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8. "Specification for Road and Bridge Works." H.M.S.O., 1951.
9. "Roads in Rural Areas." Ministry of Transport Memorandum No. 653, H.M.S.O., 1950.
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FURTHER LITERATURE

12. "Memorandum on the Lay-out and Construction of Roads." Ministry of Transport Memorandum No. 575, H.M.S.O., 1949.
13. H. Criswell, "Highway Spirals, Superelevation and Vertical Curves." Carriers, London, 1948.
14. F. G. Royal-Dawson, "Road Curves." Spon, London, 1936.
15. "Soil Mechanics for Road Engineers." Road Research Laboratory, D.S.I.R., H.M.S.O., 1952.
16. H. E. Aldington, "Design and Layout of Motorways." J. Instn Highway Engrs, vol. 1, No. 2, p. 5 (April 1948).
17. E. C. Boyce, "Road Location and Design, with particular reference to Motor Roads." Final Report of Public Works, Roads and Transport Congress and Exhibition, p. 259, 1947.

The Paper is accompanied by six sheets of diagrams from which the folding Plate and the Figures in the text have been prepared.

Discussion

Mr R. J. Samuel said that it was possibly true that the Paper gave the views of the Ministry of Transport, but those were not unchangeable.

The Author had said that he wondered when the motorways would be constructed. Obviously, it had to be borne in mind that there was a lot of leeway to be made up in the maintenance of existing roads and small works, which would take a large proportion of the money when some was provided. When money was available, perhaps by-passes and small sections of the roads would be constructed on motor-road lines under the

Special Roads Act, and it was therefore desirable that a decision should now be reached as to the best form of construction.

Mr Samuel then raised two points concerning construction, observing that the views he expressed were his own, rather than those of the Ministry of Transport. On pp. 720 and 722, the Author had recommended that there should be a hardstanding on the side verges, with a cross-fall of 1 in 15, for the benefit of drivers who had to make an emergency stop. He was not at all sure that, if one had to leave the carriageway in an emergency, it would be too pleasant getting on the 1 in 15 slope. It was worth considering if the hardstandings ought not to be level, which would enable the side verge to be reduced. He knew that that would mean more conventional drainage. The design of the motorways largely followed the Continental pattern, and not all imports into Great Britain were beneficial. He suggested that a little more thought might be given to that matter.

His next point was one which would probably cause some consternation. Was a dual carriageway necessarily the best form of construction? The Author had said that dual carriageways were regarded as essential and that whilst only one carriageway might be constructed in the first place, ultimate plans should provide for dual carriageways so that the passing streams of traffic were separated in the interests of safety.

Mr Samuel believed that dual carriageways were first advocated in a memorandum issued in 1935, where it was stated that if the traffic flow was more than 4,000 (since raised to 6,000) vehicles per day, dual carriageways were advised. It had been assumed ever since that that was sacrosanct; but there was no proof that dual carriageways were safer than single carriageways. An instance had come to his notice a short time ago which had startled him. Several miles of a 40-foot carriageway on a trunk road carrying a heavy volume of traffic had been converted into dual 22-foot carriageways with a 6-foot strip in the middle, and the accident rate there had risen, whereas on the adjacent section which remained a single carriageway the accident rate had not gone up. He did not know whether that unfortunate trend would continue over a long period or whether it was true of all roads in Great Britain. There were a number of 40-foot and 30-foot, single- and dual-carriageway roads, and he felt that an investigation should be made into the accident rates and the carrying capacity of those various forms of road so that, before any of the motor-roads were constructed, it could be confirmed that the best, cheapest, and safest form of construction was being adopted.

If by chance it was established that a 40-foot four-lane carriageway was as good as, or better than, a dual carriageway, the 93-foot width of lay-out could be reduced to about 60 feet, with a saving in land, earthworks, and construction. It should not be forgotten that, in the present hard times, road engineers were like manufacturers and had to sell their products, and the cheaper they were, the more easily would people buy them. If a limited sum of money was available, the cheaper the form of construction

commensurate with sound engineering practice, the more miles of motor-road could be constructed.

Colonel G. T. Bennett observed that the difficulties of land appropriation seemed to be interfering with every kind of activity—not only road-building but housing and everything else. Every piece of land that one looked at was “the best agricultural land in the country.” He believed that he was correct in saying that less than 1 per cent of the land of England was taken up by highways, and considering that nothing in the country could function at all if it were not for the roads, he felt that that figure was not excessive. If 1,000 miles of full-width motorway were constructed, it would take 0.03 per cent of the country's land, which was a quite negligible amount. That was a most important point to be borne in mind by engineers, who should not meekly accept the agriculturists' objections as to the vast amount of land required for motorway construction.

