

Deterioration of Macadam Roads and the Probable Cure*

Problems That Arise From The Increased Automobile Traffic

By Samuel D. Foster †

UNDER the name of macadam roads, I expect to class both the road designed by Telford and the road designed by MacAdam.

The Telford road consisted of placing upon the level bed prepared for road materials, a bottom course or layer of stone to be set by hand, in the form of a close, firm pavement, the thickness of this foundation course varying from 5 inches upward, depending upon the material composing the subgrade and the vehicular traffic it will be called upon to carry. Upon the top of this foundation is placed a course, or courses, of varying sized stone, to form what is known as the "metal surface."

The MacAdam road differed from that of Telford in that MacAdam was satisfied with laying the metal surface directly on the surface of the ground after the irregularities had been leveled, the side ditches formed, and the proper drainage system installed. This metal surface was composed of hard stone broken to a uniform size and cubical in form, ranging from 1½ to 2 inches, and was placed to a depth varying from 5 to 9 inches.

As to the relative merits of the two roads, I will not go into detail, but will state that in Allegheny County the greater percentage of our roads have been constructed from a combination design taking the best of the Telford and MacAdam ideas.

Our roadways are graded to a width of 30 feet. In the center of this 30 feet the subgrade is formed for a width of 16 feet, having a crown of four inches. Upon this subgrade is placed a Telford foundation eight inches in depth, throughout the full width. This foundation is thoroughly rolled by a 10-ton roller, and the larger voids filled with small stones. This rolling continues until a true and uniform surface is obtained for the foundation.

Upon this foundation is placed approximately five inches of loose broken stone, either limestone or trap rock, of a size that they will pass through a three inch ring and not pass through a 1½ inch ring. This stone is thoroughly rolled with a roller weighing not less than ten tons, and the depressions filled and raked until the surface is true and even. Upon this sufficient dust or screenings of some cementaceous stone is laid as a binding course.

This course is just sufficient to bond the stone and render the surface smooth. The binding course is then thoroughly sprinkled and rolled with a 10-ton roller until the passage of the roller causes no waves in the surface. This binding of the surface stones constitutes the essential feature, to my mind, in any metal road; and in what may be termed the life of the macadam road.

Upon this surface now must come the traffic, the impact, the drag, and the wear of all horses' hoofs, wheels and runners of vehicles passing over it. The impact of a horse's hoof upon the macadam road has a tendency to spawl or crush the stone used in the wearing surface. The wheels of the wagons where the load is greater per square inch than any particular stone is able to bear, will cause the beginning of a rut, and the sliding of the wheel from one stone to another will grind more or less dust from the metal surface. The automobile, driven by powerful engines, exerts a force in the rear wheels which causes what we may term a continual slide or scraping. This scraping has the effect of pulling the fine particles of binding material from between the stone and in many cases of loosening the stones themselves and starting what is known as raveling of the roadway. These stones, drawn from the roadway, are quickly pulverized by passing wheels; and the body of the automobile, constructed as it is, passing at great speed over the road, causes a vacuum or heavy draft immediately under the car, which sucks this dust up from the roadway and the wind blows it into the fields. Inasmuch as this dust constitutes the life of the road, it is a simple matter to figure from the amount, and the kind of traffic over roadways, the life of the macadam road in each particular locality.

While in a great measure we may lay the blame of the deterioration of macadam roads to the automobile, it may be well to remember one point in particular, that it is not so much the automobile itself that is the cause of the deterioration of our roadways, as it is the fact that where one man fifteen years ago would own a pair of horses for pleasure, ten men to-day own automobiles; where a family several years ago having a team and carriage would use that vehi-

cle for pleasure driving probably once or twice a week, fifteen out of twenty automobile owners today use their vehicles twenty days out of every month during what we might term the season of good roads. So it is not altogether the automobile as much as it is the increase in traffic over our roads that is the cause of this deterioration to such a great extent of what it was a few years ago.

Experiments with a view of allaying this dust nuisance were first carried on in California, and the first asphalt oil used was about the year 1896. In 1898 about six miles were oiled in Los Angeles County, California, with the idea of laying the dust; the experiment was such a decided success that the idea spread rapidly and many miles were soon covered with asphaltic oil. It was then found that the oil not only laid the dust but also bound the dust particles together and formed a tough layer of an asphaltic nature, that acted as a real road preservative. From these simple experiments in California, the idea that there was a chance of preventing deterioration on macadam roads spread all over the country and the many highway engineers who were interested in their work began the investigation of methods for the prevention of this deterioration.

