for if it requires to run a rock crusher a 10-horse power it is safer and more economical to get this force from a 12-horse power boiler than from a 10-horse power boiler. And where the rock crusher and steam drill and dump-cars are to be operated at the same point (at the quarry) it is better to get an 18- to 20-horse power engine, as the cost does not increase in the same ratio as the horse power. Thus of the Ajax engine, which is claimed to be one of the best now on the market, the 12-horse power engine, mounted on wheels, costs about \$665 and the 18-horse power about \$780—a gain of 6-horse power at an additional cost of \$115. Engines adapted to the running of rock crushers are manufactured by the Mecklenburg Iron Works, Charlotte, North Carolina, and by other establishments.

Dump Car and Winding Drum.—It has been found that the dump cars (Fig. 42) and winding drum manufactured by J. C. Steele of Statesville, N. C., for use in hauling clay from the pit to the mills are also well adapted to hauling fragments of rock from the quarry to the crusher, and it is claimed that in this latter capacity they can be used on the automatic switch, also manufactured by Mr. Steele, to a considerable advantage, being operated by the same engine as that which runs the crusher, or crusher and steam drill, and thus saving the employment of several men and carts to do this work.

Draining Tools.—In ditching for drainage where it is intended to use tile, as advised above (p. 48), and in laying the tile, special forms of spades and other tools have been found useful and inexpensive. These can be obtained from any large dealer in road machinery. They are fully illustrated and described in Byrne's *Highway Construction* (pp. 585-6), and in *Good Roads*, for July, 1892 (p. 33).



From "GOOD ROADS."

Fig. 43.—THE RESULT OF INTELLIGENT WORK IN KEEPING A DIRT ROAD. SIXTY BARRELS OF GARDEN TRUCK HAULED BY A SINGLE TEAM ON DIRT ROAD AT CAPE CHARLES, VA.

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CORRECTIONS AND ADDITIONS.

On page 51, twelfth line from the bottom, after the word "firm" insert "as."

On pages 59 and 60, plates for Figs. 23 and 24 have been kindly supplied by the O. S. Kelly Company.

On page 62, tenth line from the top, for \$176 read \$282; in the ninth line from the bottom for \$60 read \$94, and for \$120 read \$188; in the footnote, for 5,867 read 9,387.

On page 64, second line from the top, for \$900 read \$1,400, and for \$1,500 read \$2,300.

On page 65, tenth line from the bottom, for "yearly" read "daily."

On page 67, in the bottom line, between the words is and of insert $\frac{1}{16}$.