He remembered being involved in an argument, just after the war, about a diversion to avoid an aerodrome which had been built across the line of a trunk road. One possible method was to use an existing road, widening it, and the other was to construct a new road which would have been shorter by half a mile. It was not difficult to make a reasonable calculation as to what the shortening would have meant in saving of transport costs; in fact, assuming a very low figure for the ton-mile cost of transport and capitalizing the annual saving, a saving equivalent to a capital sum of £1,000,000 would be achieved if the shorter route were adopted. The objection to the proposal was that farm land would have been severed; but how many farms could be bought outright for £1,000,000? If manufacturers' costs could not be reduced by cutting transport costs, then Britain would grow its food but grow it very dearly; only half Britain's food was home-produced anyway. As a nation, the British had to rely primarily on the fact that they manufactured, and manufactured cheaply, and exported in order to buy their food. If that were forgotten, there would be sufficient food but little else, and it would be very dear food at that.

With reference to alignment, Colonel Bennett put in a plea for occasional very long straights. The last thing he wanted to see was the English road always going perfectly straight like the Roman roads, for the practice in England of following the contours provided half the attraction of the countryside to motorists, but, speaking for himself, he liked occasionally to get on to a 10-or 20-mile straight. Some of the straight roads up to Newmarket or across Wiltshire were very pleasant. When there was an opportunity to build a straight road of reasonable length he did not see why it was necessary to construct sweeping curves which the contours did not require.

However the foundation of the roads was built, whether it was of concrete or a flexible construction—and he would not take sides on that question; he was sure that some would be one way and some the other—he

hoped that the roads would be finished with a "black" top. He did not believe that a beautiful road could be built in exposed concrete; nothing could make concrete surfaces look well in Great Britain.

He wondered whether the rounding of slopes in cuttings and embankments was really necessary. He had built many embankments and cuttings with straight slopes and once they were planted they looked well. He could not see the need for the extra land and cost, and the extra work and difficulty from the point of view of the engineer in setting-out.

Mr S. M. Lovell said that he wished to make one point in connexion with the safety factor which seemed to be quite predominant in the construction of the new motor-roads. In the Paper and in his introductory remarks, the Author had referred to the fact that there would be no kerbs but that there would be marginal strips, and he had referred in particular to a marginal strip 1 foot wide of a colour contrasting with that of the carriageway, especially at night. Mr Lovell held a purely personal view that the definition of the road edge was one of the most important factors, which appeared to have been forgotten. Certainly it had not been given the attention which it deserved; it was a vitally important matter in relation to safety on motorways in particular and highways in general. He did not believe that 1 foot was anything like a sufficient width. The idea should be extended, and something very much bolder should be adopted.

The matter of hard shoulders arose from the fact that there would be a flush carriageway channel margin of more or less the same level, there being, in fact, no vertical rise. Instead of building hard shoulders 4 feet 6 inches wide, the opportunity should be taken of making them sufficiently wide so that traffic of all sorts could pull off the road if it wanted to. Those who had built roads to that type of design knew that traffic would pull off the road. It was rather "spoiling the ship for a ha'p'orth of tar."

Another important point arising from his personal experience in connexion with flush-margin construction was that subsequent to altering a road to that type of construction the non-productive maintenance costs on the road had dropped by 75 per cent, which was a striking figure. The road never had to be swept now, for it cleared itself, which was an important point. The gravel which was put down in the winter for gritting was cleared to the side by the traffic itself. The more it was possible to reduce the non-productive costs, the more money there would be available for future construction work.

He believed that about 4 or 5 years previously, the Ministry of Transport had issued its recommendations concerning the types of foundations to be used for motor-roads. He had not had time to refer to them, and he wondered if the Author could tell him what they were. He hoped that the Ministry would consider the granular type of foundation—that was, building up on Macadam's principles rather than on those of Telford, which consisted of building up with large pieces of stone. The Macadam

method would utilize local aggregate more than did the Telford type of foundation.

Mr James Drake observed that, on p. 712, under the heading "Preliminary Considerations," the Author had referred to the siting of motorways. Mr Drake entirely agreed with the Author that motorways generally should be sited close to large centres of population. What a great benefit it would be if all the motorways shown in *Fig. 1* were built. However, in spite of the benefits from the peace-time and war-time points of view, he was afraid that the full programme would never be completed unless the first lengths to be constructed were very carefully chosen. He felt that if the first lengths did not attract a great deal of traffic and also save a large number of accidents, the motorway programme would just wilt and die.

To illustrate his point, he displayed a slide (reproduced in *Fig. 7*) which showed the large towns in Lancashire. The diameters of the outer circles were proportional to the population of the towns, and the diameters of the inner black circles were proportional to the traffic entering the towns. The Figure indicated immediately which towns in Lancashire had a large proportion of by-passable traffic, namely, Preston and Lancaster. Lancashire had carried out a very careful traffic survey to find out what traffic would use a north-south motorway through the county. That motorway was shown by a broken line by-passing Wigan and Preston.

The survey, based on present traffic figures, had shown that the number of vehicles on the length adjacent to Preston would be 3,600 during the peak hour, while the figure on the length just south of Wigan would be about 750 vehicles per hour. He hoped that the Author would agree with him that it would be inadvisable, indeed foolish, to construct the Wigan length of the motorway before the Preston length.

