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THE HISTORY AND DEVELOPMENT OF ROAD BUILDING IN THE UNITED STATES

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Between this Sesquicentennial year and the founding of the first colonial settlement at Jamestown the great event of 1776 stands almost at the midpoint of time. The men who gathered in this city to affix their signatures to the Declaration of Independence looked back upon a period of American history a little longer than that which has since unfolded. At the end of their sesquicentennium the journeys they made from their several homes were only slightly less arduous and time-consuming than they would have been at its beginning. Today, 150 years later, the same journeys are made in hours instead of days and days instead of weeks.

The Signers insisted that they acted for thirteen independent States. Today, we find it difficult to conceive of the States as separate commonwealths possessing original authority and yielding only to a restricted power which they, themselves, have conferred on the Federal Government. In the popular mind they have become no more than the political subdivisions of the Republic.

To what extent was the form of our government, as originally established, the product of inadequate facilities of communication between the Colonies; and what relation is there between the gradual

transfer of authority to the Federal Government and the development of the railroads, the telegraph and telephone, the radio, the motor vehicle and the modern improved highways? I am convinced that we would be a wiser people if in the teaching of American history in our schools more time were given to the study of such fundamental economic questions, and less to the lives and ambitions of political leaders and the wars in which we have been involved by their blundering.

As I read history I find it an absorbing pursuit to speculate upon the effect of transportation in shaping our destinies as a nation. To what extent do we owe to the general improvement of roads which followed immediately after the Revolution, the preservation and gradual strengthening of the bond which precariously united the thirteen colonies?

What seeds of disunion are to be found in the fact that the later movements of the people and the building of roads, canals, and railroads were mainly westward both from the South and the North; and that between the Hudson and the Mississippi not a single major waterway runs north and south?

What would now be the Western boundary of the United States if exploration and travel over the Oregon trail had been delayed by as much as a decade?

What conception of the true role of the railways was held by those who built the early roads? I am convinced that they

thought of them as merely a new form of highway, to replace entirely the common roads. No other conception and no less profound ignorance of the economics of railway transportation can explain the hundreds of thousands of short lines, without connection or possibility of adequate revenue, which were built. And no other conception will account for the complete abandonment of the common roads.

What importance as an underlying cause of the Civil War attaches to the fact that in 1850 there were less than 10,000 miles of such inadequately located railways in the entire country and in 1860 but slightly more than 30,000 miles? And what, in view of the general agreement that the South was starved into submission, was the effect of the fact that in 1864 there were less than 6000 miles of railway under Confederate control, all in a state of utter disrepair?

These are, to me, interesting historical speculations. I find in the forces with which they are concerned a truer cause of the course and progress of the nation than many of those of a purely political nature to which such importance has been attached by the historians.

And I derive amusement also, as well as intellectual profit, from this study of the history of transportation. Whenever I hear opposition expressed to the granting of franchises for the use of the public highways by common carrier motor trucks, I think of the completeness with which the governor of New Jersey disposed

of a similar complaint by the assembly in 1707. Of the result of this so-called monopoly he said:

"At present everybody is sure, once a fortnight, to have an opportunity of sending any quantity of goods, great or small, at reasonable rates, without being in danger of imposition; and the sending of this wagon is so far from being a greivance or monopoly, that by this means and no other, a trade has been carried on between Philadelphia, Burlington, Amboy, and New York, which was never known before, and in all probability never would have been."

Let the legal retainers of the public service commissions strive as they may I can think of no more adequate answer to the numerous complaints, which it is their duty to answer, than that.

And when I hear the fear expressed, as I frequently do, that the improvement of roads and their use by motor vehicles will destroy the business of the railroads, I can not but remember the instance cited by a citizen of this State in an essay he prepared in 1891 in the hope of winning a prize offered by the University of Pennsylvania. He was informed, so he says, "by a gentleman in the business of furnishing road material that a prominent official of a great railroad refused to deliver material for him at a point on their road where it would have been a great convenience to have had it, and gave as a reason that they did not wish to accommodate the turnpike company that wanted the material, as their road was

too good already, and was competing with the railroad to the injury of their business."

If, in 1891, before ever the honk of a motor horn had disturbed the quiet somnolence of the peaceful Pennsylvania countryside a "prominent official of a great railroad" could scent danger in highway improvement, I am not surprised when in this day of greatest railroad prosperity, other "prominent officials" betray similar fears, but I wonder whether by means of high rates on road materials they still hope to halt the proper development of highway transportation!

These are merely random historical allusions by way of preface to the specific subject of my paper, which, as befitting the character of this meeting, is confined to a review of the development of highway construction and maintenance from an engineering point of view.

With the exception of the primitive streets of Jamestown no roads were built in the colony of Virginia by the first settlers. The settlements were close to the river banks and fear of Indian attack kept the colonists from wandering far inland. The first road law of the colony, which was also the first American law with respect to highways, was passed by the General Assembly in 1632. It provided for the laying out of the simple ways which were required by the small settlement in the following terms:

"Highways shall be layd out in such convenient places as are requisite accordings as the Governor and Counsell or the Commissioners for the monthlie corts shall appoynt, or accordings as the parishioners of every parish shall agree."

Brief and elementary as were its terms it was doubtless entirely adequate for a community in which, according to the inventory of goods and chattels made in 1625, there was but one horse, and that in the possession of the governor.

The first New England law of record, and the second to be passed in all America was enacted in Massachusetts in 1639. Although somewhat longer than the Virginia act its terms were similar in their general effect. It is notable from the point of view of the engineer, however, as the first law in which there is any specification as to the manner in which the roads were to be constructed. After providing for the laying out of the roads by two or three men chosen from every town, and after carefully protecting the rights of property owners from encroachment by the road builders, it lays upon the locators this single injunction: that "in common grounds, or where the soil is wet or miry, they shall lay out the ways the wider, as six, or eight, or ten rods, or more in common grounds."

In this law we find the first provision, loose and flexible as it was, governing the width of the highways. As yet there is no definition of the manner in which the ways were to be made; and

it is not until 1664 that we find in the regulations established by the government of New York the first definite prescription of this nature. That part of the regulation was as follows:

"The highways to be cleared as followeth, viz, the way to be made clear of standing and lying trees, at least ten feet broad; all stumps and shrubs to be cut close by the ground. The trees marked yearly on both sides - - sufficient bridges to be made and kept over all marshy, swampy, and difficult dirty places, and whatever else shall be thought more necessary about the highways aforesaid."

But while we see here the first legal definition of a method to be followed it is probable that the regulation merely embodied the common practice of the day and that methods and practices very similar were followed in all the colonies.

That but little advance had been made by the opening of the eighteenth century is indicated by the Maryland law of 1704, which contains much the same provisions with respect to clearing and grubbing, and merely increases the width to twenty feet. This law, however, is of interest mainly because of its fifth section which constitutes what is perhaps the first definite regulation for marking of roads in America, and, incidentally, indicates how easy it must have been to lose one's way on the rude tracks which served for roads. This curious provision was as follows:

"V. And that all the roads that lead to any Ferries, Court-house of any County, or to any church, or leading through any county to the port of Annapolis, should be marked on both sides the Road with Two Notches; if the Road lead to Annapolis, the Road that leads there, at the leaving the other Road, shall be marked on the face of the tree, in a smooth Place cut for that purpose, with the letters A A set on with a Pair of Marking-Irons and coloured; and so with Two Notches all along the Road; and where at any Place it leaves any other Road shall be again distinguished with the Mark aforesaid, on the Face of the Tree, with a Pair of Marking-Irons, and coloured as aforesaid. And any road on the Eastern Shore in Talbot County, that leads to the port of William-Stadt at the entering of the same, and in parting with or dividing from any other Road, shall be marked on the face of a tree, in a smooth place cut for that purpose, with the letter W, and so with two notches all along the road. And the Roads that lead to any County Court-house, shall have two Notches on the Trees on both sides of the Road as aforesaid, and another Notch a Distance above the other. And any Road that leads to a Church, shall be marked at the entrance into the same, and at the leaving any other Road, with a Slip cut down the Face of the Tree, near the ground. And any road leading to a Ferry, and dividing from other public roads, shall be marked with Three Notches of equal distance at the Entrance into the same. And these Rules and Methods the several Justices of the County Courts, shall, from Time to Time, give in charge to the

overseers of the Highways, by them to be appointed for that purpose; who are likewise enjoined carefully and strictly to observe and perform the same, under the Penalty aforesaid."

