The mixing of the flux oil into the bitumen is carried out as follows: The bitumen should be broken into small lumps and weighed. The weighed quantity of bitumen is then placed in a suitable heater (e.g. Johnston Heater, Midget Boiler, or similar) and heated until it is molten (between 200° and 250° F.). During heating the bitumen should be well stirred.

When the whole of the bitumen in the heater is in a molten state the flux oil should be added slowly in the above proportions.

After adding the flux oil the whole should be well stirred to ensure thorough mixing, after which the compound is ready for use or for storing for future reheating, as required.

Under no circumstances should the materials be heated to more than 350° F.

It will be found that the mixed material can be poured readily at temperatures of between 200° and 300° F.

Treatment of the Joints before Resealing.

Cleaning.—The joints should be raked out clean and free of all old bitumen and grit down to the top of the original expansion jointing material. If this is solid bitumen or cork-filled bitumen, as much of this as possible should be removed. After the joint has been raked out it should be brushed clean with a hard brush.

Filling.—If the open depth of the joint after cleaning is greater than 1 inch from the surface, the joint should be filled to within 1 inch, using a non-extruding compressible material such as sawdust, hemp, chopped fibre-board, or other available fibrous material, which should be rammed well into the joint.

Priming.—Before pouring the sealing compound, the sides of the joint should be painted with a thin bituminous primer; this should consist of 66 per cent. 200-pen. bitumen fluxed with 14 per cent. creosote oil and 20 per cent. solvent naphtha. The faces of the concrete should be dry before priming.

Sealing the joint.—After the joints have been prepared as above, and after the primer has dried, the mixed sealing compound should be heated to approximately 250° F. and poured into the joints from a suitable pourer; an ordinary watering-can is suitable for this purpose. In warm weather the sealing compound should be poured to the level of the top of the concrete and in cool weather it should be kept slightly low.

Where filling transverse joints on a camber it will be found more convenient to commence pouring at the lower end, to prevent the material flowing along the joint.

Discussion.

Mr. R. M. Finch, in introducing Part I, said that after the 1914–18 war it would have been desirable to employ as much labour as possible, to the entire exclusion of machinery. Now, however, circumstances were very different and economy of labour was essential; but engineers were still reluctant to use machines in towns. Transportation of men and materials was a problem to the county surveyor, but the city surveyor usually had everything readily available, except that he might be in the hands of contractors with regard to the delivery of some material.

The best use was not being made of research departments; in many towns, experiments were being carried out with devices which had already been proved to be useless. Insufficient use was made of overtime and Sunday work, particularly in towns. In relatively large towns the streets were crowded during the day-time, and in Nottingham Mr. Finch had

made it a rule that no major operation in road maintenance should be carried out during ordinary working hours. That would have been regarded as an extravagance some years ago, but with mechanization it could be a real economy, since the higher cost of labour on Saturday afternoons and Sundays became of little account when machines were used.

The considerable over-expenditure in the comparison of estimates and expenditure given in Appendix I of the Paper might need explanation. Expensive asphalt works were more appropriately carried out in the summer months, and he rather welcomed the sight of a little over-expenditure about November, knowing that some of the less expensive work would be carried out during the winter months.

He suggested that any department with about 250 employees could usefully employ an accounting machine of a certain type. For a department with 2,000 employees, more elaborate machines were available. In the case of departments with 3,000 employees, the punched-card system could be very effective. He took considerable interest in the personnel of his department, and he attributed as much credit to that as to mechanization for the very low costs of highway maintenance in the city. That absenteeism had been reduced from $3\frac{1}{4}$ per cent. to about $\frac{1}{4}$ per cent. was due mainly to the encouragement of the Employees' Committee, mentioned in the Paper. That scheme, which had been in operation for 2 or 3 years, had now developed to such an extent that the men came to him with suggestions for improving the work of the department and increasing its efficiency.

Mr. R. R. W. Grigson introduced Part II with the aid of a series of lantern-slides.

