

### Discussion.

The President. The PRESIDENT, in moving the vote of thanks to the Author, referred to the fact that only a brief synopsis of the Paper had been read, and remarked that he thought it was better to have a short abstract of a Paper read than to attempt to give a longer abstract, which did not help discussion, and reduced the time available. No doubt members who were interested had obtained advance proofs to enable them to enter into the discussion.

Sir Henry  
Maybury.

Sir HENRY MAYBURY, K.C.M.G., said he had peculiar pleasure in supporting the vote of thanks. The Author had carried out extremely valuable work in Sheffield, and had described very fully the methods adopted in the reconstruction and maintenance of roads in order to make them fit to support satisfactorily modern traffic; and, in doing all that, the Author had had great regard to costs. It was common knowledge that the country was spending on its highways and bridges about £50,000,000 a year, rather more than a third of which was raised from the taxation of mechanically-propelled vehicles, the balance being provided by the ratepayers. The charge upon the rates was of necessity a heavy burden upon trade, because every manufacturer must take rating-costs into consideration in his establishment charges. It was, therefore, extremely important, if this country was to maintain its position as the chief industrial country of the world, that local burdens should be kept down to the minimum. In that direction the Author had taken a great lead. Although it did not appear in the Paper, it was gratifying to know that, notwithstanding the improvements the Author had made in the road-administration of the county borough of Sheffield, this had been accomplished with a falling charge upon the rates. In 1902 the rate levied for the maintenance of highways was 14·21*d.* in the £, whilst in the year ending the 31st March, 1924, the cost to the ratepayers was less than 9*d.* in the £. Therefore he thought it might be said that, given good engineers and good organization, and a clear perception of what was required to support modern traffic, the work of reconstruction and maintenance could be done at no very greatly increased cost to the ratepayers of the country. The Author pointed out what a large volume of traffic could be carried upon a road 24 feet in width. He did not know why the Author had adopted 24 feet as a unit of width, unless it were that, before reconstruction, there were many roads of that width in Sheffield; but his own view was that, unless there was a large amount of standing traffic,

24 feet was unnecessarily wide or unnecessarily narrow. The maximum legal width of a vehicle on the highways of the country to-day was 9 feet 6 inches, that being the extreme width of a traction engine. The greatest width of a motor-bus or lorry was 7 feet 6 inches, and it was difficult to see how 24 feet could carry three lines of traffic. In the built-up areas it gave room for two lines, with space for vehicles whilst standing near the curb; but on the main traffic roads of the country it was important to get a unit width of 10 feet—the road being either 20 feet, 30 feet, or 40 feet wide, in accordance with the requirements of the traffic, making allowance always, close to the big centres of population, for standing traffic. The Author mentioned the abandonment of granite setts, and Sir Henry Maybury happened to know, as he had inspected the work, what had been done in Sheffield in dispensing with granite setts, particularly on the tramway-tracks. To municipal and county engineers responsible for roads carrying very heavy traffic he would recommend a visit to Sheffield, where exceptionally heavy traffic was found. It was not uncommon for a 100-ton boiler to be hauled over those roads, on an eight-wheeled bogie carriage, by two traction engines. Misgivings had been voiced as to whether the Sheffield roads had a sufficient foundation to support such weights, but the Author had shown, by the confidence he had in laying asphalt to take the place of granite setts, that he had no fear of the crushing effect of these loads. This introduction of asphalt, as against setts, must mean a very large economy to the community, to say nothing of the comfort of less noise and reduced vibration, resulting from a smooth surface. A few years ago the burden of the complaints received was that roads were being made so good for motor-cars that horses could not stand; but there had been complaints lately about some of the new road-surfaces being slippery, even for motor-cars. There was a certain amount of justification for those complaints. Under particular atmospheric conditions it was difficult for motor-cars travelling at a fair speed to maintain their equilibrium when they had to pull up in consequence of some obstruction; but the Author stated that he had had no trouble and no complaints from the users of motor-vehicles on the highways in Sheffield owing to alleged slipperiness. He wished he could say the same about the rest of Great Britain, because just at the moment he was "snowed under" with complaints, more or less justified. It was well known that, when once a complaint was set going, it was snowball-like in its growth. He was glad to observe that the Author was replacing and abandoning materials which in the old days were thought to be necessary to obviate slippery conditions, and that no complaints had reached

Sir Henry  
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him, although he had substituted asphalt. He would conclude by expressing his keen appreciation of the Paper and his thanks to the Author for having brought the subject in such a concise form before The Institution.

Colonel  
Crompton.