Naturally this investigation was along the line of saving the roads already built, and in the main consisted of applications to, and treatments of, the surface alone. Oils of various grades and containing different amounts of asphalt were soon on the market. The first of these were the natural asphaltic oils of the Texas, California and Kentucky districts, which have a more, or less, asphaltic base, but at the present time almost all the oil companies have residuum products that are for the most part the study of their chemists and experts. The use of tar as a road preservative dates back to about the year 1886, when it was used in the city of Melbourne, Australia, with a great deal of success. It seemed to bond the road together thus both laying the dust and preventing deterioration. These experiments were continued in several countries, France, England and the United States leading.

At present these road preservatives may be roughly classed under the following heads: Residuum-asphalts, or asphalts obtained from crude oils, Natural asphalts such as Bermudez, Cuba and Trinidad and the tar products.

Experiments have also been carried on with a material named by its inventors "Glutrin," and is made from the residuum of the wood pulp of the spruce tree. It has a tendency to thoroughly bind together the particles of the road and render the surface of the roadway waterproof.

The writer's first experience with oil for use on roads was in 1907, on the Isthmus of Panama, where it was used to lay the dust on the roadways leading through the hospital grounds at Ancon. The oil used was the natural California oil and had a rather heavy asphaltic base. We were successful in what we attempted to do and had little or no complaints from dust thereafter. I have followed very closely the use of oils since that time and have had more or less success in the application of oils for both the laying of dust and the preservation of the roadway. At first, the application of the lighter oils, or what may be termed the road preservatives, looked like a solution of this very vexing problem; and perhaps is for roads over which the auto travel is predominating, as the tendency of the automobile is to iron out the road and keep it smooth. Where this is so the road readily sheds the rainfall and affords very little chance for the frost to do much damage; but, where a roadway is subjected to a very heavy wagon traffic, the horses' hoofs constantly cut into the soft asphaltic surface and the rain has easy access and forms a muddy condition that holds the water and causes a puddle that eventually breaks the bond between the small surface stones and causes the road to start to ravel. Then again the lighter oils in these asphaltic surface treatments penetrate the road, and in many cases entirely surround the small surface stone with an oily film and in so doing bring about a condition that prevents the road being rebonded and the stones coming loose are quickly crushed into dust.

The experiments carried on in this country have been many and varied; the first were, as stated before, for the purpose of laying the dust which had become such a great nuisance; the idea that the oil had another value that held out a vision of road preservation caused a number of experiments along the

line of increasing this value, and I believe Allegheny County has had as much success along this line as probably any other country. Our method consists to-day of the application of an asphaltic oil running about 50 per cent asphaltic base. This oil comes in tank cars and the oil is fluid enough to be readily pumped from the cars, in ordinary summer weather, but during the first few days of each season it has been necessary to apply steam heat to the cars to cause it to flow readily. This oil is pumped into tank-wagons, that hold from 400 to 500 gallons and are provided with a valve and distributor arrangement that allows the operator to govern the amount of flow at all times. The roadway before being treated is swept thoroughly by a horse sweeper and with hand brooms to entirely remove all dust and dirt from the surface. This also loosens the immediate surface and gives the oil a chance to penetrate the road and form a bond. The road is then left to dry by the natural evaporation of the lighter oils, or is covered with small stone or sand, to alleviate the disagreeable condition that sometimes follows the application of this light oil. The work done during the past three years has worked up extremely well and we have cases where the oil has stood an extra heavy travel for a period as high as two years without showing a dusty condition, and this is on such roads as the Brownsville and Steubenville Pikes.

The cost of applying this light oil for the various years since 1907 is as follows:

	1907	1909	1910
	Per sq. yd.	Per sq. yd.	Per sq. yd.
Oil material	0.01599	0.01599	0.012212
Labor	0.0615	0.00663	0.007086
Demurrage and frt. chgs.		0.00018	0.000315
Supplies, tools, wagons, etc.			0.001265

Averages 0.0615 0.02280 0.020878

The heavy cost during 1907 was probably due to the fact that the work was done by contract. During the years 1909 and 1910, the work was carried on by our own maintenance force, and correct cost data has been obtained.