Mr. Stanley Mehew observed that whilst a welfare organization, as described by Mr. Finch, would be beneficial for County Council roadmen, it would be exceedingly difficult to operate on a County basis, because of the very wide area over which the men were scattered.

Mr. Grigson had referred to the advantages of mobile gangs in comparison with isolated lengthsmen. In Mr. Mehew's own experience a change-over to mobile-gang organization had been disappointing, the primary reasons being the present scarcity of roadmen involving difficulty and waste of time in collection and transport.

Mechanized road-sweeping and collection offered a tremendous field for replacing manual labour on County roads, and he would welcome further information about it.

A difficult problem in connexion with mechanized surface dressing was the junction between adjacent widths covered by the machine. No matter how well designed the machine, the success of the job at those vulnerable joints depended on the skill of the operator. Had Mr. Grigson had any experience of the use of skimmer scoops for loading aggregate? Mr. Mehew believed that they would be less likely than the grab to pick up dirt when the stock-pile was getting low. His experience had been that

fully mechanized methods of surface dressing at least doubled the output per man-day. In Derbyshire that represented the considerable saving in the season of at least 5,000 man-days as compared with semi-mechanized process.

There was a need for low-loading transporters, particularly for such work as fully mechanized tar-spraying, and he hoped that it would be found possible to make use of the Council-owned Mack tractors, of which there were many in the country.

In connexion with the use of gully emptiers, he thought that Mr. Grigson's figure of 100 gullies per day was rather conservative. He had found that the machines under his control were dealing with from 130 to 140 gullies per day.

For efficiency, mechanization required to be applied over fairly large areas so far as County work was concerned: the old conception of comparatively small County road-districts was unsatisfactory when the work was fully mechanized.

Mr. John Carr said that he was concerned with a metropolitan borough with a population of nearly 250,000, about 200 miles of roads, and an area of about 7,000 acres.

He was not clear whether the highway maintenance figures given in *Fig. 1* included cleansing as well as repairs. In Mr. Carr's own district, highway cleansing had cost £22,000 per annum before the last war, and now cost about £41,000 per annum for a slightly better service. The cost of highway repairs had risen from about £60,000 per annum before the war, to £156,000, largely because the borough had been badly damaged during the war and highway repairs had had to be neglected to a great extent, leaving a good deal of leeway to make up, whilst much work was still to be done in replacing wood blocks. Most of the residential streets in the borough were water-bound and attention to them was now essential.

In the years before the war, as Mr. Finch had said, the emphasis had been on employing labour. At that time, Mr. Carr had concluded that it would be difficult and not worth while to use a machine for street sweeping. Now, however, he had begun to use a sweeper-collector, and he hoped to expand its efforts to the maximum, although some of the work would always have to be done by hand. He had found that a towed sweeper or a sweeper mounted on a lorry, which did not collect, was quite useful after the winter to remove the grit resulting from gritting the roads in frosty weather or in light snow.

He agreed that the distribution of work over the year was very important. In his own case, he did not provide for snow-clearing in the annual estimates. If the winter were a mild one, useful work was done: if otherwise, all the men were brought into an organization for snow-clearing, avoiding the necessity for casual labour. Therefore, although the distribution of the work was altered, the same amount of money was spent covering either snow-clearing or useful work.

Surface dressing was a very important matter, but Mr. Carr considered that authorities and manufacturers were still not taking a sufficiently urgent view of it. For instance, it often happened that a spray nozzle stopped working and the fault was not discovered until much later, when a strip of road became denuded of chippings. Manufacturers could perhaps design a tell-tale similar to the device used on a petrol-pump, which would enable the operator to see at a glance whether all his jets were working.

He also suggested that a mixture of cement and tar or sand and tar should be projected on to the road by some kind of tar-gun, on the same principle as a cement gun, and the chippings then spread and rolled in ; by that means the chippings would be physically held in place much more securely than by a film of tar only. Tar cost about 10½*d.* per gallon, and a 10-per-cent. cement/tar or sand/tar mixture would cost about 6½*d.* or 2*d.* per gallon respectively.