Colonel R. E. B. CROMPTON agreed with the Author in most of the points he put forward, but he hoped Sir Henry Maybury would forgive him when he said that the Author was right in advocating 24 feet width instead of the 30 feet asked for by some, since the provision and maintenance of the extra 6 feet had to be at the cost of the ratepayers. Unless it was considered necessary to give special consideration to the fast and unskilled motorist who required wide clearances in order to swing safely past other vehicles, a width of 24 feet, accommodating three lines of traffic, was quite sufficient for most of the roads of this country; but in all cases there should be large wastes or margins on to which the road-surfaces could be extended as traffic increased. He disagreed with the Author on the question of using very heavy rollers, and was of opinion that over-rolling was in all cases to be avoided. He thought that many surveyors were in agreement with him that over-rolling in the past had been the original cause of much of the wave-formation, and had in no case increased the durability of the road-surface. Rolling a new surface required great skill—so much so, that it was an art by itself. The Author made a statement which Colonel Crompton thought required some explanation, namely, that road-surveyors were only now beginning to use bituminous macadam—though, of course, much depended on the definition of the expression “bituminous macadam.” He himself was under the impression that the use of such macadam had been originated by the old Road Board, which made a great many experiments and developed surfaces that now, after long use, were considered very satisfactory. He thought that the whole group of surfaces specified during the later years of the Road Board’s existence might be classed as bituminous macadam. He agreed with the Author in all his remarks as to reducing camber and with Sir Henry Maybury’s remarks on slipperiness, which was one of the most important questions of the day. It could not now be denied that the chief factor of road-traffic was speed, not only the speed of the passenger motor-car, but also that of the commercial vehicles now used for the transport of goods on the roads. Speed must be limited in towns, whereas three times the speed permissible in towns could be allowed on country roads. This increase of speed was the chief reason why the maintenance of country roads presented a far more difficult problem than that of the urban roads. For instance,

it might be said that a lorry carrying 5 tons might average, when traversing London, 10 miles per hour, or in some cases, only 7 miles per hour. When the same lorry passed beyond the outskirts of London, it moved at 18 to 20 miles per hour; and, as the force of impact which deformed the road-surface certainly increased at an index in excess of the square of the speed, the increase of 10 to 15 miles per hour meant an increase in impact force of not less than  $2\frac{1}{4}$  times, and at the higher speed mentioned quite possibly 4 times. Designers of vehicles should make every effort to reduce such impact forces, and he suggested that a further reduction of unprung axle-load was desirable. But he was glad to see that recently constructors dealing with the question of carrying heavier commercial loads at the high speeds had been introducing several types of six-wheel three-axle vehicle, and it was quite possible that four-axle vehicles might be developed in the near future. Such sub-division of the load over a larger number of axles provided a satisfactory method of reducing road impact. Turning to the remarks in the Paper on surfaces inside towns, he was glad to see how successful the Author had been in substituting in Sheffield asphaltic surfaces for granite or wood-block pavements. He would point out the importance of considering whether the time had not arrived when wood-block pavements should no longer be used, on account of the difficulty of procuring wood of even and fair quality. Wood-block pavement was no longer what it had been before the war, and it was obvious that a large part of the present traffic delays in London was due to the long time needed to replace wood-block surfaces which had simply been forced up out of place by the swelling of the wood during the recent very rainy season. Road-users in London had suffered terribly from the long delays caused by the use of wood blocks.

Colonel  
Crompton.

Lord MONTAGU OF BEAULIEU, K.C.I.E., congratulated the Author, not only on his Paper, but also on the work he had done in Sheffield. He had noticed the various experiments that had been made in Sheffield, especially with reference to the substitution of bituminous road-surfaces for stone setts, and he was sure that a move in that direction was necessary to prolong the life of any doomed vehicle like the tramcar. He was inclined to agree with Sir Henry Maybury, and with his advisers at the Ministry of Transport, that it was necessary to think of roads in terms of the width of vehicles. He had seen a good deal of waste in widening a road by a few feet, when really the money would have been better spent in widening the road only at certain places and there widening it by 8 or 10 feet—by a vehicle-width. In some places there might be an excuse for a

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slight widening—for example, roads with a cab-stand at one side, or a street where vehicles were continually pulling up to deliver goods; in that case a few feet made a difference, but in general it was better to have 30 feet than 24 feet, and it was advisable to wait until there was sufficient money to widen the roads to 30 feet. With all deference to Colonel Crompton, he had never been persuaded that the roller had much to do with corrugation. Corrugation took place on steel rails, stone setts, and sometimes on wood pavement. He was in entire agreement with proposals to increase the number of axles on vehicles. He had always held that road-builders and vehicle-designers were not sufficiently in contact with each other. Looking at the evolution of the ordinary railway passenger-coach, it would be seen how there was a gradual growth from the four-wheeled vehicle with two axles, to the latest twelve-wheeled coach. The ordinary commercial road-vehicle was habitually over-laden. Sometimes the proper load, or that provided for in the construction of the road, was exceeded by as much as 50 per cent., or even more, and it was difficult to say how strong the roads should be built. Heavy materials had to be carried, and the only way to get over the difficulty was to increase the number of axles. The Scammell lorry was a step in the right direction. He did not see why there should not be more than three axles in the course of time, when difficulties in connection with steering and bogie-wheels should have been overcome. He did not think Sir Henry Maybury need take many complaints regarding slipperiness very seriously. Remembering that at present there were more than  $1\frac{1}{4}$  million drivers, and that many of them had been driving only a year or two, perhaps only a few months, some of the complaints could be understood. Had they been driving as long as he himself had, they would know that a great deal of the slipperiness and skidding was due to bad driving and not to any fault of the road. It was obvious that the development of the motor-vehicle was towards four-wheel brakes, which practically eliminated any tendency to side-slip. He thought Sir Henry would recognize that the trend of vehicle-design was in the direction of more axles and four-wheel braking, which would overcome the tendency to side-slip. There was a good deal to be said for and against all-concrete roads. The longitudinal and transverse cracks which appeared in the concrete were a disadvantage. As long ago as 1912, when he was a member of the Road Board, he went to inspect certain roads in America—the latest concrete roads on Long Island—and found them terribly cracked in every direction. In the month of July the bitumen, which had been put in to fill those cracks, was pouring out, causing a considerable nuisance. That was