On p. 717, reference was made to soil survey. The advantage of carrying out a soil survey had already been proved in Lancashire, where one had been in progress for a considerable time. One hundred and eleven boreholes had been sunk on the line of the motorway to a total depth of about 2,600 feet.

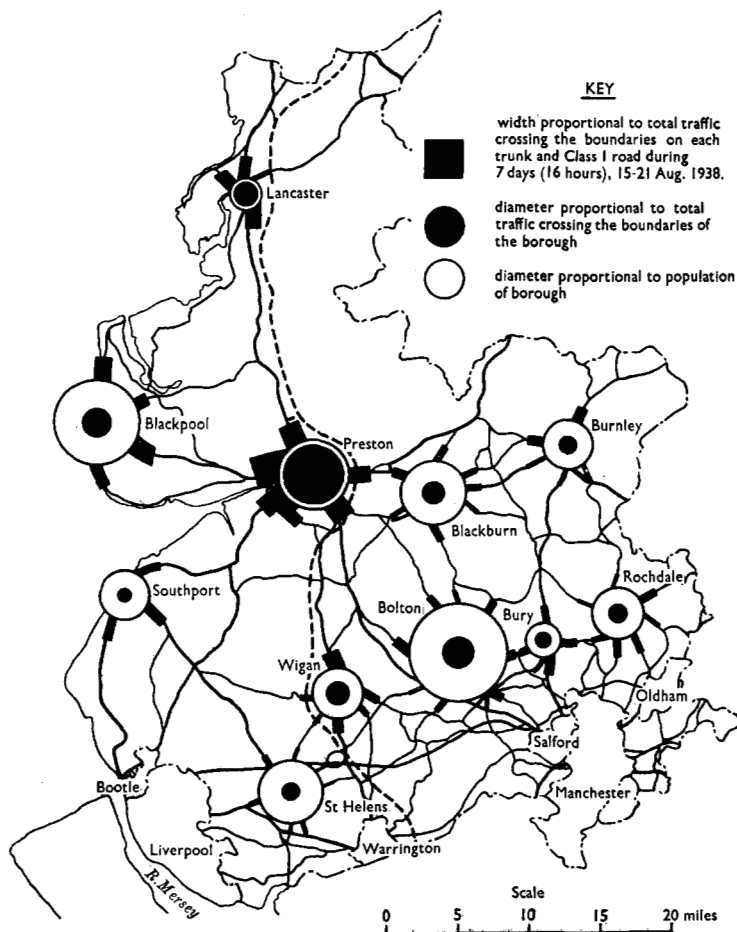
Mr Drake's second slide showed the California Bearing Ratio of various samples tested so far. Roughly 40 per cent had a C.B.R. of between 2 and 3 per cent. That was because the siting of the motorway was predominantly on clay and boulder clay. Fortunately—from a road construction point of view—Lancashire had a large number of burnt-pit-shale heaps which could be used as a sub-base. The soil survey had shown that there was no need to vary either the intended horizontal alignment or the profile, but it would have very valuable results in other ways.

On p. 718 there was reference to fitting the road to the landscape, and to flowing alignment. He was of the opinion that with the very flat curves required by the Ministry for motorways there was little danger of getting into trouble from an amenity point of view. That did not mean that all the research into flowing alignment could be ignored, but it should

not be treated too rigidly or it would put up the cost of the road to such an extent that the work would never be carried out.

His next four slides showed a model of the motorway in Lancashire

Fig. 7



RELATIVE POPULATIONS OF, AND TRAFFIC ENTERING AND LEAVING, THE COUNTY BOROUGH AND LANCASTER

just south of the Westmorland length dealt with by the Author. The Lancashire Section of the Council for the Preservation of Rural England had agreed that the motorway, according to the design shown on the model, would not detract from the amenities of a very pleasant part of the county.

Mr Drake appealed to the Author to amend his views with regard to the suggestion to allow two-way traffic on the ramps at certain junctions in order to save expenditure and land.

Despite what Mr Samuel had said about dual carriageways, he was still a firm believer in them. Mr Drake had calculated that if single carriageways were adopted, the saving in land would be $\frac{1}{5}$ acre per junction and the saving in cost would be about £2,000, and he considered that that trivial saving, which would reduce the safety and attractiveness of the entrance to the motorway, was simply not worth while.

He agreed with Colonel Bennett—and he was sure that the Author would also agree—that if one wanted to save costs on the motorways, it would be preferable to dispense with the rounding-off of the bottom of slopes on embankments. That would prevent the disturbance of 200 acres of land in Lancashire alone, and he did not believe that it would ever be noticed once the hedges were planted.