It was not always advantageous to use machines for surfacing work ; in his own borough many of the residential roads needed only about ¼ inch of asphaltic covering to make them fit for 10–20 years' further use, and a machine would probably lay more than was necessary. In view of the urgent need for conserving materials, that risk should not be run.

He agreed in general with Mr. Finch's contention that it was a good plan to keep a machine working full time, but considered that the importance of that could be exaggerated, for if it were not working it would not be wearing out. Machinery was subject to fatigue and should be overhauled periodically. If, however, the machinery was hired, it was obviously desirable to obtain full use from it.

He was surprised that Mr. Grigson had omitted the metropolitan boroughs from the list of highway authorities given in the Paper. A metropolitan borough was surely a 100-per-cent. highway authority.

Mr. Grigson had stated that grouting methods were not particularly good, and although Mr. Carr agreed to a certain extent, he had treated several old roads during the war by scarifying, regulating, and grouting with tar, and they were still nearly as good as they were when the work was done. Before the war a large quantity of material had been disposed of by tipping which might have been re-used if some such device as grouting had been adopted. Those spacious times were past and nothing should now be wasted.

Mr. B. F. J. Bradbeer observed that it was interesting to note, from the figures given by Mr. Grigson, that such a simple operation as grass-cutting could be very much improved and that great savings could be effected. In most counties from 3,000 to 6,000 miles of roadside verge had to be attended to ; expenditure on grass-cutting alone in the English counties amounted to about £1,500,000 per year. In East Sussex cutting had tended to be postponed for so long, because of the shortage of labour, that the grass had become matted and coarse, and machines of normal design

were unable to cope with it efficiently. The smaller machines, for instance, were geared so that the rate of cut of the blade depended on the rate of forward travel, and when the work was postponed until late in the season those machines were inadequate to deal with it. Greater success had been achieved with horse-drawn machines having cutter-blades driven by an independent motor, the speed of which could be regulated. It had been found difficult to use the tractor-drawn machine, as illustrated in *Fig. 32*, since a telephone insulator or a stone in the verge was sufficient to wreck the machine, and the driver was not in a position to see the danger in time. The type of tractor on which the scythe was alongside of and fully visible to the driver was very much preferable. A safety device was fitted on some American machines which caused the blade to swing back if an obstruction was encountered.

Jointing of concrete used to be the responsibility of the lengthsmen, and it had become obvious that their methods were extremely crude and much of their work was wasted. In East Sussex a 25-gallon oil-fired cauldron, with temperature-control and a stirring device, was operated by a gang of three men and, used in conjunction with a paraffin flame-gun, had expedited that work considerably. The flame-gun softened the old material in the joints, so that they could be thoroughly cleared out, and in wet weather it was employed in drying out the joints. With that simple equipment three men could cover nearly $\frac{1}{4}$ mile of two-lane road per day, at a cost of about £50 per mile and with a considerable saving in materials.

A word of warning should be given regarding the application of concrete haunches on subsoils which contained a high percentage of clay and had a liquid limit of 60 per cent. or more, as was sometimes the case in East Sussex. In those circumstances a narrow haunch construction might be unwise, since it was at the junction, where there was no physical bond between the edge of the concrete and the old carriageway, that some of the heaviest wear and tear took place from the inner wheels of heavily-loaded vehicles.

Dr. B. H. Knight said that he wished to ask three questions. The first was about the physical properties of the aggregates used in tar and bituminous surfacings, described on pp. 16 and 19. Mr. Grigson had dealt with binders in some detail, and had mentioned the gradings required of aggregates, but nothing had been said about the toughness, hardness, and other features of the stones used. According to the Paper, the gradings given would apply equally well either to steel shot or to chalk ; he was sure that Mr. Grigson had not intended to convey such a meaning.