inevitable in that climate. This country did not experience the same extremes of temperature as did the United States, but he did not see how it was possible to prevent a concrete road from cracking to a certain extent. It was only by putting a carpet on the top that the cracking could be limited. He believed the concrete road was in its infancy and would develop. As time went on, better methods of laying concrete would be discovered, and road-makers would not mind laying the concrete on one side of the road only while the traffic was using the other side. The longitudinal crack, which was bound to be produced in making roads in that way, might be got over by making a new form of joint in some way or other, and there would be no absolute bar to its use. The Author on p. 28 said: "It is difficult, from the financial point of view, to find justification for using in roads of average width, carrying even 4,000 to 5,000 tons a day... materials which are suitable for the vastly greater traffic of the Strand or Oxford Street." In connection with the vexed question whether wood pavement was a good material to lay down—and he agreed with Colonel Crompton that it had been found wanting lately—it was necessary to consider the future as well as the present. A road which to-day was bearing 2,000 to 3,000 tons, would in a few years bear double that amount, and it was by using methods of road-construction that had proved themselves to be good for heavy traffic in the towns that guidance would be obtained for roads for the suburbs and country. He did not think it was possible to have too good a road; although it might be necessary to spend more money on it at the moment, it was a very good investment. The more solidly the roads were built, the better they would carry the heavier traffic later; and, if six-wheeled vehicles were developed, arrangements would have to be made for them on the roads of the future.

Mr. W. WORBY BEAUMONT remarked that the Paper, although brief, was one of the most practice-based Papers The Institution had had for a long time. The Author pointed out (p. 25) with regard to the roads of the country that counts had been made at 2,791 points, and that at 1,623 points the daily tonnage was less than 1,000 tons, and only at 452 points did it exceed 2,000 tons. It was necessary to be careful with regard to averages of that kind, because it would be seen that the daily burdens which more than 40 per cent. of the roads carried exceeded 1,000 tons, and that had to be provided for. It should not be said that, say, 1,600 tons required only such and such width or strength of road; it had to be remembered that more than 40 per cent. of such roads carried a burden of the heavier kind. With regard to the question of rolling, Colonel Crompton had

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Mr. Beaumont.

Mr. Beaumont. said that he did not believe in heavy rolling, while one of the points which the Author made was insistence on heavy rolling. Considering the loads that had to be carried when a road was finished, looking at the experience that had been gained of the effect of only moderate rolling, and remembering that, unless the road-material was thoroughly compacted, it would be afterwards more compacted in a destructive way by ordinary vehicles, he thought it would be clear that the heavier rolling was the right thing. He would like to emphasize the necessity for a good foundation. The best of concrete roads, made with the best concrete, could not be expected to be of a lasting character unless there was something really firm for the concrete to rest on. Concrete roads were often taken up, the material was carried away, and a new concrete road was made on an old foundation which was often not uniformly good. Mere rolling, which was very seldom done, did not properly compact the foundation; hence it was that even comparatively new concrete roads in various places had given way in a very few years. He would like to call attention to the method of compacting roads first suggested, he believed, by Messrs. W. H. P. Gore and R. Green,<sup>1</sup> who proposed to compact roads by tamping. They described a plant, which was good as to notion but bad as to mechanical design, for employing a perambulating steam-hammer on the roads. Nowadays, with modern motors and machinery, there was a possibility of using tamping, which was very much better than rolling for such purposes. He had pointed out some years ago that the 10-ton steam roller was a very poor presser, as compared with even the ordinary omnibus of the time, which had a 2¼-inch iron tire and a small total load. The weight of the roller was carried on very wide wheels, the pressure per unit of area at any place was small, and the wide wheels passed over and left interstitial areas that did not get properly pressed. With a tamping machine that difficulty could be got over. He asked why it was necessary to provide 20 feet of grass margins between the footpaths and carriageways shown in *Fig. 2*, as well as the 6-foot way, which might be a pathway, for pipes, etc., if the cost must be kept down as much as possible. Also, why provide for tramways? The Author stated that small defects in tar-macadam roads under his charge had been promptly attended to, and the surface had been painted with tar and bitumen when necessary. Mr. Beaumont thought that bad work in dealing with small defects in most towns, and particularly in London, quickly brought about a worse condition than before the repairs were undertaken. He had noticed quite a number

<sup>1</sup> British Patent No. 3079 of 1866.

of roads which had comparatively good surfaces except that here and there small humps or hollows existed. When such roads were re-tarred or re-covered, the workmen just filled a little material into the hollow, so that the filling was a little above the ordinary surface. The vehicle-wheels hit the hump, fell on either side of it, and began to make another hollow just beyond the hollow that had been filled; and thus another hump was made. It was often forgotten that the springs of modern vehicles did not reduce the effect of the blow of the tire on the hump or on the farther side of the hollow; the effect was just as though the vehicles were without springs. He would like to emphasize the Author's view that "engineers and authorities who are willing to make reasonable experiments should have every encouragement to do so, that being, in his (the Author's) opinion, the best way of arriving at the perfect road." The Author had suggested that some day standard roads might be made, but the time was not yet ripe to talk about the standardization of roads.