On the Steubenville Pike, outside the city limits west, granulated calcium chloride was used to allay the dust. Calcium chloride is a chemical salt, white, clean and non-corrosive and is without odor. Its main property when applied to a road is that it immediately absorbs moisture from the atmosphere and holds that moisture in the road, thus keeping the road moist and dustless, and by preventing dust lengthens the life of the surface. It is distributed on the road either by hand or by machine distributor, and costs approximately between three and four cents per square yard during the season. It is necessary to treat a roadway with calcium chloride every four or six weeks, dependent a great deal on the humidity of the air. The main point of merit in this treatment lies in that the disagreeable conditions arising from the first applications of oil are not present where calcium chloride is used; on roadways in close proximity to a number of houses and where there is much travel of a pedestrian nature it might well be recommended. Another point in favor of this material which I have gathered from our experiments is that ice and snow do not remain as long on the roadway and in this way helps to solve the question of slipperiness in wintry weather. These experiments looking towards the prevention of deterioration have been carried on by most engineers with the idea in view of merely tiding over the immense systems of macadam roads already built, until a more satisfactory surface could be obtained. As it was evident from the start that any application of this nature would not bring about a permanent result, practically all the state highway departments and the large corporations and several universities have been carrying on experiments either along their own lines or under partial supervision from the Department of Public Roads of the United States Government, with the idea in view of obtaining a pavement that would withstand the great tractive force of the automobile and still present a surface that would not be injurious to horse travel.

It will not be attempted in this paper to go into the relative merits of brick, or block, construction and the macadam roads, as this paper deals entirely with the macadam road. It was at first though by engineers that the macadam road was done for, and that a new type of road would have to be studied out, but as experiments went along, it was found that the principle of the old macadam road was right and that a first-

* Proceedings Engineers' Society, Western Pennsylvania.

† County Road Engineer, Allegheny County, Pittsburgh, Pa.

class surface could still be constructed under the old general macadam idea and that the fault and cause of deterioration lay in the binding material.

These binders consist of asphalt materials, natural asphalts, Gilsonite products, coal-tar products, and portland cement, and the surface treatment, by penetration method or by the mixing process. The general manner in which the penetration method is carried on is to put down macadam in the ordinary way up to the point of beginning of binding, which had been previously done by water and stone chips. The binder then sprinkled upon the roadway either by hand or by machine distributor. This method has been varied in several ways, as for instance, larger stone have been placed on top and the smaller stone on the bottom of the surface course. The bitumen has been applied to the stone and a layer of sand placed over the bitumen; another where the stone were put on in two courses and the bitumen applied to the surface of the first course and surface of second course. The amount of bitumen varies from $\frac{3}{4}$ gallon to as much as five gallons per square yard. The use of five gallons, however, was a rare instance. The cost ran from 48 cents to \$1.25 per square yard.

The mixing method may be classed in two types, that of the pavement where the aggregate is carefully graded and the least possible percentage of voids is present, and the type for less heavily traveled roads in which the aggregate is not graded and has a large percentage of voids. In the first type, the materials are broken stone, and sand of graded sizes, mixed so as to form a dense mixture. This aggregate is heated and thoroughly dried and dumped into a mixer in approximately exact proportions, the amount of bituminous material being that necessary to make a mixture of the highest density. These materials are thoroughly mixed in machines, of which there are various types, and placed on the roadway while hot. The results secured by the use of this pavement may be classified with the results obtained from brick or block pavements as to durability, but they have in a few instances proven rather hard and slippery surfaces. This may be obviated by the application of a rough sealing coat.

In the second type, the stones are thoroughly dried, being what is termed "run of the crusher" grade of stone. With this stone are mixed sufficient sand to fill the greater percentage of voids and enough bituminous material to thoroughly permeate the whole mixture. These materials mixed under the second type have been laid both warm and cold and very satisfactory results have been obtained from both.

Another method of surface construction is the penetration method, using portland cement as a binder. The stone is placed on the road to a depth of approximately eight inches and thoroughly rolled with a 10-ton roller, until a true and uniform surface is obtained. Upon this is distributed cement grout of a one-part cement and two-parts sand mixture, and the road again rolled, and allowed to set. This form of roadway has been successful in some parts of the country. The writer had some considerable experience and a great deal of success in the mixing of a concrete pavement of a one part cement, $2\frac{1}{2}$ part sand and five part traprock in Panama City. On this pavement, the mixture was made and placed in the street to a depth of from four to six inches, thoroughly rammed and brought to a uniform surface by means of a templet. The uniformity of temperature, however, in Panama may have been in a measure responsible for the success of this pavement. In a northern climate where the contraction and expansion of concrete must be taken into consideration, it is very doubtful if this form of pavement would be practical.