His second question arose from the reference on p. 19 to foundation failures. Did Mr. Grigson use any method of determining the bearing power of doubtful foundations ? If so, what method did he use ?

The third question related to the patching of concrete roads with new concrete. In describing his lantern-slides, Mr. Grigson had stated that the failure of certain stretches of concrete roads was due to too high a water/

cement ratio in the original concrete, whilst the patches of new concrete on those faulty lengths had a low water/cement ratio. It was difficult to bond new concrete to old and Dr. Knight had always thought that that was due largely to the contraction of the new concrete on setting. Had the Author had any subsequent trouble with those patched sections due to scaling or disintegration of the patches ?

Mr. J. McCarthy Lee stated that he did not wish to decry the use of the Barber-Greene machine in its proper sphere, but there were times when that machine in its present form did not meet the needs. On roads only 18 feet wide, or narrower, which had either kerbs or raised margins, it was impossible to use the Barber-Greene machine to lay tar macadam in two strips, the only solution being to operate the machine in the middle of the road, with all its extensions fitted, and to spill out at the sides so that the whole width was covered ; but that method had the disadvantage that the road was completely occupied. A machine similar to the Barber-Greene, but only 7 or 8 feet wide, would be more useful on narrow roads.

Perhaps other methods of spreading tar macadam or stone on roads could be devised. Reference was made in the Paper to blade graders ; he had tried them, but had obtained poorer results than with the Barber-Greene machine.

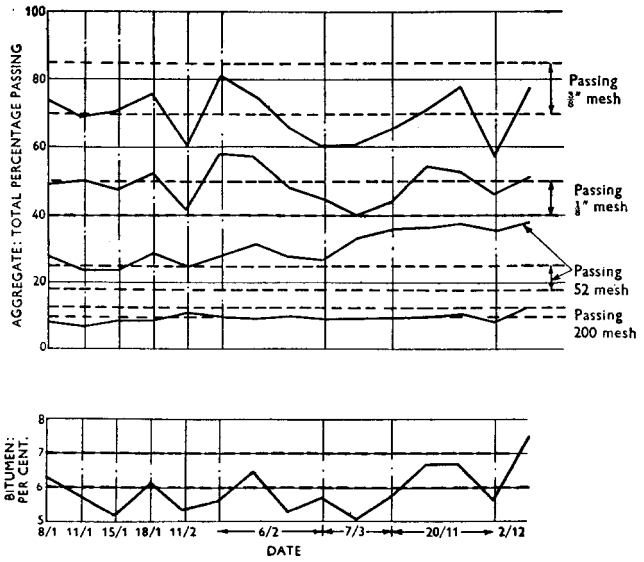
How long was required to load a lorry with a mobile crane ? Mr. Lee imagined that plant of that type would leave the site in a bad condition and that there might be considerable loss of material. The Chaseside shovel-type of plant was a very clean worker ; it could be used on margins, provided that they were reasonably dry, and it did not require any additional labour.

Two pieces of plant used in East Sussex were not mentioned in the Paper. One was used in connexion with scarifying. In any attempt to scarify a tar macadam road, particularly in the winter, even with one tine, a steamroller would be brought to a standstill ; Experiments had been made, however, with a tractor of 110 horse-power, weighing about 15 tons and having an arrangement on the back very similar to the U-shaped apparatus which operated the blade when the tractor was used as a bull-dozer, with the attachment of a bar holding nine scarifying tines. A similar apparatus had successfully scarified a tar macadam road, using all the tines at once for a width equal to that of the tractor. Experiment had first been made with the American apparatus known as a " rooter," which, unfortunately, repeatedly pulled out of the road. The apparatus was now arranged so that the arm was controlled hydraulically and more than one-half the weight of the tractor could be transferred to the tines. After the scarifying operation, the tractor was run up and down the road over the lumps of tar macadam, cracking them up after passing over them four or five times into the original stones of the macadam. The material could then be shaped to the desired camber with a blade grader, the American type of Auto-Patrol being used for that purpose. On one job on which

those two types of plant had been used in combination, the cost in man-hours had been reduced by 60 per cent.