Sir WILLIAM ELLIS, G.B.E., observed that, as a fellow-townsman of the Author, and one of his largest ratepayers, he would like to thank him for the Paper, first because of the eminence he had reached as a road-maker in Sheffield and as Borough Engineer, and secondly because he was carrying out the work in a very creditable and economical manner. He was not in agreement with the 24-foot width; he thought it ought to be at least 30 feet, because it was impossible for any surveyor to foresee what the requirements of a certain road in a big city would be, and it was much more economical to over-step the mark in taking a little additional width in clearing property than to have to widen that road afterwards. He would also say, as a motorist, that he found 30 feet much more convenient than 24 feet! He found many road-widenings in various parts of the country which were incomplete, largely because of the great power which the owner of a small piece of property had, when he found a corporation or public body was bound to acquire that property at his own price. He would urge that things that were necessary in the public interest should be carried out in their entirety, and that no small portion of unacquired property should be left which would hamper the benefit of a road-widening. The first consideration to be borne in mind was the old engineering saying that a chain was no stronger than its weakest link: a road was no wider than its narrowest part. He could cite instances from all parts of the country where motorists and transport drivers were very much hampered because they came to certain bottle-necks, where the public were being inconvenienced and the ratepayers penalized, owing to extensions and widenings having been carried out piecemeal instead of the whole of the

Mr. Beaumont.

Sir William  
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Sir William Ellis. property being acquired for the extension. Too much attention was paid to sentiment in connection with, say, a few old trees, which should be taken down to carry out a road-widening. They were a public danger at night, and they met their inevitable fate in the course of a few years, because someone ran into them. Could not more be done, where there were alternative routes, to give more definite instructions as to their use, so that congested villages, or busy town centres, might be avoided? Drivers found out such alternatives in practice, but he thought the authorities could do more for public convenience by putting up notices.

Dr. Brightmore. Dr. A. W. BRIGHTMORE remarked that the maintenance of roads was closely affected by the principles of design of heavy four-wheeled motor-vehicles. When the two axles of such a vehicle were connected to a single more-or-less rigid frame, the distribution of the load on the four wheels was altered by every undulation of the road-surface, and opportunity was thus given for impact and increase of pressure on the road. That effect could be reduced to a minimum by arranging that the load on each wheel should remain practically constant, notwithstanding any undulations in the road-surface.<sup>1</sup> He made some experiments some time ago, and concluded that to ensure that the load on all four wheels should remain practically constant, it was necessary, instead of having a single frame to which both axles were connected, to have two frames, with one of which the front axle was connected, and with the other the back axle. These frames should be correctly articulated together, so as to admit of the two axles taking up any angle with respect to each other, in the vertical plane, necessary to meet the inequalities of the road-surface.<sup>1</sup> As the wheels would then remain always in contact with the road, the impact would be greatly reduced. That would necessitate driving through the front wheels, or, better still, through all four wheels, which would still further reduce the resulting horizontal pressures on the road.

Mr. Dryland. Mr. ALFRED DRYLAND remarked that, broadly speaking, he was in very general agreement with the Author on most points, but he would like to say a word on the subject of the width of roads, and particularly on the question of the unit width. It was quite true that a road 20 feet wide would take two units of traffic, but quite a large margin was required to give users of a road a feeling of safety. When a road was confined to the width only just sufficient to take two lines of traffic, there was a tendency to get "tracking" of the surface. If there was room for both vehicles to vary their tracks,

<sup>1</sup> Minutes of Proceedings Inst. C.E., vol. clxix, p. 89.

more even distribution of wear took place over the whole width. Mr. Dryland. He had proved by experience that it was possible to maintain a 24-foot road as cheaply as a 20-foot road, because of the greater distribution of traffic over the whole width. In the past the tramway roads had been nearly universally paved with setts or wood blocks, and the margins of the road had been of different material, and that had always led to very unsatisfactory conditions. He had ventured to imitate the Author's interesting innovation on a length of road which at present was standing up remarkably well, and he would probably extend that, if his experience continued to be favourable. With regard to Colonel Crompton's remarks about wood paving and Mr. Beaumont's remarks about concrete foundations, he was afraid that the road-material had the blame for a great deal of trouble that it did not cause. Much of the disturbance in the streets of London in the last few years had been due not to failure of the road-material itself but to those who burrowed into it. There had been great delay in carrying out extensions and renewals of all kinds of mains, owing to the war, and of late considerable disturbance had been caused in overtaking those arrears. It was very seldom the case that concrete gave way, unless the failure was caused by the subsidence of trenches opened in the road. On roads which were not disturbed, 14 or 15 years of life could be obtained from wood paving, and he thought it would be a long time before wood paving disappeared from the roads of London. The Author advocated laying concrete in two layers, putting in the lower layer the day before the top layer, and said that he believed that in that way cracks would be avoided. Mr. Dryland hoped that might be so, but he did not believe it. He could not conceive that it would stop the concrete from cracking, and thought it would rather tend to increase the cracking. Those who had to do with roads appreciated very much the fact that the Author had done excellent work in Sheffield, and were always glad to read anything he wrote about his work.

