Notes on Wheel Diameters.

By Colonel R. E. CROMPTON, C.B., M.Inst.C.E.
(Member.)

IN the judges' report of the R. A. C. Commercial Vehicle Trials attention is called to the necessity of increasing the wheel diameter of commercial vehicles. The judges point out that the difficulties connected with the weight, cost and material consequent on this increase of wheel diameter must be grappled with both for the sake of the vehicles themselves and for that of the roads on which they are to run. The diameters must be increased as much as possible compatible with the present requirements.

The time, therefore, seems opportune to call attention to certain facts connected with wheel diameter which ought to be useful to designers. Most of us have hitherto assumed that the relation of weight to diameter of wheels must approach the usual cube law; at any rate the increase of weight must be in excess of the square of the diameter. This supposed rapid increase of weight has no doubt in many cases deterred designers from considering any considerable increase in wheel diameter.

The wheels of vehicles may be divided into three classes. The first and most commonly used are the wooden wheels with which we are so familiar. In this case the material used is generally in compression, and only resists side stresses by its transverse strength. The second class, rapidly coming into universal use, are composed wholly of metal; in this case the material is partly in suspension. This is notably the case in steel or iron wheels, especially those of the traction engine type; and finally we have the third type, which may be called purely suspension wheels, such as those used in bicycles and by Mr. Lanchester and others in motor cars, in which the weight of the vehicle is suspended from the rim by the wire spokes, the side stresses in this case being borne by

the splaying or spreading of the spokes to the two ends of a lengthened hub.

The wooden wheel is not suited for any considerable increase in

**— DIAGRAM OF WEIGHTS & DIAMETERS OF WHEELS —
— TO CARRY 3 TONS EACH —**

FIG. 1.

diameter, it cannot stand extremes of climate, and will probably eventually give way to metal wheels, at any rate for self-propelled vehicles.

The data I am now about to furnish relate to the last two classes, and more particularly to the traction type and to the wire wheels.

Diagram No. 1 shows wheels of 3 ft., 1 metre, 4 ft., 5 ft., and 6 ft. diameter, all of the traction engine type, that is to say, having cast iron hubs, wrought iron T-headed spokes, and T-section rims fitted with cross-pieces. The design of these wheels is taken from existing traction engine practice, in each case the material required has been carefully disposed so that all five wheels should possess to an equal extent the power of resisting the vertical and sideway stresses and shocks met with in ordinary road work. The width of rims shown have in each case been calculated from the Local Government Board regulations. Under each wheel is given the weight of the three principal parts, hub, spokes and rim. From these figures it will be seen that the hub weights increase approximately as the diameter, the spokes increase approximately as the square of the diameter, but the rim increases at a less rate than the diameter. The totals show that the increase of weight for diameter for the complete wheel as a whole increases very slightly in excess of the lineal dimension. The case will not be altered if the rims were calculated on a more liberal basis, that is to say, with thicker T-pieces or thicker strips, it will be found that the relation of weight to diameter will approach even more closely to a straight line law. If these same wheels had been pure suspension wheels, that is to say, with wire spokes, as the spoke weight as a whole would be reduced, the relations between weight and diameter would be still more favourable to the large diameters; in order to test this, I have made a careful study of a pair of 8 ft. wheels and axle to carry the same load, namely, 3 tons per wheel or 6 tons per axle, and find that a thoroughly good and substantial job can be carried out, including the weight of the chain rings, at a weight of 26 cwt., which is a somewhat surprising result.

In order to throw some light on the advantages to be expected from the use of wheels of large diameter, both as regards their effect on the road and on reducing rolling resistance, I have prepared a diagram (Fig. 2) which shows the effect on a road of wheels varying from 2 ft. up to 8 ft. diameter, all loaded to the same weight, namely three tons, and having the tyre width required by the Local Government Board regulations. If we suppose that these wheels are rolling on a road sufficiently plastic to allow them to sink in to a fixed depth of $\frac{1}{4}$ inch, it will be seen that the volume of road material displaced, or partly displaced and

partly compressed, is the same in each case, namely, 8.15 cubic

FIG. 2.

inches, and that the projected bearing surface on the road in each

case is the same, namely, 48·8 square inches. This shows that whoever was responsible for the preparation of the Local Government Board regulations is to be congratulated on having founded the recommendations as to tyre width on a satisfactory scientific basis.

We have now to ask ourselves what are the advantages and the causes of the advantages which we expect to obtain from the use of wheels of large diameter.

One method of looking at the matter is to point out that apparently the 2 ft. wheel has to continuously attempt to rise out of its $\frac{1}{4}$ inch depression by rolling up an incline of 1 in 10, whereas the 8 ft. wheel is required to roll up an incline of 1 in 20. It appears practically certain that the tractive effort due to rolling resistance must at least be reduced in this proportion, and from this saving we have only to deduct the extra weight drawn, due to the increased tare weight of the wheels; but, at any rate, from this point of view, we may suppose that a road in the above condition, if the rolling resistance were 50 lbs. per ton in the case of the 8 ft. wheel, it would be 100 lbs. per ton in the case of the 2 ft. wheel, but it is probable the advantages are greater than this. The small wheel, in rolling forward and depressing the road $\frac{1}{4}$ inch, does this partly by depressing and partly by tending to move the road material forward. The 8 ft. wheel rolls the road to a much greater extent by depressing it with less movement of translation in a forward direction, and this must be accompanied by a saving of power.