Mr J. E. Cardell said that he wanted first of all to emphasize the usefulness of contours. There was still a tendency among road engineers to think that successful road location was a question of a flair or a gift of God, or solely a matter of personal judgement. He was firmly of the opinion that even when all the information available had been obtained there was still scope for the exercise of all the judgement that any one of them had. That applied particularly to the use of contours. With many plans, the project could not be visualized in relation to the detail of the terrain, but with contours that was possible, and a number of different lines could be tried in order to determine which was the best. It was very difficult to assess the merits or otherwise of road lines without contours and sometimes one suspected that they had been sited by guesswork.

With reference to fitting the road to the landscape and the relation between the horizontal and vertical curves, when Mr Howarth and he had presented their Paper¹⁸ they had suggested that something on the lines of a really large-scale model should be constructed, which would enable the inter-relation of the curves to be properly explored. He still thought that that would be a good thing. Rules had been evolved which were safe and foolproof, but it had never been demonstrated that they were the most economical.

Reference had already been made to the question of hard shoulders. With hard shoulders, were lay-bys really needed? After all, if a car had a burst tire, it could not run any distance to a lay-by but had to stay where it was. The question arose, therefore, of whether or not it would be too costly to widen the hard shoulders; even if a big vehicle could not draw completely clear it might be able to draw partly clear.

If lay-bys were to be incorporated, was it right to have them at the bottom of a hill? That would enable vehicles to coast down to them, but there were several adverse factors. It was often found that the softest

¹⁸ See ref. 1, p. 736.

ground was in the valley and the hardest at the top of a hill. A good view could be obtained from the top of a hill, and lorry drivers often selected stopping points on high ground rather than on low ground. Another factor was that a vehicle might get over-heated through climbing a hill and the driver would want to stop at or near the top to allow the engine to cool. Again, for starting off from cold it was advantageous to have a falling gradient to begin with, rather than a rising gradient to ascend. For those reasons, he suggested that if lay-bys were necessary, hill bottoms should be avoided rather than selected.

He had another point to make concerning the idea of locating major roads alongside railways. He had seen that recommended many times but in his experience he had never found a case where it was a feasible proposition for any length. In difficult country, for example, a point would be reached where the railway line had gone into a slope as far as possible, and if the road was on the up-hill side the proposition was not a practical one, for to cross over it was necessary to make a big swing outward. Various other difficulties arose and he had never found it feasible in practice, but if anyone had done so he would be interested to hear about it.

Mr G. C. Wilson observed that, with regard to soil surveys, the Author had advocated a logical approach employing a preliminary exploration to give general data on the ground conditions existing over a proposed road line. On the whole, his outline of the scope and methods of such an exploration was reasonable, but Mr Wilson doubted if on any major scheme hand auger boring and identification tests alone would ever be sufficient.

Under favourable conditions, geophysical methods could be of great assistance on extended sites such as roads. They were not precise methods, but they enabled an approximate rock profile to be obtained quickly. Since depths down to, say, 50 feet could only be measured to within plus or minus 10 per cent, frequent boring and drilling had also to be carried out if it was necessary to determine accurately the rock surface. The results of a geophysical survey could be used to locate boreholes where they would give most useful information. Such a survey could also indicate if there was any likelihood of rock excavation being required. If so, the possibility should be considered of modifying the vertical alignment so that the rock was avoided and expensive construction operations eliminated. Approximate quantities for rock excavation could also be estimated. It would be uneconomical to explore long lengths of road line for that purpose by borings.

During a site investigation carried out on the Lune Valley section of a proposed motorway in Westmorland, difficulties had been encountered in boring and sampling in soil which contained a very high proportion of large rock fragments. For very shallow exploration it was found best, as the Author had suggested, to use trial pits, but for deeper exploration no such simple solution was found.

The rate of penetration was improved considerably by substituting diamond drilling for percussion boring, but it was a moot point whether or not it was cheaper—to the contractor anyway—because of the high cost of diamond bits. “Undisturbed” sampling in that type of material was virtually impossible, although some satisfactory cores had been obtained where the soil was free from large rock fragments. Tests on such cores, however, did not truly reflect the properties of the soil mass as a whole, even though the laboratory work on the samples gave a fair idea of the limiting values for the different properties for each main soil type. Nevertheless, it should be emphasized that whilst calculations based on such data were useful in the early stages of a project as a guide, the various design problems associated with all important structures and major earth-works should not be resolved without further detailed study of the soil conditions at each position individually.

The Author had mentioned that the preliminary soil survey might suggest that the horizontal alignment of a road should be altered to avoid areas of bad ground. Where re-alignment was out of the question, soil mechanics could offer considerable help in overcoming the engineering difficulties involved in carrying a major road over bad ground. Developments directed towards accelerating settlement and removing soft deposits provided the means for dealing with difficult conditions without changing the route.

Mention should also be made of the value of detailed geological surveys. For example, the characteristics of rocks in situ might exert considerable influence on the designs of cuttings and retaining walls. The information required in that connexion was not normally available from geological publications.