Mr. H. T. TUDSBERY remarked that the Paper raised many questions which were very prominent in this country at the present time. He was surprised to find that the Author had managed to compress so much information in such a small compass. There was only one statement in the Paper that he felt needed to be put more clearly than had been done by the Author, namely, that the modern asphaltic surface was not slippery. He agreed that it need not be slippery, but, as a fact, it could be very slippery. Whether, as the Author suggested, the slipperiness was caused by a film of mud or not, seemed to be rather beside the point. A film of mud on a gravel or waterbound macadam road did not render it slippery. Mr. Tudsbury.

Mr. Tudsbery. Surfaces were often made of too hard, or wear-resisting, material. To point to the extreme, a polished steel surface would probably wear extremely well, but it would be well-nigh impossible to walk on. The solution of the problem, in his opinion, was to be found in the more extended use of surfaces which wore more readily than asphalt, but of course evenly, and the first cost and maintenance of which were not greater. With regard to the layout of arterial roads, it might be possible to persuade the Author to communicate more of his knowledge of that particular branch of the highway engineer's problem than was contained in the Paper. On any given route it should be easily possible to form an estimate of the reduced cost of operating transport over an improved road, from a study of the existing costs, carefully detailed, and reduced to a lorry-mile basis. For example, the lorry-mile costs of "country" journeys of a certain fleet of ten 4-ton motor-lorries amounted to 12·3*d.* per lorry-mile. It might be assumed that, over a better road, the same weight of traffic would be carried (a conservative assumption, for improved facilities would be almost certain to induce a greater use of road transport); then the costs over the new road, on the assumption that owing to gradients being reduced from a maximum of 1 in 12 to 1 in 30 twice the load could be hauled for roughly the same consumption of petrol, might be estimated to amount to 13·7*d.* per lorry-and-trailer-mile. For twice the load those figures would show a saving of 45 per cent., but as it would be more difficult to get twice the quantity of merchandise constantly arranged per trip, the probable saving might be taken as 30 per cent. without allowing anything for the shortening of the distance, which would probably be effected in all arterial road schemes. Assuming that 1 million tons a year passed over the road, and the old average load on a wagon was 3 tons, but that owing to improvements the new average amounted to 6 tons, then the total saving per mile per annum would amount to £5,125, which, capitalized at 5 per cent., represented an initial outlay of £100,000 per mile. Those figures, he believed, were reliable enough for all practical purposes, and therefore an improvement scheme was usually worth the expenditure of £100,000 per mile for every million tons of annual traffic expected. There were two other vital things which should always be taken into consideration in the layout of any arterial road, namely, the relative values of distance and gradient under average conditions. For that purpose the type of vehicle he would consider was a 4-ton petrol lorry, taken as travelling 9 miles per gallon on the level, and about 3½ miles per gallon up a 1-in-30 gradient on a good road-surface; the average consumption for long journeys would be about 7½ miles per gallon,

which was the figure he had ascertained for the "country" work done by the lorries already mentioned. Experiments had shown that on such flat gradients as 1 in 30, the fuel used in the descent was very little less than that on the level; in fact, the saving was not more than about 15 per cent. It had also been ascertained that, as might be expected, the petrol used in climbing a definite number of feet was not affected by the steepness of the gradient, provided no gear-changing was necessary, and the distance in all cases was the same. Keeping that in mind, and taking the cost of petrol at 1s. 6d. per gallon, the net additional expense in climbing worked out at 0.016d. per foot of rise. On that basis, and if the average load were taken as 3 tons, there would be an annual charge of £22 occasioned by every foot of rise, which, capitalized, amounted to £400. In other words, a capital expenditure of £400 might be incurred economically to save 1 foot of rise. In the same way an estimate could be made of what expenditure would be reasonable with a view to reduce distance. The overall cost of running might be taken as 4.11d. per ton-mile; and, if the cost of running 20 miles from one town to another was 20s. 6d., the average cost by a route built to the same standards but 2 miles shorter could be reasonably taken as 20s., showing an annual saving on 1 million tons of £8,333, which corresponded with an initial outlay of £8,000, in round figures, to save 0.1 mile in distance. Comparing that result with the one arrived at for gradient, it seemed that, in general, 1 foot of rise might be introduced to avoid increasing the length by 25 feet, or vice versa. He had endeavoured to show how certain of the fundamental principles underlying the economical layout of arterial roads might be approached. Rule-of-thumb methods had served their purpose well enough in the past, but with the increasing dependence of modern life on the economical use of every kind of power, it should be the primary consideration of any engineer who was called upon to advise in those matters, which involved the expenditure of large sums of money, whether public or private, to consider seriously in every case the bearing of the principles underlying success as estimated by the general community.