Much experimental work is required to thoroughly test this matter. On the whole, it is probable that Morin's original deductions that, within reasonable limits, the rolling resistance and axle resistance, taken together, decrease almost as the diameter increases are approximately correct, and will hold good even in these days when so much has been done to reduce axle friction.

It is evident that a strong case can be made in favour of designing the driving wheels of motor wagons of diameters not less than 4 ft. 6 in., even when these are used on the best urban roads, whether these be paved or macadam, and that a strong case may be made in favour of the use of wheels up to 8 ft. in diameter for use on colonial roads or for military purposes.

THE DISCUSSION.

The PRESIDENT (Mr. DUGALD CLERK): We have had three important papers dealing with different sides of one subject to-night. It is a pity so much good work should have to be compressed within one hour, but I must compliment the readers of the papers on succeeding in giving us a very clear and accurate idea of the substance of the papers which they have presented, and yet keeping within a very moderate time limit. It is natural in discussing a subject like this, where you have the motor against the road, that you should have some conflict of opinion, just as, in other branches of engineering, you have, for instance, the projectile against the armour plate, and one type of engine against another. It is quite natural that there should be differences, both in point of view and of opinion. I am sure we must thank Mr. Taylor very cordially for the great care he has taken in preparing this excellent paper, and we shall all be able to study it more minutely when it appears in our proceedings.

Gathering what I can from Mr. Taylor's views, as he has presented them, it seems to me that the question tends towards this: that undoubtedly motors *do* destroy the roads to a very large extent. I think we must admit that, and that they destroy the roads to a greater extent on the trunk roads than on the side roads. That would seem to point to the necessity for some central organization, some governing body, dealing with the question of all the main roads throughout the country. It does seem unfair that the burden of the great trunk roads should be borne locally, and I think that the road engineers, such as Mr. Taylor, would be very glad indeed if they had behind them some governing body to deal with roads involving the great problems that he has so graphically and well described. Under these circumstances, the whole nation would bear the burden of keeping up first-class roads, and we would not be in the difficulty, that he has so well put, of finding an adequate sum from the local people, who naturally object to the burden put upon them by motors rushing past their doors, doing nothing but raising a dust and making their houses uncomfortable. I quite agree, as a resident of the country myself,

although I also am a motorist; and I sympathise to some extent with those people who object to the motor car for its capacity of deteriorating roads and increasing local burdens.

Mr. Douglas Mackenzie's paper is also a valuable one, and it is truly complementary to Mr. Taylor's. I have followed his points with very great interest. He has studied all the minute actions of motor car tyres, resulting in that wonderful specimen of grooving shown in Fig. 10, where the studs of the tyre cut holes in the asphalt in the same manner as the cutting tools of lathes did their work. This illustration showed even more clearly than one had appreciated before, the damage which studs on tyres are capable of doing on road surfaces. The moral drawn by Mr. Taylor in his opening remarks is a very true one. These two papers show most conclusively the necessity for a discussion of this question in a friendly way, by the representatives of the Road Engineers who have to build the roads and maintain them, and the representatives of those who have to design cars which are to travel upon those roads.

Colonel Crompton adds some very valuable material to the discussion of this question in his notes upon increased wheel diameters. It is quite true, indeed, that we all knew before that increased wheel diameters brought about a diminution of tractive force required. This was shown by the great French experimenter to whom reference has been made, but all the same, I did not realise that the increased diameter could be obtained at so little increase of weight in the wheel to take the load. That is an important point. There is another point that Colonel Crompton has determined, although he does not mention it here, and that is, increase in wheel diameter would help in the solution of the dust problem. It is a fact that at the Royal Automobile Club Dust Trials, those cars which were highest off the road made the least dust. I think a wheel of large diameter would make much less dust than one of small diameter on the road.

I now ask you to give a very cordial vote of thanks to Mr. Taylor, Mr. Douglas Mackenzie, and Colonel Crompton, for their excellent papers.

The vote of thanks was carried with acclamation.

Mr. J. F. HAWKINS (County Surveyor of Berkshire): I heartily appreciate Mr. Taylor's paper. As to Road Signs, there is no doubt whatever that the allowing of people to put up motor signs over the country is a great curse. In some places we find some old

lady, perhaps, who particularly objects to motor cars, putting up a notice warning motorists to drive slowly along the particular road where she lives. Any considerable number of these private notices make motorists callous to the genuine notices put up at really dangerous places. If some legislation were passed so that only recognized authorities should be empowered to erect motor signs it would be a great blessing. As to buildings being erected on the land near the roads, at the present time, on the Oxford Road, I have been trying to get the adjoining owners to give land towards the widening of the road. The first thing they say is, "We have had to buy all this land right up to the road; and look what an amount of money you are taking away from us." It seems to me that if only a building line could be adopted by county councils, so that any houses that were built would not come in front of that line in future, the roads could be widened to a satisfactory width. Then, coming to the question of foundations, I think if there is one county more than another in England which suffers greatly in this respect it is Berkshire. We are practically waterlogged on three sides. During the past week I have had about fifty miles of main roads with a foot of water on them. It is impossible to alter this unless we can get the Thames Conservancy to help us by lowering the flood level. At Wallingford last week, during the evening I was there, the Thames was practically at its normal level, but on the following morning there was a rise of 2 ft. 10 in. When you come to main roads you find that a good many of them follow the line of the river. It is often impossible, therefore, however much draining you do, to prevent them being flooded. It does not matter how much foundation you put to some of these roads, you seem to be always seeing it disappear, because it is below the bank of the river.