Along at least one of these ancient roads in Southern Maryland, still known as the "Three Notch Road", notches, some of a remote date, may still be discerned in the bark of many of the oldest oaks.

The law in which this odd provision was made constituted, with minor amendments, the sole road legislation of the province of Maryland for nearly three generations, and Maryland was not more backward than the other colonies. Indeed it must be said that from the point of view of the road builder the progress made during the entire colonial period was practically negligible, as may be seen from the following passages taken from the work of the Maryland historian, Thomas Scharf: " * * * * where water routes were not available, the means of locomotion, though various, were all primitive. Long journeys were made on horseback. People of consequence rode in their coaches, with four horses attached, the leaders mounted by liveried positilions. So Washington came from New York to Annapolis, to attend the ball given there in his honor after the peace. He left New York December 4, and arrived at Annapolis, December 17, thirteen days to a ride which may now be made inside of eight hours. So Washington went to Philadelphia from Mount Vernon to attend the Constitutional Convention, having to lie over at Havre-de-Grace all night because

it was too stormy to cross the Susquehanna. The stage-coach was just coming into use in this country at the time of which we write, and the importance of regular communication between one point and other was beginning to be seen. There were a few, but not many post-routes, and those chiefly maintained by private enterprise.

"The carriers' cart plied between Alexandria and Philadelphia, by way of Baltimore; the conestoga wagon was the means of communication between Baltimore and Harrisburg, Frederick, Hagerstown, etc., while these outlying places in their turn were brought into intercourse with the backwoods and the wilderness by means of strings of pack-horses. * * * * Roads were all bad and ill-kept, narrow, obstructed by gates and seldom permitting two vehicles to pass one another. * * * *

"The good roads - comparatively good, we mean - and the best post-routes were due to private enterprise. The Kent Island post-route was owned by a Tilghman, and Henry Callister threatened an opposition unless it was better managed. * * * * It took a day of almost twenty-four hours, to ride from Elkridge Landing to Annapolis (about 30 miles) - yet the thrifty Germans of Frederick County traded with Georgia by way of the Valley of Virginia, sending their manufactures of wool, flax and leather on the backs of pack-horses."

If such was the state of the roads in the settlements during the Revolution it may be assumed that the few roads which previously had been pushed westward across the mountains were even more primitive.

The first of these was laid out in 1743 by the Ohio Company, a party of Virginia gentlemen who had been granted two hundred thousand acres on the Ohio River between the Monongahela and the Kanawha on condition that a hundred families should be settled on it in two years.

According to Hulbert: "The road was probably nothing more than a blazed trail with possibly some alteration of route at certain points; it may be that in low ground which could not be avoided the road was 'corduroyed', but this is quite doubtful."

It was over this road that Washington traveled, in 1753, at the behest of the Virginia governor to inquire of the French their rights to build forts on the Allegheny River. Again in 1754, when war with the French seemed inevitable, he made the same trip over the same road, this time taking with him 300 men and possibly 10 swivel guns, to move which it was necessary to widen and strengthen the road. Finally in the following year (1755) it was over this same road that Braddock advanced from Fort Cumberland with 2,200 men and 600 pioneers, leading the way, to widen and corduroy the trail for the army. This time the road was evidently made with some care, for Washington complained that the movement of the army was being delayed because the road-makers were stopping to level "every mole-hill".

This, the first road across the mountains, was the only one until 1758 when General John Forbes, sent against Fort Duquesne to redeem the failure of Braddock, built or rather opened a new one by way of Bedford and Ligonier in Pennsylvania; and this road with its predecessor remained as the only routes of white-man travel across the mountains until 1775.

In that year the Transylvania Company was organized and Daniel Boone was sent to mark out the Wilderness Road through the Cumberland Gap to Kentucky. Though made later than the roads of Braddock and Forbes, the Wilderness Road quickly became the most important of the three as a thoroughfare and for a time actually outrivalled the Ohio River as a pioneer route.

Of this road a Kentucky historian says:

"The road marked out was at best but a trace. No vehicle of any sort passed over it before it was made a wagon road by action of the State legislature in 1795. The location of the road, however, is a monument to the skill of Boone as a practical engineer and surveyor. It required a mind of far more than ordinary caliber to locate through more than two hundred miles of mountain wilderness a way of travel which, for a hundred years, has remained practically unchanged, and upon which the State has stamped its approval by the expenditure of vast sums of money."

But, though the State did undoubtedly approve and profit greatly from the work of the intrepid Daniel, its approval apparently did not express itself in any substantial way. For in 1796 we find Boone writing as follows to Governor Shelby:

"Sir, after my best Respts to your Excellency and famyly, I wish to inform you that I have sum intention of undertaking this New Rode that is to be cut through the Wilderness, and I think my Self intitled to the ofer of the Bisness as I first Marked out that Rode in March 1775 and Never rec'd anything for my trubel and Sepose I am no Statesman I am a Woodsman and think my Self as Capable of Marking and Cutting that Rode as any other man. Sir if you think with Me I would thank you to wright me a line by the post the first oportuneaty and he Will Lodge it at Mr. John Milers on hinkston fork as I wish to know Where and when it is to be Laat (let) so that I may atend at the time I am Deer Sir your very omble sarvent.

Daniel Boone."

But alas, the contract was given to others, to Boone's great disappointment. Such was the experience of the first American "engineer" who took it into his head to "go into contracting". How many have been the similar experiences of his successors the record does not state.

The mountains crossed, progress of exploration westward was rapid after the Revolution. The pioneers opened the trails

and the army followed close behind, establishing forts for the protection of travelers and settlers against Indian attack. But the "road building" that was an incident of the advance of those brave and adventurous spirits was invariably of the sort already described; that is, a mere breaking and blazing of trails in the difficult places, and, in the open country, only the chosing of a path which by continued use was worn into a well-marked route.

For the opening of certain of these routes, Congress, which, under the Constitution was given the right to govern the territories, was urged to contribute money, and did actually contribute to a few, among them the famous Natchez Trace which ran from Nashville, Tenn., to Natchez, Miss., and Zane's Trace in Ohio. The character of the work done on the former is indicated by the fact that the appropriation was $6,000.

Of similar character were the great trails of the West, on which exploration began early in the nineteenth century. In all the annals of America there are no more thrilling passages than the records of the travels and the path finding of the pioneers who, following the Santa Fe, the Overland and Oregon Trails, settled and held for the United States the great dominions of the West. The highways they marked out were so truly remarkable that they are still, in the main the principal routes of travel in the territories they traverse. One of them - the Oregon Trail - has been described as "the most remarkable road known to history * * * * . Considering the

fact that it originated with the spontaneous use of travelers; that no transit ever located a foot of it; that no level established its grades; that no engineer sought out the fords or built any bridges or surveyed the mountain passes, that there was no grading to speak of nor any attempt at metalling the road bed; and the general good quality of these two thousand miles of highway will seem most extraordinary."