The experiments in Allegheny County have been carried on along practically the same lines as in general throughout the country. On the Steubenville Pike a bitumen pavement was constructed in which the stones were supposed to be graded very carefully and mixed with a heavy bitulithic binder. The stones were graded, thoroughly dried, and conveyed into a large roadway mixer, mixing a batch of approximately 2,500 pounds at a time. To every ton of stone were added 130 pounds of bitulithic binder. This material was carried immediately from the mixer and placed in the road by small hand-barrows. It was raked into a true and uniform surface, rolled with a 10-ton roller, and allowed to thoroughly set before travel was allowed to go on the road. This road at the present time does not show any cracks, and gives promise of making an exceptionally good roadway. The one objection seems to be in the nature of a slippery surface; but it is my opinion that as soon as sufficient wear has been placed on the road to cause the stone aggregate to be exposed that this condition will be much improved. The cost for this type of pavement will approximate between 80 cents and 90 cents per square yard, according to the location of the roadway.

On the Freeport Road a type of the second class was constructed in which traprock of size, $1\frac{1}{2}$ inch

to dust, "run of the crusher," was thoroughly dried and mixed with asphaltic binder, about 110 pounds of asphaltic binder being used to one ton of stone, together with two bushels of sand. A precaution on this work was used by cleansing the stone thoroughly with naphtha before placing the asphalt. This material was placed in the road both warm and cold and like results obtained from both experiments. This material at the present time shows a very satisfactory surface, and gives promise of withstanding the extra heavy wear of the traffic placed upon it. The detailed costs of this type of pavement are as follows:

Amiesite material, cost per square yard..... 66.25c.
Labor cost per square yard, including rolling. 10.17c.

Total cost of placing same on road, per sq. yd. 76.42c.

On the Lincoln Way Road, just outside the city of McKeesport, a mixture of granulated slag and asphalt tar binder was used. This material was composed of slag screenings $\frac{1}{2}$ inch and under, fine slag dust, asphalt tar binder, and an asphalt residuum oil. Twelve per cent in weight of slag was mixed with 7 per cent, in weight of slag, of the asphalt tar binder, at a temperature of 300 degrees. The $\frac{1}{2}$ inch slag screenings were mixed with two per cent, in weight of slag, of the residuum oil at 300 degrees. The two mixtures are then combined and thoroughly mixed, and must be placed on the road while hot. This experiment shows a very satisfactory condition at the present time, and seems to turn the rainfall quicker than any of the other experimental work, and gives promise of being able to withstand extra heavy traffic. The costs of this experiment, as near as possible to obtain, are as follows:

A mixture of one ton of material cost \$3.02. The cost of the oil was 60 cents and the cost of labor in mixing, 60 cents, making a total of \$4.22. We are able to obtain approximately 10 square yards to the ton, making a total cost per square yard of 42 cents. To this add the cost of placing and rolling of 10 cents per square yard, bringing the actual cost to 52 cents per square yard. This is by far the cheapest and if it holds up anyway well at all, will make an economical and serviceable pavement.

On the Perrysville Road the penetration method was tested by placing four inches of limestone ballast, thoroughly rolling the same, and applying by hand sprinklers a coal-tar binder to the amount of 3.8 gallons per square yard. Unfortunately, this work was done very late in the fall, and the binder became chilled on striking the cold stones on the roadway and a sufficient penetration was not obtained. Consequently, about twice the amount of binder necessary was present in the upper two inches of stone and none penetrated to the base. When the warm suns of last summer and very hot days came, very naturally the excess of binder was drawn to the surface and ran into the gutters and made a very disagreeable condition. This was obviated by distributing $1\frac{1}{2}$ to 2 inches more crushed stone over the road and thoroughly rolling the same. This apparently cured the defect. The cost upon this type of road is as follows:

Tarvia material, cost per square yard..... 24.5c.
Stone material, cost per square yard 45.6c.
Labor charges per square yard 9.4c.

Total cost per square yard 79.5c.

On our Peoples Road an experiment was made with Kentucky rock asphalt. This material is a disintegrated sandstone, thoroughly impregnated with natural mineral asphalt to a percentage of approximately eight to ten per cent. The foundation course of two to three inches of ballast is placed on the road and thoroughly rolled. On top of this one inch of rock asphalt is distributed and thoroughly rolled into the surface. The surface is then raked over with an ordinary rake in order to roughen up the asphalt binder. Another inch or inch and a half of rock asphalt is then distributed over the surface and the road again rolled until thoroughly compacted. This surface presents a rather rough appearance for six weeks or so after construction, inasmuch as this material contains some light volatile oils and does not obtain its initial set until these oils are evaporated. After it has been thoroughly exposed from four to six weeks it presents the appearance of a sheet asphalt pavement, and for some districts where the traffic does not include extra heavy hauling, and for level roadways, this type of surface—with some improvements which we expect to experiment with this coming summer—it is believed will make a cheap and economical road. The cost of this type of road is as follows:

Rock asphalt material, cost per square yard,
f.o.b. cars 36.6c.
Crushed stone on road, cost per square yard.... 18.4c.
Labor cost per square yard (including hauling
asphalt) 21.1c.
Total cost per square yard 76.1c.