A MEMBER: You mean the surface of the river?

Mr HAWKINS: In some cases it is below the bed of the river.

With regard to the cost of roads, there is no doubt the average cost of roads in some counties is very high. In my county we have been going into the question, and I find, if I take the four trunk roads, they cost about £200 per mile to maintain, while the other roads only cost about £60 per mile, which shows that it is the great amount of through traffic we get that makes it necessary to spend so much on these trunk roads.

With regard to Mr. Douglas Mackenzie's statement about the broken-down farmer very often being appointed as local road

surveyor, I am afraid, in some rural parts of England, this is still the case. I had an instance the other day, where I asked a surveyor what was the weight of the roller he used on his district roads. His reply was, "I always use a 15-ton roller." "That is very heavy," I replied, "considering the bad foundations of the roads." "Well," he said, "I am only allowed a certain amount for rolling the roads, and I get a 15-ton roller to roll the material in quicker." Now that betrays an ignorance on his part which is lamentable. You do not want to crush the stuff out of sight; that is absurd.

Mr. F. W. LANCHESTER: I think we all have been very much interested in the paper which Mr. Taylor has read to us, and I think we have all been sobered by having put before us the facts as to why it is that we cannot get better roads when we should like them. I expect most of us know of the financial difficulty which underlies almost every problem with which we are faced, and that difficulty is at the bottom of the road question, as it is at the bottom of everything else in engineering. When it is a matter of introducing new plant into a factory, improved plant in order to do some operation better or cheaper than it has been done before, the first thing which it is necessary for the Works Manager or for the engineer to do is to ascertain what the new plant is going to save as well as what it is going to cost. Now in the case of roads, Mr. Taylor has told us a good bit of what road improvement means. I confess he has given me a much better idea than I ever had before what it would mean financially to improve the roads of the United Kingdom to the degree which would be necessary to meet the requirements of the idealist, but we do not know, and as far as I am aware, we have no means of knowing what these improvements would save, and it appears to me that the weakest link at the present time in the whole subject is that we have no means of estimating what saving would be effected by a given improvement in the roads. There seems no possibility of ascertaining whether it would pay to make an improvement or not. When you are dealing with some millions of money there is no man can tell by intuition whether the expenditure of two or three millions in some particular way is going to pay the community. Those who benefit from the improvement of the roads in the first instance are the road users, but it is the community that reaps the final advantage. The cost of transport goes down and the price of goods that have been carried from one part of the country to another is reduced, so that the public benefit. As far as I can see we have no means of assessing the

benefit which the community derives from road improvements, and although we know what that improvement will cost, we have absolutely no means of knowing whether it will pay. It may save double, or it may only save one-half of what it costs. We have before us no means of making up an account to show whether it will do the one or the other, and I should like to ask Mr. Taylor whether he can give us any information as to such an account, or as to whether anything has been done to his knowledge in the way of preparing a real account of the saving likely to be effected by improvements to roads. Until we know that, we may just as well be in ignorance of the cost.

We may take it that if the present roads had been presented to the inhabitants of this country four or five centuries ago, and the expenditure necessary to maintain them had been put before them, it would have seemed to them as absurd as it would be to make the roads of solid indiarubber; yet time has shown that, under conditions of greater population, this enormous expenditure—this prohibitive expenditure, as it would have been to them—has been justified. I think we want some means of assessing the actual saving that road improvement will effect.

As to Mr. Mackenzie's diagrams, I should like to offer a little criticism. I have listened with wonderment to hear him say that the studs on a rubber tyre cut like turning machines, making the stroke up and down, or down and up—I forget which he put first—and produce grooves in the asphalt one-eighth of an inch deep. I would ask how he ascertained that these grooves were made in that way, or whether it was not due to the centrifugal slip of the car as it was going round a corner. I am sure he has ascertained it, or he would not have put the matter before us in such a circumstantial manner. There is another point. I am quite satisfied myself that if a wheel is on the ground, and the tyre is in firm contact with the road, you can move that wheel quite a small distance without the tyre following suit. Mr. Mackenzie has treated the tyre as if it is rigid and made of cast iron. I do not think it would behave as he describes in turning a corner at a reasonable radius.