A secondary site investigation should include a study of any geotechnical processes that might be employed, and also a search for evaluation of potential constructional materials such as filling and concrete aggregates. It was encouraging to note that soil-survey drawings were included in the Author's list of contract drawings. Mr Wilson would go even further and recommend that all available soil and other data should be provided with the tender documents so that the contractor had the fullest possible knowledge of site conditions when he was considering his prices. That would undoubtedly lead to more intelligent tendering and keener prices.

In his comments on the treatment of slopes, the Author had mentioned a procedure for estimating the slopes for both embankments and cuttings. Whilst that might be acceptable in so far as it produced pleasing profiles, S should not be assigned an arbitrary value, but should be determined from the results of the soils investigation. Mr Wilson asked if there was any particular reason for the sharp edges being left to the shoulders of embankments and the toes of cuttings. His opinion was that curves at both those positions would be advantageous, especially on embankments where it

was extremely difficult satisfactorily to construct and preserve a sharp edge which would always be susceptible to weathering.

Finally, in view of the Author's reference to the C.B.R. method of pavement design, Mr Wilson asked whether, in fact, that method had been adopted and endorsed by the Ministry of Transport, for use on such schemes as the Lune Valley motorway.

Mr H. S. Andrew suggested that if the Author had in any way failed, it was perhaps in not starting with a definition of the aim and purpose of motorways. It was not known what sorts of traffic were being catered for, or at what speed it was intended to move the traffic from place to place.

Mr Andrew felt that a great deal of harm might be done to motorways when the time came to construct them if not enough boldness were shown in constructing a reasonable length of motorway connecting two big centres of traffic.

Personally, he would like to see a road constructed from London to Birmingham, or from the outskirts of London to the outskirts of Birmingham, the ideal being a road on which specially designed heavy goods vehicles with trailers could move with safety between the outskirts of the two cities at a speed which would enable the driver to take a train of vehicles there and back during an ordinary working day. The road conditions, the curves, and the gradients should be such that the driver would be able to move at a uniform speed, so that his average speed would approximate very closely to his normal cruising speed.

That was possible over country of that nature, but it would not be possible in the Lune Valley. Different standards would have to be adopted for different parts of Great Britain. If a road of that nature could be built and put into operation, the response of public opinion, of the transport industry, and of industry generally would be such that the remainder of the motorway problem would probably be solved without difficulty. If bits of motorways were built here and there the real benefits to be derived would be lost.

The Author had suggested that it might be necessary to open a motorway with a single carriageway of 22 feet. Mr Andrew appreciated that that might appear necessary under present conditions, but he believed that no greater dis-service could be done to the cause of motorways in Britain than by opening a road of that nature. He did not know any details of Mr Samuel's 40-foot carriageway turned into two 22-foot lanes, which was said to have caused an increase in accidents, but he felt that on a motorway with, presumably, no right-hand turning traffic, there could be no doubt that the twin carriageway would be safer than the other method. He was sorry to see that twin 22-foot lanes were the maximum that could be asked for, but he suggested that, if possible, land should be acquired and the lay-out on many sections of the roads prepared so that twin 30-foot lanes could be adopted. He was not suggesting that the volume

of traffic would immediately require twin 30-foot tracks from London to Birmingham, but the varying speeds of vehicles on the road might be such that those lanes would be required.

To return to the question of lay-bys, had they the right conception of a motorway? Was it a place where a man would be allowed to stop and admire the scenery? Previous speakers had mentioned acceleration and deceleration lanes at junctions, which were obviously necessary, and the Author had suggested, Britain being a small, densely-populated country, that the spacing of junctions would range from 5 miles to 1 mile. Surely any lay-by which was needed should be located somewhere where those lanes would enable him to get into it, and any stop between them should be a matter for police inquiry. It should only be an emergency stop which would permit a driver to pull-in on the hardstanding.

Mr Andrew said that he would like to see a hard shoulder on the central reservation. It would be far more useful there to the overtaking vehicle than it would be on the inner channel to the vehicle being overtaken.

Reference to land severance had been made by Colonel Bennett. The only hope was to find a motorway enthusiast with a good knowledge of agriculture. It was no good finding an agriculturist with a slight knowledge of motorways!

Colonel Sydney Green observed that it was stated in the Paper that motorways were expensive to construct and that full justification for them would be necessary. Traffic volumes, journey times, and safety were factors in that. In a Paper¹⁹ published in 1937, the point had been made that a bird's-eye view of the traffic on the roads of Great Britain would reveal that the principal roads in country areas would be sparsely trafficked and in the great cities congestion would be observed.

From a recent Paper²⁰ on "Roads in Europe" it appeared that France had taken the same viewpoint, and their programme of motorways had started outwards from the great cities, as instanced by the rather lovely motorway to the west which started at St Cloud, near Paris, and did not go farther than 20 miles from the city.

