

raised by rapidly-moving motor vehicles are not only a great waste of the material of which the road is composed, but this dust is carried by the wind and disseminated over adjacent property to such an extent that it has, in many instances, affected the value of real estate as well as the comfort of near-by residents and pedestrians. The road surface becomes so loosened that water makes its way to the foundation, and in general the cost of maintenance has very greatly increased. With a constantly increasing motor traffic, these are, briefly, the conditions we find to-day, and which have to be met. The problem is such a serious one that it has called forth the best efforts of highway engineers in every civilized country. By the proper use of bituminous materials the mechanical difficulties have in a large measure been overcome, but the cost of such treatment is so great that it is hard to believe, at present, that such methods can ever be generally used on the many thousand miles of rural highways affected.

As already stated, the broken stone road has been developed to withstand the wear of iron-tired horse vehicles, and has met successfully the demands of suburban and rural traffic until the advent of the motor vehicle. When in its highest state of perfection, the rock from which such a road is made is so suited to the volume and character of traffic which passes over it that the amount of dust worn off is only sufficient to replace that removed by wind and rain. The dust remaining should be just enough to bond the surface stones thoroughly, forming a smooth, impervious shell. A road of this character wears uniformly under the traffic for which it was designed, and when properly maintained always presents an even surface.

When such a road is subjected to continuous fast motor traffic, entirely new conditions are brought about. Since the advent of this new traffic its effect on the road has been the subject of much study, by both highway and mechanical engineers, and many highly interesting and ingenious theories have been advanced to account for the injury to roads derived from it. While the slipping of the tyre, skidding, shape of car body, suction and other causes contribute more or less to the injury of the road surface, I think it is quite generally agreed that the suction of the pneumatic tyre on the surface is the main cause of the trouble. The object of this paper is to show, however, that the great tractive force, or shear, exerted by the driving wheels of motor-cars is the main factor of injury.

It has been demonstrated by connecting both front and rear wheels of motor-cars with separate speedometers that there is a considerable amount of slipping of the driving wheels on the road surface, and, on account of the numerous irregularities on the average road surface, this is what should be expected. This slip, due to the decrease in the bearing surface of the tyre, undoubtedly increases the amount of finely divided material of the road surface thrown into the air. The increased amount of damage done on this account will be in proportion to the irregularities in the road and the speed of the car. While it is an important factor, its effect is greatly reduced if the road has a smooth surface.

The effect of skidding is only observable on roads that are subjected to a considerable volume of fast motor traffic, and only then on curves. The result of this is to shift the crown of the road tangentially to the gutter. While very annoying to those having the maintenance of such roads, it is not one of the serious or costly causes of injury, as it is generally confined to rather sharp curves.

It is my belief that too much stress has been laid upon the effect of the car body and its shape in removing dust from the road surface. After a number of experiments and observations, I am now convinced that little or no dust is removed from the road surface by this means, except on very dusty roads. The dust lifted by the wheels, however, is greatly accelerated by the action of the car body and the air currents set up in its rear, which has much to do with the dissemination of dust. This is one of the important factors to be considered, as much of the dust lifted by the wheels would not be carried from the road but for the air

currents developed by the car body, and these, of course, are much affected by its shape.

Probably no single factor has been considered of as much importance as the so-called suction of the pneumatic tyre. Some writers have even gone so far as to maintain that a slight vacuum is created in the rear of each tyre, which is sufficient to lift the finer particles of the road surface in the air. In my opinion, entirely too much importance has been given to this phenomenon, for if it exists at all, its effect is probably so slight that it can be considered a negligible quantity, and I shall endeavor later on to give my reasons for this view.

Beyond a doubt, the most injurious action of motor traffic is the great tractive, or shearing, force exerted by the driving wheels of these cars. The fine dust which ordinarily acts as a cementing agent to the road surface is thrown into the air to be carried off by the wind, or that remaining on the road is so loosened that it is easily washed into the gutters by rain. The pneumatic rubber tyre wears off from the broken stone of the road little or no dust to replace that thus removed, and the result is that the stones become loose and rounded, giving the greatest resistance to traction and allowing water to make its way freely to the foundation of the road.

For the purpose of studying this phenomenon I recently conducted a series of tests with motor-cars of various shapes and sizes, from the 4,000-pound limousine to the small runabout. These cars were run at various rates of speed, and their effect studied on a section of average broken stone road. The most interesting result was obtained with a 60 horse-power car stripped for racing. The wheels of this car were 36 inches in diameter, with 4-inch front tyres and 4½-inch rear tyres. The weight of the car with driver and mechanism was 2,800 pound. This car was driven over a level section of broken stone road at speeds varying from five miles an hour to sixty miles an hour. The road used was a section of a Government road which had been resurfaced two years previous to the test and was in very good condition. Up to fifteen miles an hour little or no effect was produced on the road, and even at twenty miles an hour it was judged by those present that no serious damage was done. From twenty miles an hour on, however, the effect was markedly noticeable with each increase in speed. At a point on the road designated for the proper speeds, photographers with the necessary high-speed cameras were stationed for the purpose of taking photographs from different points of view of the effect produced. I have some photographs which I think illustrate the action of the wheels very clearly. They show the car travelling at various rates of speed, from five miles an hour to 60 miles an hour.

The chief point of interest in these photographs is the difference in effect on the road between the front and rear wheels. Now, if it is true, as has been claimed, that a vacuum is formed in the rear of the pneumatic tyre, or that it possesses any power of suction, this should be equally true of both front and rear wheels. I am convinced after most careful observation that this is not the case, and I think this point is illustrated by the photographs.

To sum the matter up briefly, the pneumatic tyre, or any type of tyre which propels a vehicle, must have sufficient tractive resistance to overcome the load of the vehicle. This, of necessity, must cause a shear on the road surface, which varies with the weight and speed of the vehicle. The broken stone road surface has little power to resist a shearing stress, consequently the fine material of which it is composed is thrown into the air. Once lifted from the road, this fine material is subject to the effect of air currents generated by the car body, and subsequently by the wind. In this manner large quantities of the material of which the road is composed are carried from the road and must eventually be replaced or the road will rapidly deteriorate. This action may be greatly accelerated by other causes, but in the main it is sufficient to account for the observed results. Apart from the dust carried from the road in this manner, this shearing force of the motor-car has a decided disintegrating effect on the surface of the road.