Mr. H. P. MAYBURY (County Surveyor of Kent): I did not come here to speak, but to listen and to learn something from the able papers which have been presented. I should like to thank you for the kind invitation to be present and to listen to those papers. I need hardly say that, as County Surveyor of Kent, and

therefore very intimately connected with Mr. Taylor in an official position, how cordially I endorse all he has so ably written. He has made it clear, from the road engineer's point of view, what difficulties we have before us. The greatest difficulty is one of finance. If ever there was a case made out for the taxation of motor cars it was the one which has been so ably put by Mr. Mackenzie. Mr. Asquith, had he had this information before him before compiling his Budget, would not have let motorists off. The case against the steel-studded tyre has never been put by any county surveyor so strongly as Mr. Mackenzie has put it. I congratulate him for having obtained in three months information which we, as road engineers, have for several years past been collating. If the steel stud does so much harm by its tooling action or centrifugal slip, if it has the effect upon asphaltic surfaces that is described by Mr. Mackenzie, what must it have upon granite or flint-surfaced roads? I have seen granite surfaces which have been cut to a depth of three or four inches by steel studs. We do not mind much the ordinary rubber tyres, but we do abhor the armoured ones. In face of the destructive action of these, it is almost impossible to maintain road surfaces tight and in good condition. Colonel Crompton has almost convinced me that when we have wheels of motors as big as the wheel at Earl's Court we shall have no damage at all to the roads. Still, I am not *quite* convinced of that, seeing that the roads have little or no foundations. Seeing that the roads have no foundations, the wheels of the motor tractor, motor lorry, and traction engine shear through everything, and go right down into the bottom of the road, into the natural sub-soil. Although I have a very great regard for the opinion of Colonel Crompton in these matters, I am not quite satisfied that, however big the wheel, a great deal of damage will not be caused to the roads.

Mr. R. W. A. BREWER: I should like to speak for a moment on one point only, and that is the work done by the tyre on the road, and the re-action of the road on the tyre. If you turn to Fig. 4 on page 379 and also Fig. 2, page 373, you will see there a lateral deflection of the tyre, and adverting to Col. Crompton's remarks with regard to the action of large and small wheels, I think you will agree with me that he made the case clear for the large wheel, in that it requires less propulsion than the small wheel, because the displacement is less in a lateral direction. If that is the case with the road, it is also in a measure the case with the tyre, as I have

found out from some experiences with tyres. I imagine such a thing does take place if you have a tyre similar to the one which is on the stand on the platform. This is the Drury-Medhurst tyre and is fixed between two flanges. You have thus an arch section supported at its springings. For that reason the lateral displacement is considerably less than is the case with the ordinary tyre, and the suction would therefore be less. In this case you get a diagram of bearing area which, instead of being wide in the middle, is almost parallel. You also have a proportionately longer form for the area of contact. If you make a narrow track on the road, you do not get so much dust raised because you get less suction, as indicated in this paper at the bottom of page 373.

Mr. F. L. MARTINEAU: The dust nuisance seems to be one of the chief problems we have to face. I have been studying it a little, and it seems to vary not so much according to the road surface as according to the position of the road. In studying the subject, I have come to the conclusion that the Romans originally when they built their roads appreciated this fact themselves. The amount of dust that a flock of sheep raises is enormous, and probably the amount of dust raised by a legion of soldiers marching on the road was also enormous. Apparently the method of getting over this difficulty which they adopted was to raise the road above the surface of the country so that it was always wind-swept. If you have studied their roads you will see that this gave several advantages, apart from the mere question of dust; the roads were wind-swept and therefore clean, probably. They also of necessity had a good foundation, and, too, they automatically drained themselves whether on waterlogged ground or not. As regards the wear of roads, I do not think that sufficient attention is paid by local authorities to the breaking of stones, so as to get stones with flat surfaces so as to lie close up against one another. In my district they use flints unbroken, therefore a vehicle rolls the road out in front of it as if it was a series of balls, and the result is terrible.*

Mr. R. J. THOMAS (County Surveyor of Bucks): I am very much at one with Mr. Taylor. There are two or three small points of detail, however, which surveyors can discuss amongst themselves and agree to differ in, which perhaps would not appeal to an audience of road users very much. In reference to Mr. Mackenzie's

* Some additional observations by Mr. F. L. Martineau will be found on p. 414.

paper, I cannot agree with him in very many of his references to road work, and I am sorry that with an experience of three months Mr. Mackenzie should feel justified in criticising the work of surveyors who have had many years' experience in road-making, and who have seen and studied the effect of motor tyres for years. I do not think it desirable to enter into a controversy, but statements of the kind that have been made do not conduce to that harmony which should exist between road-users and road-makers. It is a serious matter to surveyors and the authorities they serve to have to find the means for road maintenance, and to improve their roads to meet your traffic. The roads have to be improved, and the difficulty is this: that out of the seven and a half millions which the roads and streets of England and Wales cost in the year, the total grant made by Government to county councils in Exchequer contribution does not exceed one and a half millions. The result is that six millions have to be found annually by the local ratepayers, of which the larger portion should be found by the taxpayers. It is unfair, and it accentuates the great ill-feeling there is against the new traffic. It seems to me it is only by combined action that we can get to that point where the ill-feeling against motors will be reduced by the better distribution of the cost of maintaining the roads. I have had 500 miles of main roads to maintain for the last eighteen years. During the first fifteen years we converted about ten miles of flint roads into granite roads annually, and were able to do it out of the rates. Now we have had to stop it because we had not the money to spare, as it had to be devoted to maintaining trunk roads, where the motor traffic is. The entire question is, "How is the additional money to be found?" Take the Bath road. I have had 1,200 cars along that road in twelve hours, cutting the granite up in a most alarming manner. The granite surface lasts only a few months before it requires renewing. So we have to use Tarmac at a cost of 2s. a square yard. That money would otherwise have been spent in converting more flint roads into granite for the general benefit of traffic, but now it has to be concentrated on those granite roads which are suffering under the new traffic. It is a great mistake to put one's head in the sand and imagine that these difficulties do not exist. The only way to meet the difficulty is to adjust the cost of road maintenance as between the local ratepayer and the national taxpayer. Mr. Mackenzie says the horse padway is worn down more than the wheel tracks on many roads. It may have been so years ago, but is not the case now, because as the