But it will not be possible in this paper to follow the development of the routes of exploration westward. Our principal concern being the study of the development of road construction methods, we must return to the Eastern States, where, immediately after the close of the Revolution, the first great movement for the betterment of American roads was at its inception - the establishment of the turnpikes.

The first American turnpikes of which there is record were established in Virginia, Connecticut, and Maryland. From the interesting book by Frederic J. Wood entitled "The Turnpikes of New England", we learn that Virginia led the way by the erection of gates on the roads leading into Alexandria from Snigger's and Vesta's Gaps. The travel on these roads had become so heavy that extensive repairs had become imperative and, the resources of the territory traversed being inadequate, it was proposed to set up toll gates as a means of collecting the necessary revenues, an idea suggested, no doubt,

by the English experience with turnpike trusts which had been in operation for at least twenty years previously. The act of the legislature providing for the erection of the turnpikes was passed in 1785, and, as an existing road was taken over and the only construction necessary was the erection of the gates, it is safe to say that they were in operation by 1786.

A heavy travel passed over this road for several years and the tolls imposed by the legislature were insufficient to maintain its surface. Accordingly we find that in 1795 representations were made to the legislature that "an artificial bed of pounded or broken stone" was necessary, and that the expense of this, being too great to be financed by the usual methods, it should only be assumed by private enterprise. This is the first reference I have been able to find to any form of construction resembling what is now classed, very loosely, as a macadam surface. It is probable that stone and gravel surfaces had been laid in England for some years previously, and there may have been some more or less unsystemmatic use of stone in America also at an earlier date; but it is reasonably certain that this Virginia road was at least one of the earliest to be deliberately planned as a stone-surfaced highway. As a result of the representations made the "Fairfax and Loudon turnpike-road company" was incorporated on December 26, 1795 and given the privilege of reconstructing the old turnpike from "Little River,

where the present turnpike crosses it, to Alexandria." The first company, finding the task too great, nothing was accomplished under its charter, and, in 1802, a new charter was granted to the "President, Directors, and Company of the Little River Turnpike Company." Under this charter, with the help of the State of Virginia, which appropriated the "muster fines" in 1805 to the purchase of 100 shares of stock, the old road was rebuilt and operated as a toll road for over ninety years.

The second and third turnpikes were in Connecticut where, in 1792, the Mohegan Road, between New London and Norwich, and the Old Post Road, in Greenwich were made subject to toll. A year later, in 1793, a gate was set up on the Reistertown Road in Maryland and later on other gates were established on the York and Frederick roads near Baltimore. These Maryland cases were followed, in 1801, by the establishment of a gate on the old road through Cumberland Gap in Tennessee, and, in 1804, North Carolina provided for the construction of a 14-mile road through the Cherokee lands by granting to the builder the privilege of collecting tolls for 15 years. All these were government enterprises, and they are the only exceptions to the practice, which was shortly to become general, of allowing the turnpikes to be built by private capital. Later these too were transferred to private companies, but the first road to be built in this manner was the famous Lancaster Turnpike in Pennsylvania which was built by the Philadelphia and

Lancaster Turnpike Company, incorporated by the governor on April 9, 1792. This road which was more than 62 miles in length was built at a cost of $7,450 a mile and was finally completed in 1796.

Following this example similar corporations were created in rapid succession in all the States, and in his report to Congress, in 1808, Albert Gallatin, the secretary of the treasury was able to report definitely that 770 miles were completed in Connecticut, more than 3,000 miles were under construction or completed in New York, and hundreds of miles in other States.

This same report of Gallatin's gives us the first detailed description of the character of the "artificial roads" which were built by the early turnpike companies.

Referring to the road from Trenton to Brunswick in New Jersey he reports that:

"The distance is twenty-five miles; the greatest angle of ascent, three degrees; and the road is nearly in a straight line, the only considerable obstruction being the 'sand hills', through which it was necessary to dig at the depth of thirty feet, in order not to exceed the angle of ascent. The road is thirty-six feet wide, fifteen feet of which are covered with about six inches of gravel. A few wooden bridges, with stone abutments, and piers have been erected across the intervening streams. The whole expense is stated at $2,500 a mile."

Of the road in Pennsylvania from Philadelphia to Perkioman, which had two branches to Willow Grove and Chestnut Hill, he wrote:

"The distance * * * * * is twenty-five miles and a quarter; the two branches extend one ten miles, and the other seven miles and a half; making together near forty-three miles. The angle of ascent is four degrees; the breadth of the road fifty feet, of which twenty-eight feet, having a convexity of fifteen inches, are covered with a stratum either of gravel eighteen inches thick, or of pounded stones twelve inches thick. One-half of the stones forming the lower part of the stratum are broken into pieces not more than five inches in diameter; the other half or upper stratum consists of stones broken into pieces not more than two inches and a half in diameter, and this difference in the size of the stones is represented as a considerable defect. Side or summer roads extend on each side of the gravel or stone road. The five miles next to Philadelphia have cost at the rate of $14,517 a mile; the other twenty miles and a half at the rate of $10,490 a mile. Yet there were no natural impediments, and only small bridges or culverts were necessary. The capital expended on these twenty-five miles and a half is $285,000; the tolls amount to $19,000; the annual repairs and expenses to $10,000; the nett income to about $9,000, or a little more than three per cent. on the capital expended."

Among Maryland roads he notes the Reisterstown turnpike, twenty-four feet wide and surfaced with twelve inches of pounded stone not more than three inches in diameter; the Frederick road, twenty-two feet wide and surfaced with ten inches of pounded stone not more than three inches in diameter over which were spread two inches of gravel or coarse sand the entire surface having a crown or convexity of nine inches.

South of the Potomac he reports that few "artificial roads" had been undertaken. One, which he briefly describes - the road from Manchester to the coal mines of Falling Creek, in Virginia - was thirty-six feet wide and gravelled and the cost of twelve miles he gave as $50,000. This construction, he reports, was sufficiently substantial to admit wagons carrying four tons.

"The greater progress made in the improvement of roads in the northern parts of the Union," he ascribes, "to a more compact population, which renders those improvements more necessary, and at the same time supplies with greater facility the means of effecting them. The same difference is perceptible in the number of bridges erected in the several States."

In this famous report we have direct evidence of the construction, prior to 1808, of roads surfaced with both gravel and broken stone. In the case of the Philadelphia-Perkioman road we see the construction of a stone surface in two courses in a manner

similar, except for the large size of the stone and the heavy crown and the absence of rolling and sprinkling, to the methods used in building modern macadam roads. Wherein lay the "defect" of using two courses, as mentioned in the report, is not made clear.

It is not to be assumed, however, that these roads embodied in their construction the principles of MacAdam; nor can we say with truth that our present roads do. They were probably patterned after the roads then being constructed in England, and the great roadbuilder, whose name is now associated with any form of stone surface, had not yet demonstrated the particular methods which properly should be attributed to him. He was still engaged in the preparatory studies which led to the development of the methods he first applied when he became the surveyor of roads in Bristol in 1816.

According to MacAdam's view, the function of the stone surface was not to support the weight of vehicles but to form a covering or roof over the natural soil upon which, in its dry condition, he relied entirely to support the load.

He, therefore, regarded a heavy course of metal as unnecessary, and large stone as positively objectionable in that a road so formed would be likely to be more pervious than one made of small stone. His idea was that, "every piece of stone put into a road, which exceeds an inch in any of its dimensions, is mischevious"; and he

based this conclusion not only upon the thought that the use of larger stone would increase permeability, but also, and perhaps mainly, upon the greater tendency for the larger stones to be dislodged by the wheels of vehicles. He was also opposed to the use of heavy crowns on the ground that they were unnecessary for drainage purposes and that they tended to concentrate traffic at the center and, thereby, actually defeat the ends of drainage by causing the formation of ruts.