In his "Preliminary Considerations," the Author had mentioned that the bulk of traffic moved between centres of population. It was known what he meant, but perhaps it could be more clearly expressed. In fact, the bulk of traffic moved within centres of population, and the distribution of the traffic converging on large cities was a very big problem indeed. The confluence of the roads in London as shown in *Fig. 1* was an example. There were twenty-nine principal roads at a 15-mile radius from the centre of London, of which the six shown in *Fig. 1* formed part. It was not generally known that about two-thirds of London's traffic was generated inside a 15-mile radius. At a 25-mile radius, only a quarter of the traffic

¹⁹ S. Green and A. C. Kain, "The Flow and Distribution of Traffic along Highways." *Surveyor*, vol. 92, p. 35 (9 July, 1937).

²⁰ M. de Bussy, "Roads in Europe." *Instn Highway Engrs*, 1953.

came from outside. The whole point was that the sting of a journey was often in the tail. One could travel by plane from Paris to London in an hour and a half, only to be faced with a 40-minute journey for the 13 miles from the airport to the heart of London—which included 2 minutes for negotiating the congested intersections at Hammersmith Broadway.

Traffic volumes on roads linking cities might range from 2,000 vehicles per day to 16,000 vehicles per day, and it might well be that more striking economic justification could be shown, taking into consideration traffic volumes, journey time, and safety, for the improvement of, say, the last 10 miles of a road than for the whole of the 90 miles which preceded it.

It was stated in the Paper that a considerable volume of commercial vehicles could be expected on the motorways, so that the range of speeds might lie between 20 and 70 miles per hour. In those conditions, with that speed range and the consequent desire to overtake, he was sure the Author's safe capacity for the dual two-lane motorway (4,000 vehicles per hour) was much too high if reasonable speeds were to be achieved.

It was perhaps a good opportunity to mention the valuable Paper by Mr Wardrop on "Some Theroetical Aspects of Road Research,"²¹ in which he had given a practical example from a study of east-bound traffic on Western Avenue, Middlesex. That traffic flow of 450 vehicles per hour had a speed range of 2 to 61 miles per hour, and the calculated density of desired overtakings was 1,090 per mile per hour. Since the number of desired overtakings increased as the square of the traffic flow, it was easy to see that with a traffic flow of 2,000 vehicles per hour (the Author's capacity for two lanes in the same direction) and allowing for a speed range of 20–70 miles per hour, the desired overtakings would be very high. The actual overtakings would, however, be low, and the two lanes would become a procession, taking on the speed of the vehicle in front.

On p. 719, the Author had mentioned a motorway with a single two-lane two-way carriageway. Colonel Green hoped that they would be spared that, because the safe capacity of a motorway with two 11-foot lanes, having regard to the mixed traffic and the incidence of overtaking, would be extremely limited.

With regard to lay-bys for drivers' meals and rest periods, he agreed with Mr Andrew. In view of the experience gained of the amenities which drivers desired for those purposes—and they were fairly extensive—Colonel Green felt that it would be preferable to make such arrangements off the motorway, perhaps near a convenient junction.

Mr R. E. Rolt Hammond said that he did not agree with the idea of very long straights of, say, 20 miles. He understood that in the United States it had been found that drivers were apt to go to sleep, or something of that sort, on long straights, and curves had been introduced to keep them awake.

²¹ Proc. Instn Civ. Engrs, Part II, vol. 1, p. 325 (June 1952).

Motor vehicles ranged from the very heavy road trains which were at present being developed to travel at 40-50 miles per hour to super sports cars which could travel at 100 miles per hour or more. In view of those possible speeds, Mr Rolt Hammond felt that the roads should be designed so that drivers could "go all out" and get from place to place quickly.

The Chairman said he was a great believer in motor-roads. He wished to underline what Mr Andrew had said. He hoped that no one would hurry into the making of the first motor-road until everything was so arranged that a result could be given which would make the public believe in motor-roads.

He was not at all sure that an important factor ought not to be a lower-speed limit. It would not do to have the motorways patronized by the dear old lady out for an hour's spin in the country. The roads were designed to get traffic moving and get it out of the way.

**** Mr A. J. H. Clayton** observed that the Author had dealt on pp. 724 and 725 with the question of "design speed." As he had rightly pointed out, although cars were capable of speeds in excess of 100 miles per hour, the probability was that the most common speed would be between 45 and 50 miles per hour. That being so, it had to be considered whether a "design speed" could in fact be adopted, and if so, what the expression meant. If the road was designed to be ideal for vehicles travelling at 70 miles per hour, it might be unsuitable for the majority of vehicles. It seemed that the road should in fact be designed for a wide range of speeds, on the principle of "the greatest good to the greatest number." It was already the practice to use a degree of superelevation considerably less than that ideal for the "design speed," but transition curves were commonly made longer than really necessary. Would it not be more suitable to design the road to be as near as possible ideal for, say, 50 miles per hour and check the design for higher speeds to see that they were not positively unsafe?