road surface improved the horse was able to draw a heavier load at a quicker pace, so that a greater weight is now borne by the wheel track. I am quite confident you will not find a single main road where the horse padway is worn lower than the wheel track. I hope something will come of the suggestions thrown out by Colonel Crompton as to the increased diameter of wheels, because the larger the wheel the less the damage done to the road, assuming there are no iron cross-bars on the tyres. It is a matter for the mechanical engineer, and as far as we are concerned we will do our part as road surveyors; that is, we will act as buffers between the road-users and the ratepayers, but until we have the money we cannot do the impossible.

MR. DOUGLAS LEECHMAN: In many cases I do not think the money spent on the roads is spent to the best advantage; in some cases I am sure it is not. Some of the London park roads are a disgrace to whoever is responsible for their construction and maintenance. The virtues of the steam-roller are very often greatly exaggerated; the pressure is distributed over much too large a surface. When the road is finished off by a steam-roller, if an ordinary horse omnibus goes over it you can hear the stones crunch under the wheels. They should not crunch under the wheels of any ordinary traffic. A great deal too much water is used when the road is repaired. It is desirable to use enough water to lubricate the stones, so as to help them jam together; but when so much water is used as to form a very large factor in the total mass of the road surface, I think it is a great mistake. That water will dry up, and where it was there is bound to be space left, instead of solid road material. The question of camber has been referred to. In some cases it is excessive, and because of the excessive camber the traffic is forced to keep to the middle of the road. It is extremely uncomfortable to ride on a much-cambered road, and if the roads were less cambered the traffic would be more evenly distributed over their width. Reference has been made to the consolidating of some roads by the pressure of the feet of various animals. In Ceylon they pound the roads with a vertical weight, called a bishop. If one could construct a steam bishop, instead of a steam roller, one might get very much better results.

MR. C. W. S. CRAWLEY: I came here to learn a little more about roads, more especially about the action of tyres on roads, as that question is being brought up at the Touring Committee of the Royal Automobile Club to-morrow. It is a matter we have taken

seriously in hand, and I have been sorry to come to the conclusion that motors do damage the roads to some extent; though I thought we might have heard a little more about the damage caused by heavy traction on roads than about that caused by pleasure cars. When you see a lot of coarse grit just in the track of the motor cars, and not elsewhere, don't necessarily say that they have pulled it out. Go to the side and fan the dust there with a newspaper. You will often find just as much grit when you have fanned the fine dust away. With regard to dust and its abatement, we must have good roads before we can get dustless ones. The Royal Automobile Club is doing its best in trying to meet surveyors halfway, and motor cars are getting better every year. Some are really no nuisance at all on a decent road. One surveyor spoke as if motorists in general did not appreciate all the good work that road surveyors were taking for the improvement of the roads. All I can say is that, at the Royal Automobile Club, we realise to the fullest extent that they are doing their level best to get the roads right, and we thank them for it; and I hope they will not judge the majority by the few grumblers.

Mr. TAYLOR, in replying upon the discussion, said:—I thank you all very much indeed for the most indulgent way in which you have listened to my paper and for the considerate criticisms made upon it. Both your President and Vice-President have put to me one or two very pertinent questions. Mr. Dugald Clerk referred to the question of State control or State aid of roads, but as a county official I am afraid I cannot venture to say much about that, as I should be treading on difficult ground. At any rate, for the present, and for some time to come, I do not think there is the slightest doubt that you will have to rely on the local authority for the maintenance of the roads, therefore I would like to take this opportunity of suggesting that whilst road authorities and their engineers are always ready to welcome helpful criticism of a practical kind, the useless and unfair abuse of a non-professional press is not only galling but it does no good; it is unfortunate to see daily and some other papers introducing to the public so-called new methods of road maintenance as great discoveries, and as complete solutions of the whole problem, when they give only part of the facts, half of the cost, and all the advantages, but make no mention of, or are ignorant of, the great expenditure involved, and of the difficulties which have to be encountered. I believe these people do great harm not only to

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road users but road makers, and discourage those who really have to grapple unaided with the question. It is not often that we road engineers have an opportunity of addressing a body of fair-minded gentlemen such as those to whom I am speaking to-night; I therefore venture to express the hope that road users will assist us in deprecating such wild criticisms as those that are levelled at us by Sir John Macdonald. I have read one of his speeches and one of his papers, and I can find no indication of any desire to assist road authorities. Sir John Macdonald says that good roads can be made at a reasonable expenditure when the initial cost and subsequent maintenance put together is certain. He therefore has no hesitation in emphatically assuring the public that the cost of these perfect roads is a simple matter which can easily be got over. With this view I do not agree. The initial cost of such roads is, as I have shown to-night, enormous. Sir John Macdonald also remarks that the only thing that is uncertain is, how long it will take to overcome the inertia of officialdom. Now as a humble member of that officialdom I can assure him that the inertia, if it exists, will be immediately overcome when the ways and means are provided.