Mr. E. L. LEEMING, referring to the subject of camber and its relation to slipperiness, considered that camber should not be reduced too far, because on a flat road with small camber mud and dirt tended to cling to the surface. That contributed to slipperiness in some degree. Also, he did not agree that reducing the camber caused all vehicles to go to the side of the road, because a good deal depended on locality; many drivers liked to be in the middle of the road, as it gave better vision in regard to side entrances and blind corners. A

**Mr. Leeming.** good deal of wear was confined to the centre portion of carriageways, although that did not hold in towns so much as on some of the country trunk roads. With regard to asphalt between tramway-rails, he had seen the roads in Sheffield and was bound to say that the Author had had considerable success where others had failed. It was exceedingly difficult to get any paving to hold against tramway-rails, and he could cite one instance where, without any trams running over the rails, the rails were worn down by iron-tired horse traffic holding to them. He felt that the Author's figure of 12s. 6d. per square yard for concrete roads was rather high. He himself could lay concrete roads at about 7s. 6d. per square yard; in fact, he believed he could do them more cheaply than roads with asphalt alone in the first instance. That being so, it seemed to him, in considering the form of paving, that a concrete road might easily be put down first, and when it had become worn—probably about 5 years later—asphalt could be applied. He thought that would prove economical, having regard to the fact that the road would be put down at 50 per cent. less cost in the first instance. Another point with concrete roads was that, where the road was wide, work might be carried on without much interference with traffic. He had carried out a length on those lines; while the centre was being concreted, the traffic ran on the sides, which were afterwards laid with tar macadam. On completion, practically the whole of the traffic ran on the concrete, which was now wearing exceedingly well. He wished he had a number of roads wide enough to permit of the adoption of the same methods, but, generally speaking, the roads were too narrow.

**Mr. Smith.** **Mr. J. WALKER SMITH** remarked that the Paper was of interest as showing how conditions had changed in the last 10 years. Although the volume and conditions of traffic changed almost daily, until a perspective view was obtained by means of reference to statistics such as the Author gave, it was difficult to realize the accumulated effect of the gradual changes. It was obvious that the reduction in horse-drawn traffic might be to the future advantage of the road-engineer. In the old days, and even now, an engineer had to construct a road-surface which would be equally convenient to the self-propelled traffic and to horses—a problem which was not easily solved. He was tempted to speculate as to the future of road traffic, and he thought that the horse would become extremely rare in the course of the next 60 or 70 years. The construction of arterial roads in Sheffield was typical of what was going on throughout the whole country, and that was due to the combination of very enlightened control at the Ministry of Transport and hearty co-operation amongst the local authorities concerned. While the construction of those

roads was a matter for gratification, he had been a little concerned at the cost. Although he had heard one of the chief rate-payers of Sheffield say that he had no complaint to make with reference to cost, it occurred to him that £34,000 per mile for construction and partial completion of roads, as described, in those virgin areas was perhaps a rather higher cost than it should be. That was no fault of the Author, but there seemed to be something fundamentally wrong with the costs of road-construction to-day. He had obtained 10 or 12 years ago some figures from the City Engineer of Liverpool, who was a pioneer in work of the kind, and had constructed roads in virgin areas and in partially-developed areas, and had undertaken the widening of existing roads. His costs under those three conditions were: for the first category of roads—very similar to those constructed by the Author, with the same measure of completion—about £10,000 per mile; for roads of the second category, about £80,000 per mile; and for roads falling within the third category, about £400,000 per mile. The difference between £10,000 and £400,000 per mile was the measure of the benefit the taxpayer obtained for the exercise of forethought, as exemplified in Sheffield. If it was possible to get now for £34,000 no more than could be obtained for £10,000 before the war, there was something fundamentally wrong. A good rough test of cost was to see how far the pre-war costs were exceeded by present costs, and if it was found that the increase was more or less comparable with the increase in the index cost of living, about 70 per cent., the cost was not unduly high. Upon that basis the £10,000 in 1912 should now be £17,000; instead of that it was £34,000, which struck him as being far more than should be the case. He had used tar macadam 25 years ago, and had found it to be especially satisfactory, in that it could be made with almost any aggregate found in almost any locality in this country. It was necessary to modify the bituminous treatment and to vary the specific gravity of the tar, but each and every aggregate could be used with satisfactory results. He thought a very large measure of justification was required for bringing tar material at heavy railway rates over tens and sometimes hundreds of miles. He was pleased to see the manner in which the Author dealt with the question of concrete roads; he had not jumped to a conclusion with reference to the future of concrete roads, but had put down concrete roads in a proper spirit of inquiry. He thought engineers were sometimes a little too apt to adopt methods of construction for their own conditions which they found suitably applied to other conditions. Concrete roads were perfectly satisfactory in many parts of America

Mr. Smith. where the roads had been made through virgin areas and through country which for many miles did not contain a bit of rock, and where therefore it was of importance to the engineer to convey the least possible quantity of aggregate. Under those conditions the problem had been solved by using the best possible matrix, which was cement. Such conditions, however, were not typical of the conditions of this country, where there was excellent rock in many parts, and where excellent road-material was readily obtained from the Channel Islands, Scotland, and Belgium. He was satisfied that the Author was setting an excellent example in solving his road problem by commencing from root principles, applying the means most suited to the conditions of his particular problem, and utilizing to the maximum extent the material most economically available on the site.