His methods, explained in his own words, were as follows:

"As no artificial road can ever be made so good, and so useful as the natural soil in a dry state, it is only necessary to procure, and preserve this dry state of so much ground as is intended to be occupied by a road.

"The first operation in making a road should be the reverse of digging a trench. The road should not be sunk below, but rather raised above, the ordinary level of the adjacent ground, care should at any rate be taken, that there be a sufficient fall to take off the water, so that it should always be some inches below the level of the ground upon which the road is intended to be placed; this must be done, either by making the drains to lower ground, or if that be not practicable, from the nature of the country, then the soil upon which the road is proposed to be laid, must be raised by addition, so as to be some inches above the level of the water.

"Having secured the soil from under water, the road-maker is next to secure it from rain water, by a solid road, made of clean, dry stone, or flint, so selected, prepared, and laid, as to be perfectly impervious to water; and this cannot be effected, unless the greatest care be taken, that no earth, clay, chalk, or other matter, that will hold or conduct water, be mixed with the broken stone; which must be so prepared and laid, as to unite by its own angles into a firm, compact, impenetrable body.

"The thickness of such a road is immaterial, as to its strength for carrying weight; this object is already obtained by providing a dry surface, over which the road is to be placed as a covering, or roof, to preserve it in that state; experience having shown, that if water passes through a road, and fill the native soil, the road, whatever may be its thickness, loses its support, and goes to pieces."

It must be borne in mind that MacAdam applied his art more often to the repair of existing surfaces than to the construction of new ones, and in making such repairs he particularly recommended and used the process which he called "lifting the road", which consisted in loosening the upper portion of the sruface and breaking all old stones over about six ounces in weight before applying the new stone. As he did not have a roller to use he advocated apply-

ing the new stones in thin courses allowing time between successive applications for the metal to be compacted by traffic. He suggested a three-time application as desirable and particularly insisted upon the necessity of keeping the road well shaped during the intervals when it was being compacted.

He surprised the members of the parliamentary committee appointed to inquire into methods of improving the turnpikes and highways by informing them that he would prefer to construct his surface on a soft foundation rather than a hard one, because "when a road is placed upon a hard substance, such as a rock, the road wears much sooner than when placed on a soft substance".

This statement elicited from his amazed interlocutor the exclamation: "You don't mean you would prefer a bog?" To which the calm reply was; "If it was not such a bog as would not allow a man to walk over, I should prefer it."

With these views, so remarkably in accord with the most modern ideas, there is scarcely a fault to be found, yet the fact remains that they have been honored more in the breach than in the observance in American practice, at least.

As MacAdam did not begin to practice his art until 1816 and as his methods were essentially different from those which were common at the time in England it is not possible that the stone surfaces constructed on the fast multiplying American turnpike-roads prior to that date were macadam roads in the strict application of

the term, though, from the descriptions available, it is probable that they were not unlike many of the roads to which the name is now applied.

When, in 1832, it became necessary to repair the surface which had been constructed on the Cumberland Road east of the Ohio River, the orders of General Gratiot, then chief of engineers, were that the macadam system was to be followed, and this system he defined exactly as MacAdam had described it in his "Remarks on the Present System of Road Making," published in 1820. It is not improbable that this was the first application of the true method in America, and it may have been the last.

The story of the National Pike has been told too many times to need more than a brief reference here. The earliest act of Congress relating to it was passed in 1802 and simply provided that 5 per cent of the revenue received from the sale of Ohio lands should be set aside for public road improvement and that two-fifths of this amount should be devoted to constructing a road from the Potomac River westward to the Ohio River.

In 1805, the building of the road from Cumberland to the Ohio River was authorized, and the act further provided that the proposed road was to have a right of way of 4 rods, a roadway of 20 feet, a maximum grade of $8\frac{3}{4}$ per cent, and a surface of stone, earth, gravel or sand or a combination of these. Later, in Ohio, the width of right of way was increased to 80 feet.

The first contract for construction was let April 11, 1811, and the road was completed from Cumberland to Wheeling about ten years later. The total length of this section is 131 miles and the total cost of construction was $1,706,845.20, or an average of $13,029.35 a mile. The entire section east of Wheeling was surfaced with broken stone put down in two courses. The specifications provided that the stone for the bottom course should pass a 7-inch ring, and that the top course, a 3-inch ring. The top course was 6 inches, and the bottom 12 inches before compacting, and as the traffic was depended upon to effect the compaction, there is little doubt that travel over the road in springless wagons was not unduly comfortable; especially as it is said that the engineers in charge of the work had a way of erecting barriers which were frequently shifted in order to prevent honest travelers from using any part of the surface after it had become compact.

The first appropriation for continuing the "National Roads" west of the Ohio River was made in 1825, and the final appropriation for completing it in Ohio and continuing it in Indiana and Illinois was made in 1838. The section in Indiana was constructed east and west from Indianapolis, and was practically completed before the Government discontinued its appropriations, but in Illinois no surfacing was laid.

Congress provided that only grading should be done on this section, in order that the government might later put down a steam railroad on the grade if it so desired.

The turnpike-road companies, by which the majority of the early artificial roads were built, were our first public service corporations. They operated under charters granted by the State legislatures, authorizing them either to build and maintain an entirely new road or to take over from the public the maintenance of an existing road.

What now seem to be very severe restrictions were imposed upon them. They were limited strictly to the building and maintaining of a road, and were not allowed to do anything else. Rates of toll were fixed in the charter and the number of gates to be erected was also specified. The location of the road was not intrusted to the judgment of those who were investing their money but was delegated to a committee appointed either by the legislature or by the judge of the county court.

In spite of these restrictions the stock of the companies at first was very attractive to investors; but it was not long before it was discovered that the roads could not be expected to pay a large return. Few of the companies were able to show, even at first, net earnings of more than two or three per cent, and as time went on and the cost of maintenance increased, as, finally, the railroad came to take away a large part of the traffic, even these small profits vanished, and the turnpikes became, generally, very unprofitable investments. Most of the hundreds of companies that were organized had failed and the roads had reverted to public control by 1850; but a few remained in operation.

after a fashion, until very recent years, their roads anathema to all who were compelled to use them.

The word "turnpike" has come to be associated in our minds with a stone surface, mainly, I presume, because the surviving "pikes" were all or practically all of that character. But in the early days many of the companies, perhaps the majority, built only a graded road. In many cases the surface was of gravel, in other shell, and in some cases, in order to make the roads passable the companies resorted to corduroy. Quite a large number, as we shall see later, were incorporated for the special purpose of building plank roads.

The railroads sounded the knell of the turnpike companies. One by one they came upon financial difficulties so great as to cause them to give up their charters, until, by 1850, few were left in existence. With their passing the roads reverted to public control - which meant county control - and so out of the picture until the late eighties, except for the rather curious vogue of the plank road.