With regard to the observations made by Mr. Lanchester as to whether the saving or gain likely to be effected by making a large capital expenditure on road improvements would be satisfactory from a purely business point of view, I must confess I cannot give a direct answer. You have heard an extract from a paper given by Mr. Howard Humphreys, in which he quoted the report of Mr. Bean, the County Surveyor of Northumberland, as to what had been done in his county towards reconstructing the roads. Mr. Mackenzie has told you the whole cost was met by loan—that the repayment of principal and interest were balanced by the saving in annual up-keep. But in the case I have given you in reconstructing a road in Hampshire—if you take £1,600 a mile which we spent for putting in the foundation, you naturally would expect to reap some great benefit from constructing a road in that solid manner; no doubt, if we had not spent the £1,600 a mile we should have incurred a great deal more in annual outlay on surface repairs, but notwithstanding all that work, owing to increase of traffic, the ten miles of road which cost £600 or £700 to maintain before, now costs about £2,300 a year; it is impossible to say exactly that by spending so many millions on reconstruction you will save so much on maintenance and on traction. If I could give an answer to that

question put by Mr. Lanchester it would be most useful, and we should know where we were if we could reduce the question to reliable figures. It is a good thing to know that you consider flat roads with a moderate cross-fall are better than those with a camber. Many years ago, when I took in hand the flattening of the road between Aldershot and London, local indignation was aroused at the project, and one of the most indignant inhabitants took half a page of a newspaper in order to refer to me as the "flat road maniac." We are extremely pleased to know we have your assistance in this matter. In addition to the flat road being easier for traffic, it is an immense gain for the reasons I have given. I had hoped Mr. Mackenzie would have told us something about running in a single track and the damage resulting therefrom. Where it is possible to vary the track, I would ask that motorists and other road users should do so. If you gentlemen will give us your assistance we can make very rapid strides, and I hope this improvement will not be greatly delayed. I was reading a weekly journal a few days ago in which the editor said that one or two surveyors had been far-seeing enough to adopt his suggestion of flat roads instead of unduly cambered roads, as the traffic was thereby more evenly distributed over the surface, but the editor went on to say that surveyors must not expect the traffic to distribute itself all at once; it would take many years, perhaps "even a generation" to do so. Now I hope Mr. Mackenzie will be able to tell us that motorists will get out of a groove in something less than a generation.

Mr. MACKENZIE, in replying on the discussion, said: I do not think there is very much left for me to say. I feel like the last speaker at a political meeting, that everything has been said that can be said on the subject. There are one or two points, however, which require answering. With regard to the equal distribution of traffic over the surface. Mr. Taylor has already told us it has taken a long time to flatten the roads, but when you do strike a reasonable piece of flat road, it is hard to get out of the bad habit of keeping to the middle. You have travelled so many hundreds of miles on bad roads, that you fear to come out of the centre lest you should go into the ditch. On the other hand, the people who live in the district where the roads are flat have gradually got into the habit of keeping to one side and varying their track. Allusion has been made to the enormous increase of motor traffic; that

increase has been so enormous that it is impossible to keep to the centre of the road for any length of time because of the vehicles you meet. When you take some roads which suffer most injury from traffic, you will find you are bound to keep to the side of the road, and that you are unable to keep continually to one track; but, of course, on secondary roads where barrelling is still excessive, you will find considerable grooving, due to the fact of the traffic keeping to the centre. In regard to the horse padway in the centre of the road, it is only within the past few years that this has disappeared from most roads. Mr. Maybury recently pointed out to me an example of this on a main road out of Maidstone, so that it is not quite extinct yet. There seemed to be several friendly hits at me because of my data having been collected in so short a time as three months. Naturally, when one leads a busy life, one is unable to concentrate one's attention upon detail unless something arises to make one do so. There are many people who travel up and down the Strand who cannot tell what colour the Vanguard buses are painted; that is because the matter has never been brought to their notice. With regard to the particular facts I have endeavoured to bring out, I am certain nobody has put in print or brought forward the enormous injury done by the deviation of a motor car from a straight line by the cutting action of the steel-studded tyres. The facts have never been really appreciated before. Mr. Lanchester seems to think they are not really so serious as I have made out, but I think if he had all the data I have accumulated within the last three months, he would agree that my conclusion is borne out. With regard to the particular diagram to which he referred, I think probably centrifugal slip had a great deal to do with that particular cut on the asphalt. Both actions probably contributed, viz., centrifugal slip and cutting due to turning.

A MEMBER: Was the asphalt soft when the cutting took place?

Mr. MACKENZIE: Quite hard.

Colonel CROMPTON's reply to the discussion (communicated): Having suffered from the disadvantage of leaving the meeting in the middle of the discussion, I have only been able to read the latter part of it, and regret to find that, although the general idea of my paper appears to receive general approval, no one has carried this part of the discussion any further, as I had hoped would be the case.