The Author. The AUTHOR, in reply, observed that he regarded it as a great honour that the Paper had been read before The Institution, and he appreciated very much the remarks which had been made by the various speakers. His only excuse for presenting such a Paper was that the present time was a time of transition; and he thought that he had had special opportunities of judging the new methods in Sheffield, where, during the war, the traffic had been out of all proportion to ordinary traffic. Experimental work carried out at that time had stood the test of that extreme traffic, and he thought it was thus possible to obtain some idea of what the roads would stand under the increased traffic of the future. It was only fair and proper to make as public as possible the economies he had been able to effect. He believed that in road-construction economy merited the closest attention; he did not advocate the cheapest road, but the most efficient road at the least comparative cost. The Paper purposely did not refer to the reduction in costs which has been brought about in Sheffield by the introduction of new methods, because the Author wished to avoid anything which might look like self-advertisement. Sir Henry Maybury, however, had been good enough to quote official figures, which spoke for themselves. As to the width of carriageways, evidently there was considerable difference of opinion, and the Author adhered to his view, arrived at after long and careful observation, that for average roads a carriageway width of 24 feet was a happy medium. Mr. Dryland had given one excellent reason for having a width greater than the minimum of 20 feet which was necessary to permit two vehicles of maximum width to pass, namely, that with the greater width there was better distribution of wear, and less "tracking" or rutting. The Author entirely agreed, and he was convinced that the additional 4 feet did not involve a proportionate additional cost. It also meant

that the average annual cost per superficial yard was reduced. The Author.  
His main reason for advocating 24-foot carriageways, however, was that there was greater freedom for traffic, and less congestion. An ordinary motor-car could stand at the edge of a 24-foot roadway while two other vehicles of average width passed it, which was not possible if the width was only 20 feet. At the moment, the question of slipperiness was very much to the front, and probably some of the statements so freely made by victims or witnesses of accidents were a little overdrawn. There might be asphaltic roads over which it was unsafe to drive at a moderate speed, even under normal conditions; but the Author had not met with such cases, nor had many of his colleagues. The answer to the great bulk of complaints about phenomenal slipperiness was contained in the words "undue speed." To those whose habit it was constantly, and almost automatically, to observe the roads, and what happened upon them, it was surprising that comparatively high speeds under bad weather-conditions did not result in more accidents. A great deal was being done for motorists, and the motorists, especially those with little experience, should do their share by always putting safety first. There was a great deal in Lord Montagu's remark, that in this country there were over  $1\frac{1}{2}$  million drivers, a considerable number of whom were comparatively new to the work. Other materials were quite as slippery as asphalt under bad weather-conditions. After a slight shower dirty wood pavement (and worn wood pavement was rarely free from dirt) presented as dangerous a surface as any the Author knew; but, at the moment, less public attention was given to accidents occurring on wood pavements. In considering the causes of accidents due to skidding, the question of camber should never be overlooked. The use of heavy rollers was a matter to which the Author had given much consideration. After observing the results of rolling with light and heavy rollers, in his own district and elsewhere, he was quite convinced that for a road with considerable traffic the heavy roller was better. With skilful rolling and a good foundation, serious corrugation could be avoided; and, if the road was thoroughly rolled at first, there was much less risk of subsequent distortion. A definition of bituminous macadam was badly needed, and the Author drew a definite distinction between tar macadam, which was extensively used in the days of the Road Board, and the macadam bound with bitumen which was now coming into use. Impact was an important factor when a road with an uneven surface was concerned. A sett-paved road with a transverse joint every 3 or 4 inches was, like the wood-paved road, extremely susceptible to the impact of heavy commercial vehicles. As the road wore, the surface became more or less uneven, because the

The Author. blocks did not all wear at the same rate. A corrugated tar-macadam road, or one repaired in the way described by Mr. Worby Beaumont (which, unfortunately, was not unusual) suffered badly from impact. A smooth asphaltic surface was much less affected in this way. After several years' experience of asphaltic roads, laid at a much lower initial cost than wood blocks or any kind of sett paving, and subject to a great volume of heavy motor traffic, the Author was able to say that on such surfaces impact was a matter of much less importance. If impact from wheels was to cause damage to a road, that road must have an uneven surface, and the asphalt road had a more even surface than any other, except perhaps a concrete road, which, if properly laid, was approximately its equal in that respect. The makers of heavy vehicles might do a good deal to help road-makers by improving the design of vehicles, and undoubtedly the wider use of pneumatic tires on heavy vehicles would play an important part; but it would be a long time before the badly-designed vehicle was eliminated, and, in the meantime, the best way of reducing impact damage seemed to be by providing the smoothest practicable surface. Tamping could not take the place of surface-rolling, but it was a very good method of dealing with weak places in the foundation. The Author had three tamping-machines, driven by petrol motors, two of which were built in England, the third being of American design. These had been bought for the purpose of ramming trenches, but had been extensively used for consolidating filled material in the embankments of new arterial roads, with excellent results. Mr. W. P. Robinson, Assoc. M. Inst. C.E., the County Surveyor of Surrey, had a machine for consolidating the foundation of the Kingston by-pass road, working on the "caterpillar" principle, which seemed very effective. There were several reasons for providing the wide grass margins between the footpaths and carriageways of the new arterial roads. Increase of traffic might require a wider carriageway than that now constructed, or even separate ways for up and down traffic, which had already been made in some Midland and Northern cities; provision must also be made for a possible tramway. However strong the conviction might be in some minds that tramways were doomed, that opinion was by no means universal, and, at the moment, the owners of successful municipal tramway undertakings (some of which had never had a loss in any year during the last quarter of a century) were extending their lines, and taking powers to extend them still farther. Perhaps tramways would disappear eventually, but certainly that would not be in the immediate future; and, meantime, the road-engineer must provide for every reasonable contingency, including tramway extensions along his new and widened roads. Sir William Ellis had