The first plank road on the continent and probably in the world was laid at Toronto in 1835 - 36. The originator is believed to have been Dr. Darcy Boulton. About ten years later a road was built, in all respects like the Toronto example, at Syracuse, N. Y. This was probably the first road of its kind in the United States. Within four years over two thousand miles had been constructed in New York alone, at an average cost of $1,833 a mile. Several were built, also, in New Jersey, and a number in Vermont and Connecticut. At least one was built in Massachusetts. These, so far as the record goes, were the only eastern developments; but the idea spread to the interior States and there the planked surfaces may still be met with occasionally,

Of the construction of the plank roads, Mr. Frederic Wood, deriving his authority from the book entitled "The History, Structure and Statistics of Plank Roads", published in 1850 by W. Kingsford, writes as follows:

"They were in nearly all cases of single track, laid on the right side of the road as one faced the large town to which it led. In the prairie regions the planking lay on the original surface of the ground, but in some places a small amount of grading was needed to avoid short, steep ascents. The subgrade once established, longitudinal trenches were dug in which sills consisting of 3-inch plank four and eight inches wide were placed, and on them were laid the planks, three inches thick and eight feet long, at right angles to the direction of the road. The sills were set slightly below the surface of the ground, and the planks were pounded down to rest upon them by means of a large mallet known as a "commander". No nails or pins were then needed to hold the planks down, and it is reported that it was hard work to take one of them up. After the planks were laid the earth was packed against their ends and soundly tamped into place. The portion of the highway not occupied by the plank road was usually maintained as a common dirt road and was locally known as the 'turn-off' , because light loads had to leave the planks and follow it when passing a team proceeding the other way. In order that a wagon might regain the planked surface without its wheels sliding along the edges, the planks were staggered, that is, one-half of them had their ends in a straight line with each other, while the other half were alternately advanced to a line six inches farther

out, producing a border effect like the battlements of a castle. Ordinarily two stringers were used but occasionally three. Over the completed planking a layer of sand was spread and maintained, which preserved the road by reducing the cutting by the calks of the horseshoes. It was claimed for this coating that a saving of forty to fifty per cent was secured in the wear of the road. Very few double-track roads were ever laid, and in the few cases it was preferred to lay two single tracks, apart from each other and supposedly on opposite sides of the 'turn-out'.

"Yellow pine was preferred for the planking in Central New York, on account of its durability and freedom from knots, but hemlock and white pine were extensively used while beech, maple, and elm were employed in some places. * * * * Of course the planks would rapidly decay, and it was considered necessary to figure that a road would have to be rebuilt at the end of every seven years."

If we now pass immediately to the later eighties we shall miss no development of any importance so far as the highways are concerned except the inventions of the stone crusher by Blake in 1858 and of the steam road roller by Lemoine in 1859, and the former, at least was apparently not received with enthusiasm because we find the author of a prize-winning essay in 1890 writing that;

"Hand-broken stone is much superior to that crushed by a machine, which is generally of irregular shape and seldom cubical, so that it does not readily bind together, which is the essential qualification of macadam."

Some time during this period, probably after 1876, the third or binder course was added to the macadam process. Q. A Gillmore

in his book entitled "A Practical Treatise on Roads, Streets, and Pavements", published in that year, makes no reference to it, except as a top dressing of gravel or earth spread on after the rolling of the last application of stone. This is the method which was practiced even in MacAdam's day and which he strongly disapproved. The consolidation of the road with stone chips flushed and rolled into the surface was apparently unknown to Gillmore when the first edition of his book was printed; but some time between 1876 and 1890 it became the common practice.

It was during the latter part of this same period (1850 - 1890) that the first brick and sheet asphalt surfaces were laid; the brick in Charleston, W. Va. in 1872, and the first extensive sheet asphalt surface on Pennsylvania Avenue, in Washington, in 1879. Prior to the latter date the first rock asphalt surface had been laid opposite the City Hall in Newark, N. J. This was in 1870; and there are conflicting claims to priority in the construction of short experimental sections of sheet asphalt, one being that the first section was laid in New York in 1873 and the other that it was in Washington Square, Newark, in 1877. For many years, however, construction of both the brick and asphalt surfaces was confined to cities. Until 1890, at least, the only materials generally considered as practical for surfaces of rural highways were broken stone, gravel, and - where the materials were available - shell and slag. The latter were laid in the same manner as gravel and stone. The plank surface was already condemned. Surfaces of "burnt clay" 1/

1/ "Road Making and Maintenance", by Charles Punchard, published with other essays in "A Move For Better Roads", Univ. of Pa. Press, 1891.

had been suggested but were still untried.

The organization of the League of American Wheelmen in 1880 may probably be considered as the turning point marking the beginning of the modern period of highway improvement, and the league itself as the first of the influences which have led to so great a change in the public attitude. One of the principal objects of the organization was to secure better roads and it worked energetically to attain its purpose; but it was not until 11 years later that the first tangible result of its efforts was accomplished in the passage of the first State-aid law in New Jersey. Writing in 1889, Jeremiah Jenks, 2/ pictures the condition

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2/ Road Legislation for the American State, Jeremiah W. Jenks.

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existing at that time when he says that:

"A very large proportion of our people, too, have never seen a really good road for hauling purposes, and have, in consequence no clear idea of the gain that would come from good roads."

The passage of the New Jersey State-aid legislation in 1891 was the first practical step taken, anywhere in the country, to remedy the situation. With one exception it was also the first instance in which any State had undertaken to participate directly in the construction of roads. The exception is Kentucky, which had a State highway department and a well defined State road policy from 1821 to 1837, and during that period completed upwards of 340 miles of roads.

The next fruit of the wheelmen's efforts is found in the establishment of the U. S. Office of Road Inquiry in accordance with an act of Congress approved March 3, 1893. The purpose of the office

as defined in the statute was to make inquiries in regard to systems of road management throughout the United States; to make investigations in regard to the best methods of road making; to prepare publications on this subject, and to assist agricultural colleges and experiment stations in disseminating information on the subject. The appropriation made for this purpose was $10,000.

It will this be seen that the renewed participation of the Federal Government after a lapse of 55 years was limited to activities of an educational character, but these it must be said were carried on with excellent judgment and the utmost vigor possible with the meagre appropriation provided.

The actual construction of the roads, being still under the control of county and township authorities the Federal Office carried its message directly to these local officials and, by actual demonstration on short sections of object-lesson road in every State, taught them the methods of road construction which, from its studies, it found to be best. The general public it reached through the medium of bulletins, lectures and good roads trains, and there is no doubt that its urging was responsible for the creation of more than one of the early State highway departments.

Following the New Jersey precedent, laws providing for the establishment of such departments and the granting of State aid were passed in Massachusetts in 1892, in California and Connecticut in 1895, and in Maryland, New York and Vermont in 1898. Thus by the end of the nineties there were seven States- all but one on the Atlantic seaboard - that had taken the initial step toward the solution of the road problem; and as the

century opened they were followed by many others. The dates of passage of the first laws in the several States are shown in the following table.

Dates of passage of State-aid highways laws

State	Year in which first State aid law was passed	State	Year in which first State aid law was passed
Alabama	1911	Nevada	1911
Arizona	1909	New Hampshire	1903
Arkansas	1913	New Jersey	1891
California	1895	New Mexico	1909
Colorado	1909	New York	1898
Connecticut	1895	North Carolina	1901
Delaware	1903	North Dakota	1909
Florida	1915	Ohio	1904
Georgia	1908	Oklahoma	1911
Idaho	1905	Oregon	1913
Illinois	1905	Pennsylvania	1903
Indiana	1917	Rhode Island	1902
Iowa	1904	South Carolina	1917
Kansas	1911	South Dakota	1911
Kentucky	1912	Tennessee	1915
Louisiana	1910	Texas	1917
Maine	1901	Utah	1909
Maryland	1898	Vermont	1898
Massachusetts	1892	Virginia	1906
Michigan	1905	Washington	1905
Minnesota	1905	West Virginia	1909
Mississippi	1915	Wisconsin	1911
Missouri	1907	Wyoming	1911
Montana	1913		
Nebraska	1911		

The State-aid policy as adopted by the various States took a number of forms. In some States the aid offered consisted only of advice which might be accepted or rejected by the local authorities who retained absolute control over all the roads. In such States no financial aid was extended. In those States which provided for financial aid its acceptance generally implied an agreement on the part of the county to accept the supervision of the State authorities until the work of construction was completed, after which the road reverted to full county control. In still other States the joint participation of the State and county in the construction of certain classes of roads, generally the most important ones, was made mandatory; and there were still other variations which differentiated the systems adopted by the various States.