I must, however, congratulate the Institution on the valuable figures relating to road construction and repair which are contained in the paper and in the discussion. I agree with other speakers, that the extraordinary case of the track-marking on the hard asphalt in Bloomsbury Square cannot be due to cutting action. I think we all must agree that this marking must have been made when the asphalt was in a plastic condition, but I cordially agree with Mr. Mackenzie's opinion that a great deal of the damage done by studded tyres is when the wheel is in the act of twisting as well as driving. I have often noticed a heavy car starting on a well-made road at a point on a sharp curve; it is very easy to see that the studs on the inner wheel of the curve twist several stones out of the road surface just at the moment of starting. As the movement is slow at this time, the action can be watched closely, and the damage to the road is, of course, very great.

When I read my paper on "Notes on Wheel Diameter" in brief I omitted to point out that Figure 13, on p. 389 of Mr. Mackenzie's paper, showing the extraordinary cutting action of the inner edge of broad wheels, was strongly before me when I prepared my paper. I had already communicated similar diagrams showing how accentuated this cutting action may be, in my previous communications to the Institution of Civil Engineers and to this Institution. It is obvious that wheels of increased diameter allowing, as they do, of reduced width enables the weight to be satisfactorily carried on a narrower tyre, and hence with a reduction of this inner-edge cutting action. This of itself is of no small importance as regards road maintenance; but I find I also omitted to point out in my paper that this fact must add greatly to the co-efficient of adhesion of large wheels—that is to say, that the large diameter narrow-tyred wheel need cut into the road to a far less depth at its inner edge in order to rest throughout its entire width, and thus obtain the full co-efficient of adhesion due to this entire width. This will become a point of increasing importance as the use of mechanically-propelled vehicles increases on our cambered roads.

Mr. Maybury, at the end of his remarks, says, humorously, that if we had wheels as big as that at Earl's Court there would be no damage at all to the roads. Although he does not appear to see it, this is undoubtedly true. With wheels of such large diameter we could do without roads at all—that is to say, enormous

wheels would enable us to carry any load over surfaces of soft material only roughly levelled ; but he entirely misses the point when he says that even such large wheels would not help much, as, after all, the roads must have foundations. What I have endeavoured to show, and now repeat, is, that heavy weights carried on wheels of small diameter, however wide they may be, do undoubtedly do most damage to the foundations of the road, and that our only chance of carrying considerable weights on roads having weak foundations is to use wheels of large diameter.

COMMUNICATED.

The following contributions have been received :—

Mr. WALTER J. FLETCHER (County Surveyor of Dorset): I should like to say a few words about danger signals. I quite agree with Mr. Taylor as to the risk there is in these becoming too common and too varied in shape and colour, but I think their use must not be altogether discarded, especially in towns and villages where the exits from school premises abut on main roads. I know of several villages in this county where the schools are so placed and are situated at the foot of hills, and where it would be impossible to improve the view of the road, or in any way to warn the drivers of motors of the existence of such schools without some sort of signal; and it makes one shudder to see the children troop out into the road when leaving school, without a thought of the rapid-moving motor car that has just rushed past.

There can be no doubt but that the immense increase in heavy and light motor traffic on the roads is having a most serious and disastrous effect upon them, and is causing a very large increase in the cost of maintenance, which is most ably described by the writers of the papers; and the problem that faces all of us who have to do with the upkeep of main roads is, where are the additional funds to come from for providing the better and stronger materials that are absolutely necessary for maintaining the rural main roads throughout the county in such a state of efficiency as the traffic of the present day demands? It is clearly most unfair to expect the local ratepayers to bear the whole of the cost involved by this increased expenditure on roads, and for which they derive no equivalent benefit.

The figures quoted by Mr. Taylor, giving the additional cost in the county of Hants in the past ten years brought about through the use of better and stronger materials and the increased quantity required, is fully borne out by what has taken place in this county, where the progress has been in almost exactly the same proportion.

For the year 1897—8 the quantity of materials spread on the rural main roads of Dorset was 46,923 yards, which allowed an average of 102 yards a mile, and the total cost of maintenance for

that year was £14,504, or an average of £31:17s. 6d. a mile. During the past year ending 31st March, 1908, the quantity of materials used was 67,251 yards, an average of 146 yards a mile, and the total actual cost of maintenance exclusive of supervision was £23,802, or an average of £52 per mile.

The urgent necessity for additional financial aid from State funds cannot be too frequently insisted on. The fact of the through lines of main roads being now used so largely by the general public, who are not satisfied unless these are maintained in a satisfactory condition, and the extra cost brought about by the extra traffic, ought to be taken into account, and the Exchequer grant increased in proportion to the amount that has to be expended on maintaining the roads in a proper condition, for the altogether changed condition of traffic that has taken place within the past ten or twelve years, during which period the annual grant for road maintenance has practically remained the same.

With regard to what Mr. Douglas Mackenzie says as to the necessity of the use of a bituminous binding material in repairing roads, I feel sure that all road surveyors would gladly welcome the adoption of such a system, which would solve so many of the difficulties that now beset their paths; but I fear he is proposing what is almost impossible when he lays it down that all roads in the near future must be so constructed.