called attention to a very serious difficulty in the way of completing The Author. even small widenings. If anyone doubted that an Englishman's house was still his castle, let the doubter try to deal with an obstructive or unwilling owner, who was not subject to compulsory powers. In many cases it was impossible to deal with such an owner without an Act of Parliament, or at least a Provisional Order. Some method less expensive and cumbersome, and more expeditious, was badly required. Mr. Dryland thought that the Author's method of laying concrete roads in two layers would increase, rather than decrease, the tendency to crack. The Author's theory was that many cracks were due to contraction, and he thought that his method, which was to put on the top layer of concrete after the lower and thicker layer had partially set, would minimize the trouble. His concrete roads had now been completed for about 2 years, and he saw no reason to alter his methods. Several of the members present at the meeting, who had seen those roads, would agree that there were very few cracks, and none of importance. Mr. Tudsbery's formula as to the amount which it was worth while to spend to save 1 foot of rise, or to shorten the length of a journey to a given extent, was new to the Author, and well worth consideration by all road-engineers. There was a general idea that, because a motor vehicle could climb without difficulty a gradient that would be difficult for horses, gradients did not matter to the motor. That was wrong, as excessive gradients meant not only a higher petrol-consumption, but more wear and tear. The question ought to have more attention in designing new roads and in improving old ones. Mr. Leeming did not think camber should be reduced too far, but admitted that a good deal of wear was confined to the centre of the carriageway. Was not that an argument for reducing camber, not unreasonably, but as far as practicable? Besides causing undue wear along the crown of the road, the Author looked upon excessive camber as one of the most serious causes of side-slip and consequent accidents. Comparison of the cost of pre-war arterial roads in Liverpool with post-war costs in Sheffield was scarcely a comparison of like with like. The country on the outskirts of Liverpool was comparatively flat; in Sheffield, very large quantities of excavation had been necessary to obtain reasonable gradients, and doubtless there were other factors to be considered, one of them being that the whole of the Sheffield work on arterial roads had been carried out by relief labour. The Author fully agreed with the inference to be drawn from Mr. Walker Smith's remarks, that methods proved to be satisfactory under one set of conditions were not necessarily suitable under other circumstances. It was for each road-surveyor to satisfy himself as to what would meet his own requirements;

The Author. but the wise man learnt from the experience of others, and the Author ventured to submit the results of his own work, in the hope that the information given might be of use to his brother engineers.

### Correspondence.

Mr. Boulnois. Mr. H. PERCY BOULNOIS remarked that, although the Author gave some interesting particulars of the tonnage of traffic on the roads in Sheffield, he did not reduce them to the necessary unit of tons per yard width between curbs per annum, which was the only basis of proper comparison. With regard to the widths of carriageways, although the Author might find that 24 feet was sufficient in Sheffield, where probably the majority of the traffic was slow, such a width for a fast, or mixed traffic, was inadequate, and 30 feet was required. The former multiple of 8 feet per vehicle was ample for horse-drawn traffic, but with the vastly increased speed of modern traffic a multiple of 10 feet was necessary. The Author was very sound in his views on the absolute necessity for the proper drainage of roads; water was almost as great an enemy to roads as traffic. He was equally right with regard to the support of the haunches of carriageways by curbs, or other means; without this support the upper crust had a tendency to spread. There were well-known cases of this having occurred, with waterbound macadam roads, where the metal had been found pushed under the verges to a distance of 18 inches and even more. The Author appeared to be an advocate of heavy rollers for bituminous materials, which seemed to be somewhat at variance with modern opinion, as heavy rollers were held to be among the causes responsible for the inception of waves—one of the bugbears of modern road-construction. He did not say whether the roads under his charge suffered at all from this detriment. The Author's recommendations as to camber should be studied by all road-makers; he was perfectly right as to the cause of most accidents from slipping of horses or side-slip of motor-cars being due to excessive camber, and it was evident that the immunity from such accidents in Sheffield was due to his wise diminution of the gradient of camber. He did not appear to have been very successful with concrete roads, which might have been due to a variety of causes. There was no more difficult road to construct than an unsurfaced concrete carriageway. Concrete was rather a "tricky" material to deal with; each batch must be absolutely similar in composition, the cement and aggregate carefully selected and kept uniform, and the quantity of water reduced to a minimum and varied in accordance with weather conditions; and