It had always been difficult to excavate the narrow margins at the sides of roads for widening purposes; an unevenly shaped piece of margin had usually to be dug out. The machine used in Gloucestershire was not available to other counties, and in East Sussex another machine had been devised, consisting of an ordinary tractor such as was used for cultivation purposes, with spring-loaded tines attached to the back of it, two in line and one to the rear of them, the one at the back having a broad-arrow-

Figs 34.



PROGRESS OF AGGREGATE GRADING AND BITUMEN CONTENT COMPARED WITH SPECIFIED LIMITS.

shaped head. The tines were pulled through the ground, with the effect of loosening it. In East Sussex, tractors were used which had an ingenious hydraulic device whereby attached apparatus could be raised or lowered 2 feet by means of a lever. The use of those tractors had resulted in a saving of labour of between 50 and 60 per cent., since the earth had only to be shovelled instead of being dug.

Mr. D. B. Waters said that Mr. Grigson had stressed the need for control in the use of hot asphalt. Mr. Waters feared, however, that too much enforcement in that matter would defeat its own ends, since engineers and others would tend to become fogged by too many figures.

Figs 34 showed one way of making analysis results intelligible. At the beginning of a job the engineer divided his specification and repre-

sented his limits of grading by a series of pairs of broken lines. For example, the two top broken lines showed that in the specification the amount of material passing a $\frac{3}{8}$-inch mesh must lie between 70 and 84 per cent. The horizontal axes of the graphs represented the progress of the job, so that it could be seen how the composition progressed with time. In the case in question the idea had not been applied until the job was finished, so that the compositions did not increasingly improve ; but if the scheme were adopted, the engineer and contractor might collaborate to improve the composition until the curves lay between their proper limits. *Figs 34* extended the graphical system to bitumen-content also. He would like to know whether Mr. Grigson thought that such a chart was practicable.

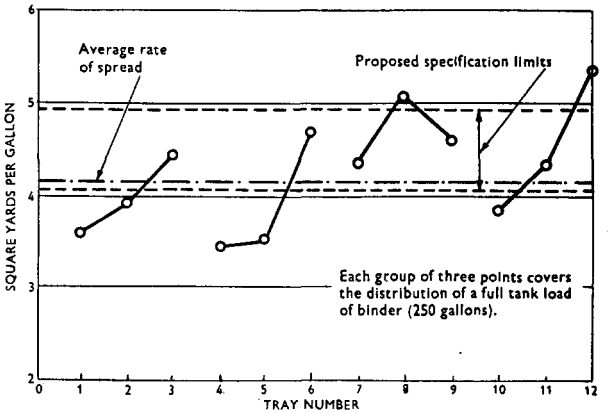
With reference to Fig. 8, Plate 1, he thought the figures would be overall average figures for surface-dressing work. Many of them appeared to show a very wide variation and, since the maximum variation would be very much greater, the situation was rather unsatisfactory. Some similar investigations had been made at the Road Research Laboratory, and similar variations had been found. One gang had done rather a poor job, the variation in that case being from 4·7 to 7 square yards per gallon on a specification of 4·5 square yards per gallon. When the object of the job had been fully impressed upon the same men they had made a further attempt and, using the same machine, had completed most of their work to within 10 per cent. of the specification.

Mr. Waters suggested that engineers should ensure that the men working tank sprayers knew what they were doing, and that all binder sprayers should have accurate low-speed speedometers ; those could be contrived fairly easily if they could not be bought. There should also be some simple test by which everybody concerned with the job could know the accuracy with which the work was being done. The Road Research Laboratory had developed a simple test in which metal trays, 8 inches square, with a lip of $\frac{1}{8}$ inch, were placed on the road in front of the distributor. After the distributor had passed they were weighed with the tar which had collected on them. The variation in rate of spread throughout the job could easily be followed by that means.