While the pioneer States were making this radical departure from long established methods of highway administration certain seemingly unimportant and unrelated events were occurring in various parts of the country. Three gentlemen - whose names were Duryea, Haynes, and Ford - had made themselves horseless carriages; and in Bellefontaine, Ohio, a road had been built entirely of concrete. Concrete had been used as a base for block and sheet asphalt pavements for many years; but the short section built in 1893 in the Ohio city was the first to be built with concrete as the wearing surface. As in the case of the brick and asphalt surfaces, it was several years, however, before use of the new type was extended to the rural highways.

And the same may be said of the automobiles. Although their numbers increased remarkably in the cities, it was some years before they became a problem from the point of view of the rural highway builder.

In 1904, the Office of Public Roads, lineal descendant of the Office of Road Inquiry, took the first census of American roads. It found that there were then, in the United States, 2,151,570 miles of rural highways of which 153,662 miles had been surfaced with various materials. Of this surfaced mileage 38,622 miles were improved with waterbound macadam; 114,899 miles were improved with gravel, sand-clay, shell, plank, and other low-type surfaces (the great majority being gravel); and 141 miles were improved with surfaces better than macadam. The latter included 123 miles paved with brick of which 104 miles were in the two States of Ohio and West Virginia, and 18 miles of bituminous roads of which 2 miles were in Massachusetts and the other 16 in Ohio. Except for the oiled earth roads, of which more than 2,500 miles (included with the gravel and other low-type improvements in the previous classification) had been built in California by the so-called petrolithic process, these 18 miles were the only representatives, in 1904, of a type which was destined shortly to become exceedingly important. As previously mentioned sheet and rock asphalt surfaces had been laid in the cities since the seventies, and both bituminous macadam and bituminous concrete surfaces had been built in England before 1890, but the only bituminous surfaces to be found anywhere in the United States in 1904 were 2 miles of tarred road in the town of Tisbury, Mass., and 13 miles of bituminous macadam and 3 miles of asphalt in Ohio.

This year 1904 marks the end of a period. Up to that time there had been no important change in the methods of road construction which had been employed for a century or more. Either of the major types of surfacing - gravel and macadam - was known to give entire satisfaction under the traffic normal to the country roads of the time. The other types that had been developed and used in small mileage, such as the shell roads of the tidewater States and the sand-clay roads of the South, were suggested by the availability of the materials rather than by any difference in the demands of the traffic which used them.

Viewed broadly the few types of surface constructed up to this time may all be considered as of one class. In the construction of all the same principles governed; in all a fragmental mass was bound together more or less firmly by a natural cement in the manner made familiar by a century of practice; and all alike depended for their efficiency upon the conic principle of pressure transmission by which they spread the vehicular loads and thus reduced the intensity of pressure borne by the subgrade.

That need was felt for no other kind of construction was due, of course, to the fact that the traffic on all roads was much the same. Even in the more populous States the greater part of the traffic using the roads consisted of relatively light, horse-drawn, steel-tired vehicles, to which were added near the cities a bicycle traffic which, though it might attain considerable volume, was never more than a negligible factor in determining the type of surface.

This was the normal traffic condition which existed practically up to 1904. What makes that year a turning point in highway history is the fact that about that time there began the great outpouring of motor vehicles from the cities which quickly set the intercity roads apart from others as a class requiring different treatment.

The peculiar effect of the automobile on waterbound macadam roads is so well known as to require no description and the manner in which the road builders met the challenge by substituting tars and asphalts for the weaker mineral binders has been an oft-told tale. First as dust layers, then as protective surface coatings, then as binders introduced into roads of the macadam type by penetration, and finally as hot admixtures according to the bituminous concrete principle, these materials, borrowed from the stock in trade of the city street builder, solved the automobile problem in a manner which was apparently entirely satisfactory.

The effect of this development in the road building art is shown by comparison of the statistics of 1904 and 1914, the dates which, to all intents and purposes, mark the beginning and crest of the wave of bituminous construction. In 1904, according to the records, there were in the entire country only 18 miles of bituminous rural roads, all in the two States of Massachusetts and Ohio. By 1914 there were 10,500 miles, a mileage which was nearly three-quarters of the aggregate length of all roads of higher type than macadam. This was the high-water mark of the lower forms of the bituminous types.

That it by no means marked the end of their usefulness is indicated by the fact that 3,367 miles of the surface-treated and penetration types were built in 1924. The recession of the tide is indicated, however, by the fact that the mileage of the two types existing in 1924 was less than 50 per cent of the mileage of all types better than waterbound macadam in comparison with the 75 per cent level reached in 1914.

It is generally recognized that these two types which came into use with the development of passenger automobile traffic are especially adapted to that class of traffic. The relative decline in their use began when motor trucks in considerable numbers began to appear on the rural highways; and coincidentally we find an increasing swing toward the rigid pavements of concrete and brick and bituminous concrete on a concrete base. The turning point was reached in 1914 or perhaps a year or two earlier.

Although the first concrete road had been built in 1893, there were no more than 5 miles of that type on rural highways in the entire country in 1909. In that year approximately 4 miles were built; in 1910 about 20 miles were added, the following year 40 miles, and then the first big increase occurred in 1912 when more than 250 miles of rural highways were paved, to be followed in 1913 with 500 miles and in 1914 with more than 1,500 miles. At the close of the latter year there were in the entire country 2,348 miles; and 10 years later the mileage had increased to 31,146 and construction was proceeding at the

rate of more than 6,000 miles a year, a rate approached by no other type better than gravel.

The more extensive use of brick, and the bituminous pavements of the mixed type on concrete base began also at about the same time and was due to the same cause - the increased use of motor trucks. In 1914 there were approximately 1,600 miles of brick pavement; in 1924 there were 4,319. In 1914 the mileage of rural highways paved with bituminous concrete or sheet asphalt was still negligible; in 1924 there were more than 9,700 miles of these types.

The decade following 1904 was marked not only by the development of new types of road but also by two other changes of even greater significance. The first of these was a general increase in the radius of travel by highway occasioned by the use of the automobile; and the second - the natural result of the first - was a change in the character of the public demand for highway improvement.

In 1904 the automobile had still to prove its ability for sustained performance. Its ownership was still limited to a small and wealthy class. The popular demand for improved roads was, therefore, still predicated upon the use of the bicycle and the horse-drawn vehicle. The farmers, always conservative, were still, for the most part, either actively hostile to road improvement or lukewarm in support of it. In general their demand was for the improvement of the roads connecting their farms with the railroad shipping points or nearby towns. More positive influence was exerted by city and town merchants who

sought by road improvement to extend the trading radius and business of their towns, and by the limited but influential class of motorists who longed for smoother, mud-and-dust-free roads upon which to operate their vehicles. All these influences combined at first to produce a demand for short stretches of improved roads radiating from the towns and rail shipping points. Later, as the automobile was perfected and its users became more numerous, the latter created a demand for longer, unbroken stretches of improved roads, forming a network connecting the larger towns, a claim that was resisted by the farmers who continued to favor the so-called farm-to-market type of movement.

In the smaller Eastern States the conflict never became acute, largely because the distance between towns and market points was so short that the farm-to-market plan of improvement when carried to its ultimate development became practically identical with the inter-town or trunk-line plan. Thus we find the issue satisfactorily settled in Rhode Island as early as 1902 by the adoption of a definite system of State highways for construction by the State Board of Public Roads. A similar proposal by the highway commissioner of Connecticut, made originally in 1906, was enacted into law by the State Legislature in 1913; and in the meantime Maryland had settled the question definitely by the adoption of an inter-county-seat trunk-line system to be improved and maintained in its entirety with State funds under the State Roads Commission. Maryland's system was designated in 1908, and was the first to be placed completely under State control for both construction and maintenance.