MR. J. S. CRITCHLEY: We have to thank the authors for very interesting papers. When I first built motor cars in 1896 we blamed the roads for all kinds of mechanical difficulties, and it appears that to-day we still are doing the same. When all is said and done, the motor will have to be made to overcome defects in the roadways of England, because—especially after what one has heard to-night—it will be a very long time before we get the perfect road—if ever.

That the roads of this country have been vastly improved during the past ten years is, I think, evident to all, and those in charge of the roads must, I think, be complimented upon the improvements. As the chairman has pointed out, the perfect road is only a question of £ s. d., and if the end justified the means I have no doubt that we should have rubber roads and use iron tyres for our vehicles.

The grumble about roads reminds me of a board of directors who laid the complaint book before their works manager and informed him that the complaints therein were matters which required explanation. His reply was: "Close the book—if there were no

complaints there would be no trade." It is much the same with roads—if there were no complaints there would not be any roads.

Since the advent of the motor car there is no doubt that the condition of the roads of this country has come very much to the front. Firstly, we have the motorist asking for better roads; secondly, we have the road engineer complaining of the extra traffic which damages his surface, and then we have the ordinary user who complains about both.

A great deal has been said about the damage caused by studded tyres. This has, I think, been very much exaggerated, and I am certain that the damage is more suspected than real, although damage does take place—but is it as much as that caused by an ordinary horse-drawn vehicle, taking into account the damage done by the horses and the road wheels—while I am sure it cannot compare with the damage done by a heavy lorry or waggon. No case has yet been brought forward by the road authorities for extraordinary traffic against the user of a motor car with studded tyres, but this is often done in the case of vehicles carrying or drawing loads.

Along the Thames Embankment travel daily an immense number of motor vehicles, but I have never yet heard it asserted that those vehicles are pulling up the surfaces or doing more damage per vehicle than the horse-drawn vehicles.

In some country districts, motors are perhaps using the roads to a greater extent than horse vehicles, and therefore it is probable that owing to the greater traffic they are responsible for the bulk of the wear, but if the same number of horse vehicles were using the roads then the damage would be even greater.

The only way to make for improvement is for the road surveyor or the motor engineer to understand each other's difficulties, and to effect the best compromise. Neither are infallible, but up to date I do think that the road surveyor has been unduly blamed, for it is evident that, in the face of great difficulties, much has been accomplished by him, to the benefit of all users. Discussions such as we have heard to-night must be productive of good if they do but bring about a better understanding between the builders of motors and the makers of the roads.

It has been necessary for railway companies to increase the weight of rails, due to increased weight of rolling stock, and so it will be necessary for the roads to be built to suit the traffic; but

meanwhile the motors must, as far as possible, be built to accommodate themselves to the existing state of things.

The English-built locomotive is quite out of place on the American railway track, for the reason that the roadway is not constructed in the same solid manner as the British rail-track, and requires a different type of locomotive. So it must be with motor cars; they must be built to suit the roads, as it will be a very long time before the roads are built to suit the motor.

One has always heard of the excellent roads of France, but I really do not think that the surface is as good as that of many of our main roads, although of course they have the advantage of having been planned with long straight stretches and easy grades. Where can one find better roads than in my own county of Kent? Again, it must be remembered that the traffic in France is not so great as in this country.

In the meantime we must agitate with the road surveyors for more money so that the existing defects may be remedied, and discuss with them in what manner the money even now at disposal can be utilized to the best advantage.

Mr. F. L. MARTINEAU: To add to my remarks on roads. In considering the situation of them and its bearing on the question of dust, it appears that there will always be wear whether the road is made with water or tar, and that therefore there will be dust; this will only vary in quantity and quality. It is impossible to keep the roads clean by manual labour, so there remains only to find out some method of making them self-cleaning. As I pointed out, this seems to have been accomplished by the Romans but of course at a cost which renders their method impossible to-day. The only other method which appears to offer any solution to the difficulty is to find some shape of fence which whilst it does not look unsightly will cause the road to be swept continually by air currents; this is done in the Highlands of Scotland on the railway to a certain extent as a protection against snow drifting. I would commend this method to the careful consideration of those who have recently been studying the lines of flow of fluids.

Mr. Taylor on pages 345—7 mentions the trouble of dangerous places; warning signs certainly seem to be erected without rhyme or reason in some places, and the control of their erection ought to be in the hands of some central body so as to have some standard degree of danger before one is erected; even then they will have little effect on that class of person to whom the name of "road

hog" rightly belongs, and who do so much harm to motoring. The remedy appears to lie in *making the place dangerous to those who neglect the warning*; this can be done by advancing the present sign fifty yards further from the place to be protected, and cutting a diagonal channel across the road where the sign now is, which it would be safe to cross at say *ten miles an hour*, but dangerous at higher speeds. This would be no hardship to reasonable users of the road, and would cure excess of speed at the place in question.

As regards grooving, this in a large measure is due to the effects of rain and water generally. This can be observed on the gently undulating parts of the Winchester—Farnham Road; here we have undulations which on a large car do not affect the speed appreciably, and yet it will be noticed that in each depression the grooving and pitting is deep, whilst on the crests it is unnoticeable.