The Author, in reply, said that Mr Samuel had mentioned the leeway to be made up in the maintenance and improvement of existing roads. All highway authorities probably had schemes which they were anxious to complete and he fancied such schemes would come before any great start on the motorways.

On the question whether a wide single carriageway was better than dual carriageways, Mr Samuel and the Author had had many arguments and there was a good deal to be said for and against each system. The segregation of opposing streams of traffic had obvious advantages but might give rise to a different form of accident. For instance, a car overtaking in the second lane of a uni-directional carriageway had little space for manoeuvre if a vehicle in the first lane swerved to the right. A common cause of such movement was a cyclist on the near side, but in the case of motorways there

****** This contribution was submitted in writing upon the closure of the oral discussion.—**SEC. I.C.E.**

would not be any cyclists nor would there be any right-turning traffic, which was also a frequent cause of accidents.

Another point, when considering economy, was that a single carriageway required a horizontal sight distance of 1,200 feet, as against 650 feet on a dual-carriageway road.

On the whole, the Author re-affirmed his view that motorways should be constructed with dual carriageways but agreed that an investigation into the relative accident rates and carrying capacity of the various types of lay-out would be of great value.

Colonel Bennett had referred to the fact that land was always regarded as "the best agricultural land." The Author had also come across that phenomenon; the exception was where an exchange of land was suggested—when the land offered never seemed to have any value at all. He had tried to put both sides of the agricultural land problem in order to get matters into their true perspective, and came to the general conclusion that motorways were necessary but had to be constructed with strict regard to economy in both money and the use of land.

Colonel Bennett and Mr Drake had questioned the value of rounding the slopes of cuttings and embankments. That was mainly an amenity feature and unless it was to be seen and did some real good there was no point in the extra expense. It had been mentioned on p. 731 that slopes could often be used for the grazing of cattle, with boundary stones as required along the slope.

Mr Lovell had asked about the five specifications which the Ministry of Transport had issued at one time. They had not been mentioned in the Paper because they were a general topic and not peculiar to motorways. One had a broken-stone type of foundation consisting of two 4½-inch layers of broken stone with a regulating course of 3 inches, making 12 inches altogether, plus "black top" surfacing. There were also the ordinary pitched foundation, concrete—both reinforced and not reinforced, and a stabilized-soil foundation. All had "black top" surfacing except the reinforced-concrete specification and the thickness of the foundation was related to the C.B.R. value of the formation. The broken-stone type was thought most likely to be suitable in the Lune Valley.

The Author agreed with Mr Drake that the choice of the first lengths of motorway was of the very greatest importance. Being a Lancastrian, he appreciated Mr Drake's point about the conditions in Preston and Lancaster. Both were towns taking a great deal of through traffic and they were also the focal points for several very attractive seaside resorts.

It had been suggested that flowing alignments need not, perhaps, be followed all the time, but he believed that it was worth while trying to co-ordinate the horizontal and vertical curves. It need not be carried quite so far as had been suggested in the past, certainly not to the point of making the construction very much more expensive, but subject to that it was something well worth doing. Mr Drake had shown some attractive pictures

of his model, and the model displayed in the Lecture Theatre had been constructed in a similar way. Although the idea was the same, Mr Drake's model was a bigger and better one, since he probably knew how to get money out of the Ministry better than the Author.

Mr Cardell had mentioned the value of contours, and the Author heartily agreed with him. It was true that lay-bys in the lowest positions might be on bad ground in some cases but not always, for one would seek to avoid the bad ground. He agreed that a better view was generally obtainable from high ground, and he had given that as one of the factors leading to the choice of a suitable site.

The question of widening the hard shoulders so that a vehicle could draw right off the carriageway had been mentioned also by Mr Lovell. They were not intended primarily as a substitute for lay-bys, although they could be used by a vehicle to draw partially clear of the carriageways in an emergency. Perhaps the most useful attribute of the hard shoulders was the confidence they would give drivers to keep in to the near side without fear of hitting a soft patch as the result of a slight error. For other than emergency stops, either Mr Andrew had the right idea when he suggested they should not be allowed on the motorway at all or they should be constructed at the carefully chosen sites of lay-bys. The latter would have adequate width, foundations strong enough for heavy standing loads and properly designed entrances and exits.

With reference to the remarks by Mr Wilson, the soil found in the Lune Valley was heavy boulder clay with many large stones, so that hand auguring was not very practical. He agreed with Mr Wilson about the usefulness of geophysical surveys for road location work and also with his suggestion that the fullest possible information on soil data should be made available to contractors tendering for a job.

Mr Wilson had asked why the edges on the shoulders of embankments and the toes of cuttings were not rounded. In practice they would not be so sharp as shown on the drawings but any pronounced and deliberate rounding as advocated for the tops of cuttings and the toes of embankments would reduce the effective width of the side verges. The Ministry of Transport had endorsed the California-Bearing-Ratio method of design and had adopted it for the design of motorways.