Fig. 35 was a graphical representation of four runs with a small flapper-type distributor. The specification had called for 4·5 square yards per gallon, and the operator had been given a tolerance of 10 per cent. The operator had seemed satisfied with his average of 4·2 square yards per gallon, but *Fig. 35* indicates that the results were not satisfactory. The distribution depended on the free head of liquid in the boiler ; when the boiler was full the liquid came out quickly and gave a thick film, but as the boiler emptied the film became progressively thinner. The operator could not know that, and Mr. Waters considered that that justified the adoption of the tray test, the results of which should be discussed quite frankly with the operator.

Both Authors had said that the Barber-Greene machine laid at the rate of 300 tons per day. Mr. Waters knew that it could do that and probably more but, in his own experience, the governing factors were always such that that figure was not attained. He thought that figures quoted for the Barber-Greene machine were often rather picturesque.

Fig. 35.



VARIATION IN RATE OF SPREAD OF BINDER. TRAY TEST.

Mr. E. L. Harber said that he fully agreed with Mr. Finch that the supplier of coating material should also be responsible for laying it.

He also considered that the aggregate control largely determined the quality of the surface obtained. He had known of 1-inch stone being specified for a thick carpet, but, owing to the fracture of the stone, some pieces which were actually $1\frac{1}{2}$ inch long had passed a 1-inch screen, and it was rather difficult to compact a $1\frac{1}{2}$-inch stone into a $1\frac{1}{4}$-inch finished thickness of carpet.

Mr. Grigson had said that Barber-Greene work became cheaper than hand work when the quantity laid exceeded about 80 tons per day. Mr. Harber's firm had always worked on a figure of about 130–150 tons for base coat, but if Mr. Grigson could assure him that the figure given in the Paper was fairly accurate his firm would revise their statement, because it would be to their advantage to do so. With regard to the production of a smaller Barber-Greene machine, to which reference had been made by Mr. McCarthy Lee, he could state that experiments were being carried out in that direction.

Dr. A. R. Lee said that it was interesting to note that the cost of maintaining highways and bridges in Nottingham was given as about £75,000, whilst the cost of cleansing services was about £130,000. Could Mr. Finch give the proportionate costs of labour? For the upkeep of the constructional

work Mr. Finch had said that the labour cost was negligible and he appeared to be in agreement with Mr. Grigson on that point, since from the figures given in *Fig. 15* for the cost of surfacing it would seem that the labour cost represented only about 3 per cent.

On p. 7 Mr. Finch had stated that, in order to develop an economic system of working, it had been necessary for him to make a survey of his streets, to enable an estimate to be prepared of the life of each street. It would be very interesting to know whether he had by that means acquired data which would indicate the life of a particular type of surfacing under various conditions of traffic. The Road Research Laboratory was trying to collect such data from various engineers, and perhaps Mr. Finch could help in that connexion.

On p. 18 Mr. Grigson had suggested that a 200-penetration bitumen gave a longer life than a cut-back bitumen. Dr. Lee could quite see that the harder 200-penetration bitumen might be less susceptible to early failure from adhesion-breakdown caused by water, but he wondered whether Mr. Grigson had more than that particular trouble in mind. Mr. Grigson had also stated that adhesion failures were largely due to the binder, but Dr. Lee would prefer to say that they were due to a combination of the binder and the particular type of stone used.

Mr. Grigson had quoted the Road Research Laboratory as advocating one particular type of sealing compound for concrete roads in preference to others. There was no doubt that the requirements for a sealing compound were that it should have certain flow-characteristics and that it should have good adhesion and be able to adapt itself without breaking, either at the bond with the concrete or within itself, while movements occurred inside the joint. The material in question had a low temperature-coefficient, which was obviously one of the first requirements, but recent investigations made by the Road Research Laboratory had shown that more attention should be given to the design of the joint itself. It was not unusual to find a joint $\frac{1}{2}$ inch wide between slabs which might be as long as 60 feet. The movement within that joint could be as much as $\frac{1}{3}$ inch, which would induce a 66-per-cent. strain in the material, and Dr. Lee thought that a material could hardly be expected to withstand that strain frequently without breakdown.