This constitutes a résumé of our experimental work in Allegheny County.

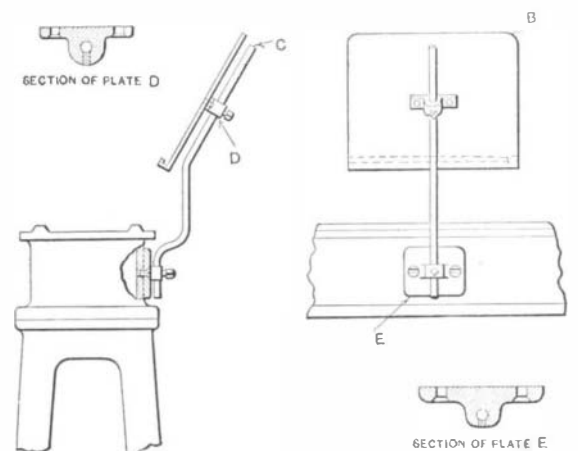
New Determination of the Moon's Distance

By A. C. D. CROMMELIN, D.Sc., B.A.

DURING the last six years the small bright crater Mösting A has been regularly observed on the meridian both at Greenwich and the Cape. It is much easier to bisect the crater with a micrometer wire than to place it tangential to the moon's limb, which is often serrated by mountains. About a hundred nights are available on which the crater was observed at both stations, and comparison of these has given a new determination of the moon's distance. The chief source of uncertainty in the result is the fact that the shape of the earth is not yet known with great precision. The distance was accordingly computed on two assumptions of the shape, viz., compression $1/293\frac{1}{2}$ and $1/300$; these about cover the present uncertainty. On the first assumption Hansen's parallax (which is 57 minutes 2.23 seconds) needs a correction of plus 0.50 seconds, and on the second of plus 0.12 seconds. On the former assumption the moon's distance comes out 238,817 miles. Another way of finding the distance is based on the observed period and the force of gravity at the earth's surface. This method also gives results that vary, though to a less extent, with the earth's figure. The deduced corrections to Hansen's parallax are 0.45 seconds and 0.36 seconds on the above assumptions. Hence to make the two methods agree we must take the compression as $1/294\frac{1}{2}$. This applies to the mean meridian of Greenwich and the Cape, for it is quite possible that it is sensibly different for different meridians. Sir David Gill has for many years been endeavoring to have South Africa geodetically connected with Europe, and only a few links are now needed to complete this great work, which would give a measured meridian extending from the North Cape to South Africa, and would give the compression of this meridian very accurately. It seems that it would be advisable for equatorial observatories to measure the moon's distance by the diurnal method (comparing observations made east and west of the meridian at the same station). The equatorial parallax of the moon would thus be given, free from uncertainty arising from the figure of the earth, and it would in addition be possible to test whether the equator has any ellipticity by comparing the results obtained at different equatorial stations. The measures might be made photographically, for Prof. Pickering and Mr. H. N. Russell have lately shown that good photographs of the moon for position can be obtained by giving the surrounding stars a time exposure, the moon being screened by a disk except for a fraction of a second, the time of which may be automatically recorded. This plan is analogous to that used for many years at Greenwich for photographing Neptune and its satellite, and double stars that differ much in brightness.—*Knowledge*.

Lathe Bracket for Blue-Prints

THE bracket shown in the illustration is very simple and will keep blue-prints or working drawings constantly before the mechanic. It is made of two cast-iron plates *D* and *E*, rod-arm *C*, bent at any desired angle, and sheet iron holder *B*. The size of screws should be determined by the size of bracket



Blue-Print Holder Attached to Lathe.

made. As the reader will notice, there are no breakable parts, and very few loose ones. I would suggest that the surface on the arm *C*, which comes in contact with the set-screws, be filed or milled flat; this will keep the bracket from turning. By using a bracket of this description, the percentage of mistakes made will be greatly reduced and more accurate work done.

Buffalo, N. Y.

L. H. GEORGER.