Mr Andrew had asked for a definition of the aim and purpose of motorways, the sort of traffic to be catered for, and the speed at which it would move from place to place. The object of the proposed system was to facilitate the flow of traffic between the main centres of population with greater safety and at a reasonable speed.

Under the Special Roads Act, the type of traffic which might use a special road—and it need not necessarily be a motorway—could be defined. In the case of motorways, the Author was of the opinion that all forms of motor traffic, including the heavier commercial vehicles, would have to be catered for if the roads were to develop their full economic value. Although

the design speed recommended was 70 miles per hour, that did not mean that all traffic would travel at that speed. It was intended that the bulk of traffic should travel at perhaps 40 miles per hour, keeping up a good even flow at around that speed. This was very much in line with Mr Andrew's views.

Mr Andrew had said he was sorry that twin 22-foot lanes were the maximum to be allowed. But that was not quite what the Author had said and he agreed there would be a few cases in which dual 30-foot lanes might be required. The capacity of the dual two-lane carriageways designed to free-flow principles would be very high indeed. For an ordinary all-purpose road the Ministry of Transport's Memorandum 653 gave the capacity of a dual two-lane carriageway as 15,000 vehicles per day or 1,500 per hour, and it was clear that with restriction of access, no standing vehicles, and no right-turning traffic, the figure would be very much higher than that. There were not many roads except in the big cities (which were outside the scope of the Paper) taking traffic of that volume.

Colonel Green had mentioned the traffic around London. The Author had looked up the average traffic on trunk roads within 25 miles of London, excluding the Metropolitan area, and found it to be about 10,000 vehicles per day. On the trunk roads of Britain generally, in the open country and again excluding the big towns, the average volume of traffic was about 5,000 vehicles per day. If one allowed for the attraction of a motorway and made generous allowance for a future increase of traffic, it seemed very probable that dual two-lane carriageways would provide ample capacity for many miles of the proposed motorway system.

Colonel Green had also drawn attention to the concentration of traffic within the big cities, especially London, and posed the interesting question whether or not it would be better to construct short but expensive roads to speed the flow of that traffic before embarking upon longer lengths between the towns. The Paper dealt essentially with the design of new motorways in more or less open country and was not intended to cover internal traffic problems, where so much depended on local factors other than the basic design of a highway.

With regard to the capacity of the traffic lanes, a maximum of about 2,000 vehicles per hour per lane had been accommodated under the conditions mentioned in the Paper. To allow for a higher percentage of slower vehicles, the Author had reduced that by half and was of the opinion that 1,000 vehicles per hour was a reasonable figure. Such volumes were not likely to be encountered on the majority of motorways, except at peak periods, when the faster drivers would have to conform more closely to the average speed.

Mr Rolt Hammond was against the very long straights advocated by Colonel Bennett. It was true they tended to monotony, but the number to be found in Great Britain would be so small that any good opportunity

should be taken. There was something quite exhilarating about being able to open the throttle with safety once in a while.

The Author agreed with Mr Clayton that the most common speed might be between 45 and 50 miles per hour. If anything, he thought the average might be a little lower, but he did not agree that the road would be any less suitable for vehicles travelling at that speed. As Mr Clayton realized, the superelevation was near the ideal at such speeds, since very little frictional force between the tires and the road surface was required to build up the necessary centripetal force. It would be misleading, however, to say the road was designed for that speed when, in fact, with modern surfacing it would be perfectly safe for very much higher speeds.

Correspondence

Mr J. J. Leeming commented on the Author's statement in connexion with transition curves, that experiments had shown that "a value of 2 feet per second³ for C [the rate of change of radial acceleration] does not cause any great discomfort to driver or passenger in a car." Mr Leeming stated that, so far as he knew, his experiments were the only ones ever carried out on curvature and comfort, and, as a description of them, that was hardly adequate. The experiments had shown that very much higher values of the rate of change of lateral acceleration Q did not cause any discomfort at all. It did appear that within the practical range, Q had no effect on comfort whatever. C was a purely theoretical quantity, without meaning for practical purposes, and should be abandoned, since it merely added complication.

The function of a transition was to enable superelevation to be brought on, and to improve the appearance of a curve. Its length was a matter of small importance provided it was neither too short nor too long. The combined length of the two transitions should never much exceed three-quarters of the length of the curve under any circumstances. The effect of doing so was merely to sharpen the curve without reducing the value of C to any material extent. The lengths given in Table 1 of the Paper for the sharper curves were unnecessarily long—the inevitable result if any fixed value of C was used. There was little object in having transitions much longer than about 300 feet, and they should not be shorter than 100 feet with the minimum superelevation gradient of 1 in 100. If there was no superelevation a transition was unnecessary, unless for the sake of appearance.

Mr Leeming concluded that in treating the slopes of cuttings, it might be a better rule to make variable slopes where possible. Any bank of constant slope produced a hard line and looked conspicuous, whereas a variable slope blended more happily into the landscape.

The Author, in reply, regretted that it had not been possible to make