Mention had also been made of an American joint-sealing machine which was said to have rather remarkable advantages, and Dr. Lee wondered whether Mr. Grigson had any first-hand knowledge of that machine. In re-sealing a joint, it was necessary to clean and dry it, prime it to obtain good adhesion, and then apply a sealing compound. It was doubtful whether the American machine in question could do that satisfactorily.

Mr. Finch, in reply, said that the cleansing costs of £130,000 included many services such as refuse-disposal and the system which Nottingham had for the exchange of dustbins owned by the local authority. He

thought that another Paper would be needed to deal adequately with the cleansing of road surfaces in an urban area.

He agreed with Mr. Carr's observations on snow-clearing. Nottingham was more liable than London to snowfall and, when it occurred, all the road staff helped to clear the snow, other road operations being temporarily suspended. With regard to his suggestion as to fatigue in machines, he was sure that it would be far more economical to replace parts than to encourage partial recovery by resting. Further information would be made available for Dr. Lee as to the record card and " life " history of streets, but no hard-and-fast rule could be made as to " life " unless related to traffic-intensity.

In the city of Nottingham a record card had been prepared for every street, showing what maintenance and reconstruction works it had undergone, the amount of traffic it took, and other facts. That information could be collected only over a very long period, and he did not suggest that the cost of highway maintenance could be reduced as a short-term policy. He had been doing that work for 12 or 13 years and, although he had not yet got what he wanted, an improvement was being made every year. The war had given him a useful opportunity in that he could, without any serious criticism from the inhabitants of the city, neglect some streets which were due for resurfacing and spend the available money on first-class jobs which he knew would have a life of 15–20 years. The question now arose of the life of different types of surface ; he did not put down any surface which would have a shorter life than 10–12 years, even in the streets with the heaviest traffic, and he hoped that some of the surfaces would last for 20–30 years. The type of construction had to be varied to meet different traffic conditions. He had checked the maintenance costs on two housing estates of very similar type and mileage and had found that £18 had been spent during the past 12 years in maintaining the one with concrete roads, whereas the one with tarmac roads had cost £150 per annum to maintain.

Mr. Grigson, in reply, observed that he had had experience of maintaining roads both with lengthsmen and with mobile gangs. In Gloucestershire, lengthsmen had been abolished and all the work was done by gangs, whereas in Leicestershire the work was done entirely by lengthsmen and there were no gangs. He thought that the general tendency would be for the lengthsman to have more and more of his duties taken out of his hands ; Mr. Mehew had mentioned that mechanized road-sweeping and collecting had hitherto occupied a considerable part of the lengthsman's time.

Mr. Grigson himself had used skimmer scoops as well as grabs for lifting surface-dressing chippings, but had found that they took appreciably longer to load lorries. It was not possible to eliminate hand labour entirely ; there should always be one or two men on a stock-pile, trimming the material to present a face to the grab or the skimmer.

He agreed with Mr. Mehew that the initial cost of surface dressing was

not the prime consideration; it was necessary to consider the cost of a particular method over a period of years. For instance, it might cost a little more to use a high-quality machine, but an improvement might be obtained in the life of the surface, so that any extra cost would be repaid.

He agreed that for mechanization to be economical large administrative units were needed. Machines such as the Barber-Greene, gully-emptiers, and others, were not economic propositions if used over small areas; those responsible for boundaries should realize that it was a retrograde step to take away maintenance functions from large units, such as counties, and compel the County Councils to delegate some of those functions to small local authorities.

Choked jets constituted only one of the many drawbacks from which surface-dressing spraying machines suffered; many features of surface-dressing sprayers required improvement and sprayer manufacturers should set out to improve their machines in a number of ways.