That the controversy was not so quickly settled in many of the other States was due mainly to two reasons: First, the important lines of travel in a number of the States were not sharply defined. This resulted in some from sparsity of settlement, and in others from the contrary condition of close settlement with numerous centers of more or less uniform size and importance. States such as Texas and Wyoming were typical of the first group. In them the long distances between centers and the condition of the roads delayed the development of highway traffic between the towns and promoted a use of the highways largely as feeders to the rail lines; and the same remoteness of the towns one from another prevented the early harmonizing of the two plans of development as in the smaller Eastern States by the evolution of one into the other. Of the second class there were such States as Iowa, Kansas and Wisconsin in which the very number and uniform size of the town centers caused a diffusion of traffic over many roads and delayed the recognition of routes of outstanding importance. In these States also the towns are essentially agricultural centers and this fact contributed further strength to the demand for farm-to-market roads as opposed to trunk lines.

The instances mentioned furnish examples of one of the reasons for the prolongation of the controversy which raged over the question of farm-to-market vs. trunk-line development. The second reason was simply that many of the States as yet had no State agency for the administration of a highway plan of State-wide scope, and the development of the trunk-line plan naturally presupposes the existence of such an agency.

The second of these reasons was promptly removed after the passage of the Federal aid road act in 1916 by the provision of that act requiring the creation of adequate highway departments in all States as a condition precedent to participation in the benefits of the Federal aid.

The Act of 1916 appropriated $75,000,000, to be expended in 5 years under the direction of the Secretary of Agriculture in cooperation with the State highway departments, for the improvement of Post roads. It provided for the apportionment of the appropriation among the several States in proportion to their area, population and mileage of post roads; and it permitted the expenditure of Federal funds for improvement in any amount up to 50 per cent of the cost, but not exceeding $10,000 a mile. This latter limit was later raised to $20,000 and then reduced to $15,000 as at present.

Since 1916, amendments have been made to the Federal aid road act appropriating or authorizing the appropriation of additional funds to a total, including the fiscal year 1927, of $690,000,000; and the mileage of road improved under the cooperative plan up to June 30, 1926, amounted to nearly 56,000 miles.

A first step toward the ultimate settlement of the trunk-line question in all States was made when the U. S. Bureau of Public Roads, acting for the Secretary of Agriculture, as one of its first administrative acts requested of all States the submission of a 5-year program map showing the system of roads upon which the State highway depart-

ments would request Federal aid during the period covered by the appropriations provided by the first act of Congress. Although the systems designated in response to this request were understood to be merely tentative the request of the bureau had the effect of directing attention - in many States for the first time - to the desirability of establishing a definite program for the improvement of a system of highways as distinguished from the more or less casual improvement of unrelated sections of roads.

The Federal-aid work had scarcely begun, however, when the world war intervened and practically put a stop to all operations; and the war did a number of other things to the existing improved roads which, however disastrous they may have appeared at the time, have turned out to be blessings in disguise. At the outset the construction and maintenance of highways were declared to constitute a non-essential industry. As a consequence new construction, except as required for the immediate service of the army, was greatly curtailed. Maintenance also was greatly hampered by the difficulty of obtaining the necessary materials and the scarcity and high wages of labor. At the same time there was released upon roads generally inadequate to stand it an unprecedented traffic of heavy motor trucks. To this experience and the heavy damage which followed we owe the development of most of the sound principles and policies which now govern the improvement of highways.

The first result was a strong reaction against the use of heavy motor trucks. There were large numbers of people who, forgetting that

a road is of service only in so far as it accomodates the need for economical transportation, demanded that the manufacture and operation of vehicles too heavy for the existing roads be prohibited. As few of the roads were designed to carry motor truck traffic, to have taken this course would have amounted to the throttling of a new development in transportation before it had a chance to demonstrate its utility, and it was rightly opposed with great energy by the manufacturers of motor vehicles. The latter, on the other hand, took a position at the opposite extreme from which they demanded the right to manufacture and sell vehicles of large capacity and heavy weight, without regard to the strength of the roads, on the theory that the greater the capacity of the vehicle the smaller would be the cost of operation per unit of capacity. Their slogan was, "build the roads to carry loads," and this was met by the opposite party with the equally dogmatic demand that the loads should be limited to the capacity of the existing roads.

The issue thus joined, the principals to the controversy - highway officials on the one side and the manufacturers on the other - wisely agreed to submit their differences to the test of mutual discussion; and out of the series of conferences which ensued there came an agreement upon certain fundamental facts and principles which have served as the basis for a harmonious cooperation of the two groups, and which now constitute the foundations of highway improvement policy in all States.

It was agreed at the outset that, for the first time in history, the weight of vehicles had become a critical factor in rural highway design. Hitherto the minimum practical thickness of road metal had been sufficient to carry the maximum vehicular load. The development of the motor truck had altered this situation. It called for stronger surfaces that would spread its heavier load over a wider area of the subgrade in order to reduce the intensity of the pressure to an amount which the soil could support.

It was clear also that whereas deterioration of the highways had previously resulted mainly from the attrition of the surface, a new form of deterioration approaching rapid destruction would result unless the roads upon which the heavier motor trucks were being operated were strengthened so as to enable them to carry the increased weights. And whereas, the amount of the deterioration had formerly been a function of the volume of the traffic and of time, the new destruction by excessive weight might be caused by a few vehicles in a very short time.

It was agreed, therefore, that the highway officials must have definite knowledge of the maximum weight to be supported as a first condition of design; and this knowledge was supplied, in a measure, by the voluntary decision of the manufacturers to limit to $7\frac{1}{2}$ tons capacity the future production of vehicles. Engineers were thus assured that if, in the reconstruction of the thoroughfares upon which heavy trucking had developed, they would design to accomodate

a vehicle of 7½ tons capacity they would not see their handiwork quickly destroyed by vehicles of much greater size and weight.

But this alone was not a sufficient basis for the design of all roads. The building of roads of sufficient strength to carry 7½-ton trucks required a heavy investment of public funds, which could be justified only if the economies inherent in the transportation of goods in vehicles of large capacity were sufficient to outweigh the increased cost of the roads. It was recognized clearly for the first time that the cost of highway transportation is made up of the cost of the highways and the cost of operating the vehicles over the highways, and it was agreed that the common purpose of the public highway officials, vehicle manufacturers and operators should be to reduce the total cost of transportation rather than one or the other of the elemental costs. It could be proved that the number of large-capacity trucks already using some of the highways, principally those radiating from and connecting the larger cities - had already grown to the point where the combined savings in operating cost would more than balance the greater cost of providing highway service for them. As to these highways there could be little doubt of the wisdom and economy of building a type of surface adequate for the heavy truck traffic. Other roads, similarly located with respect to cities, had not yet developed a sufficient amount of the heavy traffic to repay the additional cost of the stronger construction, but it was not difficult to foresee that such a condition would develop in the future. On the majority of the roads, however, the development of traffic of sufficient weight to justify the higher types of construc-

tion was very remote; and it was apparent that the one-time prevailing condition of uniformity of traffic on all roads had been definitely broken down. Instead, a new and much different condition had arisen under which the main inter-city roads were found to be carrying traffic far in excess of the much greater mileage of local roads.

Under the new condition the economic justification for the improvement of the main roads lay to a far greater extent than formerly in the reduction of transportation costs and to a lesser degree in the effect upon the value of property. The main roads had become through traffic arteries, as distinguished from the more numerous local roads which continued to be of value primarily through the service they render in giving access to the land.