The cement/tar and sand/tar mixes which Mr. Carr had suggested could be investigated better by the Road Research Laboratory than by a highway engineer.

The omission of metropolitan boroughs from the list of highway authorities was an oversight and he apologized to Mr. Carr and to others who might feel similarly slighted.

Grass cutting was a very important feature of highway work, to which he had given a good deal of thought and attention. He believed that the answer to the problem was to get verges into such a condition that they could be mowed by a gang mower in the way in which grass airfields were treated. That would involve a great deal of ploughing, levelling, and seeding beforehand but, if the highway engineer faced up to the work, ultimate maintenance expenses would be infinitesimal in comparison with present costs.

He appreciated the force of Mr. Bradbeer's criticism of the grass-cutting machine illustrated in *Fig. 32*. When machines of that type were used, the ground should be examined beforehand and all objects removed which were likely to damage the cutting mechanism. The labour thus involved could be spared when the machine was used, and the method was economical in the long run.

The flame-gun was a very useful instrument for use in connexion with concrete-road joint filling, but it should be used intelligently; he had seen spalling occur at the joints through overheating of the concrete.

A defeatist attitude should not be adopted towards haunches on clay. They should be designed in the same way as a full-size concrete road, which might mean that considerable thicknesses of concrete were necessary; but he did not know of any alternative to concrete haunches on roads which carried a considerable amount of heavy traffic.

In reply to Dr. Knight, limitations of space had precluded a dissertation on the qualities of roadstone. The surfacings described on pp. 16–19

related to mixes with igneous rock, limestone, or slag as the aggregate, having properties in accordance with British Standard Specification No. 802.

So far as foundations were concerned, if the thickness of construction appeared inadequate, it was checked by making an analysis of the subsoil, identifying the type of soil on the Casagrande classification and comparing the thicknesses shown on the empirical curves with the actual thickness.

The last of Mr. Grigson's concrete patches had been laid in August 1947; it was too early, therefore, to say how long their life would be. A great deal of the work was still sound after 18 months, but a certain amount of it had cracked and broken up, particularly where the patching had been carried out at the edge of a slab.

Mr. McCarthy Lee had referred to the difficulty of laying surfaces on narrow roads with the Barber-Greene machine. The only alternative was hand work, and Mr. Grigson thought that, although extension pieces had to be used and the sides had to be filled up by hand if the Barber-Greene machine were used, that procedure was preferable to doing the work entirely by hand, even though it might be necessary to close the road while the work was being done. Rarely was there no alternative route for traffic. He did not think that a smaller Barber-Greene machine was necessary for road work, but there might be scope for it in surfacing footpaths, which at present had always to be done entirely by hand.

Although he had been very interested in Mr. McCarthy Lee's remarks about scarifying with a tractor, he considered that too much scarifying was done, and that it should be attempted only if the kerb-levels and threshold-levels of adjoining properties made it essential.

Control by the graphical methods indicated by Mr. Waters in *Figs 34* would be extremely useful in overcoming certain difficulties. Mr. Grigson agreed that Fig. 8, Plate 1, showed a lamentable state of affairs and, whilst he agreed that it was essential to ensure that the personnel were thoroughly familiar with their tasks, he thought that the main fault lay in the fact that the available plant was not always adequate or suitable. The remedy was in the hands of the local authority engineers; if they insisted on better plant they would eventually get it.

His conclusion that 200-penetration bitumen gave a longer life than cut-back bitumen had been reached from observation of the behaviour under traffic of various types of stone with various binders.

He agreed that the design of the joint in relation to the sealing compound had been overlooked in the past and that more attention should be paid to it in the future. He had no first-hand knowledge of the American mechanized methods of sealing joints, but he did not think that the various operations which Dr. Lee had mentioned, such as cleaning out and heating, should defeat road engineers when they set out to mechanize that particular operation.

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