As to the main roads, which carried a wide-ranging traffic, it was now clearly apparent that the character of their improvement must be commensurate with the density of their traffic; that continuity of improvement was of the highest importance; and that the traffic was already so great that the loss in operation of vehicles in the absence of road improvement would exceed the cost of improvement. These roads also were distinguished in one other respect, namely, that their traffic tended to increase far more rapidly than that which was to be found on the local roads, the condition of which remained much as it had been. Where the main roads carried long-distance traffic, the local roads served the traffic of a neighborhood; where the main roads were collectors of traffic, the local roads were feeders and distributors; where the traffic of the main roads tended to grow in direct proportion to the growing use of motor

vehicles and the growing resort of industry and the entire people to highway transportation, the local roads served the much lighter, and, from the standpoint of growth, far more stable traffic produced by a single agricultural community.

It became apparent, therefore, that the economic justificatio of local road improvement would continue to rest largely in the valu and importance of the land that, in the main, the traffic would dema only a low type of improvement; and that continuity of the improveme was not so essential as in the case of the main, through roads.

The need of continuity in the improvement of the main roads was the first of the new conditions to be met with appropriate actio From 1915 on, all States in rapid succession designated systems of State roads, including generally the main inter-city roads, to be improved under the more or less direct supervision of the State highway departments; and the several State systems were substantially welded into a national network by the designation, in accordance with the Federal Highway Act of 1921, of the Federal-aid highway system upon which it is now required that all Federal appropriations shall be expended.

Continuity of improvement of the main roads thus assured it remained for a joint committee representing the American Association of State Highway Officials and the National Automobile Chamber of Commerce to enunciate a policy with respect to the rate and manner of the improvement which could win general support and adoption.

Briefly that policy may be stated as follows. It is accepted as a truism that the volume of traffic on the main roads is so great

that the economies in transportation effected by road improvement clearly outweigh the cost of the improvement. This being true the improvement should proceed as rapidly as available supplies of labor and material will permit and without other limit. All roads should be improved to the degree justified by the operating savings that may be expected to accrue to the traffic, and no road should be improved to any greater degree. Where the mileage of road to be improved is so great that the type of improvement indicated by the traffic can not be completed on the whole mileage within a short period the most important sections should be raised immediately to ultimate type, and the balance of the mileage should be advanced through the initial stages of grading, draining, and low-type surfacing in order to spread as much of the benefit of improvement as quickly as possible over the entire road system further improvement to await the completion of the first stage over the whole system. This is the practice known as stage-construction, and it is the only feasible practice in the numerous States in which a large mileage of main roads remains to be improved in the face of a traffic already highly developed. It is also the logical plan of development for the main roads of the States in which traffic has not yet grown to the proportions justifying high-type surfacing.

In any case the stage-construction plan takes account of the rapid growth of traffic, which is a characteristic especially of the main roads, by providing fully in the initial stage for the subsequent construction. Grades and alignment are designed to meet ultimate requirements; drainage structures are built of durable materials;

rights-of-way of ample width for the future are obtained; and the initial surfacing becomes the sub-base of the second-stage surfacing. Obviously the soundness of the plan is contingent upon the complete and continuous maintenance of each stage of the construction, a kind of maintenance which - thanks to the war experience and the standard established by the Federal Highway Act - practically all States are now prepared to give.

The accepted policy contemplates the improvement of the main roads, to which the above methods are applicable, as a responsibility of the States to be assumed through the agency of the State highway departments, and financed, in large measure, by the revenues derived from the taxation of vehicles and motor fuel. The local roads are viewed as the responsibility of the counties and lesser sub-divisions. With a few important exceptions, as in the vicinity of large cities, the degree of improvement required does not rise above the lower types of surfacing, the expense of which may be met, as it should be by taxation of the local land and property.

These, then, are the outstanding developments in highway improvement of the post-war period: The classification of highways according to traffic density; the designation of State highway systems in all States, the systems including the heavy-traffic highways of State-wide importance; the interconnection of the State systems by means of the Federal-aid system; the improvement of roads in accordance with traffic demands to the limit set by probable operating savings; the stage-construction plan of progressive improvement of the entire system; and the development of adequate maintenance provisions. In the main, all are outgrowths of the war experience fostered by Federal aid.

One other great advance has characterized this period - the application of scientific research to the problem of developing types of construction and methods of administration and finance adequate to meet the demands of the fast-growing traffic. In this also the initial impulse came from the Federal government, and, in cooperation with State highway departments and universities, it is continuing to support numerous studies in several fields, as a result of which there is being built up gradually the structure of a new science - the science of highway engineering.

The investigations include studies of the characteristics of materials - sand, stone, gravel, bituminous materials, cement, concrete, and brick; determination of the forces applied to road surfaces by standing and moving vehicles; of stresses developed in the structure by roads and bridges by live loads, and by temperature and other natural causes; analyses of subgrade soils and tests of methods designed for their improvement; studies of the flow of water through drainage structures, of the run-off from drainage areas, of the effect of moisture on soils, and many others of fundamental importance and value.

Popular interest has centered upon the large scale tests such as those of the Bates Road, for which entire credit is due the Illinois department, the Pittsburg (Calif.) experiments, the impact tests at Arlington, Va., and the intensive studies of highway traffic conducted by the Bureau of Public Roads in cooperation with the authorities of Connecticut, Maine, Pennsylvania, Ohio, California, Tennessee, and Cook County, Ill.

Much that is of immediate practical benefit has already been derived from these investigations; but, for the most part, they are dedicated to the future.

It is not to be expected that their fullest benefits shall be immediately realized. The building of a science is a laborious, a painstaking process, and we are still but laying the groundwork which is not much further advanced than were the foundations of the modern science of medicine and surgery 50 years ago. If 50 years hence the science of highway engineering has been built up to the point now attained by the physicians and surgeons this effort we are now putting forth will be abundantly repaid, and not too late. For the improvement of highways in the United States is a process which must be continued indefinitely.

At the end of 1924, according to reports received by the Bureau of Public Roads, there was a total of 3,004,311 miles of highway in the United States of which 707,138 miles had been improved in some degree, 235,471 miles by grading and draining and 471,667 miles by surfacing. Of the mileage surfaced, 64,086 miles was improved with sand-clay, 246,357 miles with gravel, 60,467 miles with waterbound macadam, 45,172 miles with bituminous macadam, 9,691 miles with bituminous concrete, 31,188 miles with Portland cement concrete, 4,710 miles with brick and other block pavements, and 9,996 miles with various unclassified types of surface.

It is idle to talk of completion when of the three million miles of our highways less than a fourth has been graded, but a sixth has been surfaced, and a sixtieth paved; when little more than half

the mileage of the main State roads has been improved with any kind of surfacing, and there remain on those important arteries thousands of unsubstantial one-way bridges and dangerous railroad grade crossings; when the number of motor vehicles registered is doubling every fifth year and the traffic with them; when the size of our cities, and the magnitude of our industries, and the amount of our material wealth are increasing at an almost unprecedented rate. So long as these conditions continue we shall continue to build and maintain and rebuild our roads.

At the present rate we are surfacing approximately 40,000 miles a year and our annual expenditure approximates a billion dollars. There is no indication of an early reduction in these rates of construction or expenditure, dwarfed as they are by the annual production of a 1,000-mile procession of motor vehicles and an annual expenditure for operation approaching ten billions. As a nation we have set our hand to the economic improvement of our means of highway transportation. It is not a task to be accomplished in a day. It is, and must be a continuous process. There is but one limit which may reasonably be set. It is this: No road should be improved by expenditures of public funds in excess of its earning capacity. The return to the public in the form of economic transportation is the sole measure and justification of the degree of highway improvement.