was revolving. The time taken for mixing by this method was 3-4 minutes.

As an alternative method for mixing, experiments were carried out using compressed air. The apparatus employed (*Fig. 10*) consisted of a Broomwade air-compressor with a 30-foot length of pipe connected to a 75-gallon galvanized-iron tank supported on a specially designed movable platform constructed of tubular steel members.

The tank had ¾-inch diameter holes cut 1 inch from its base and was connected to a grid, placed inside the tank, made up of ¾-inch and ½-inch water-pipes which were drilled with holes. The outlet of the tank consisted of a 2½-inch diameter pipe, 18 inches long, threaded 3½ inches where it entered the base. The end of the outlet pipe was threaded to allow the fitting of a full-way treacle valve which controlled the flow of the grout from the tank after mixing. The required quantity of water was first placed in the tank and the compressed air was released at a pressure of between 40 lb. and 45 lb. per square inch ; 1 cubic foot of sand was next placed in the tank, followed by 112 lb. of cement, and the balance of sand was then added to complete the mix. This method of mixing proved quite satisfactory.

Conclusion.

Although the Author's experience has been that cement-grouted work does not produce concrete of equivalent strength to that of ordinary concrete of a nominal 1 : 2½ : 4 mix, it nevertheless has the following advantages for certain classes of work :—

(1) At least 40 per cent. of the materials can be placed in " position " without passing through the mixer.
(2) There is a slight saving in cement-consumption.
(3) Certain fine sand can be used which would not be suitable for ordinary concrete work.
(4) Large-size coarse aggregate up to 4 inches may be used.

The Note is accompanied by one diagram and five photographs, from which the Figures have been prepared.

Discussion.

Mr. H. E. Lunn observed that Mr. Browne had presented the results of a great deal of work, which had been carried out without the best means for the purpose and in very difficult circumstances. Doubtless many members had experienced similar circumstances and could visualize what was written between the lines. The Author had expressed the view that it was remarkable how the roads in Liverpool had stood up to the war-time

traffic. It was a fact that British roads in general had withstood that traffic well, and those who were old enough to remember the state of the roads in France and Belgium during the war of 1914–1918 would realize that road construction in Great Britain was very much better than it had been on the Continent at that time and that despite all criticism it had been of extraordinarily good quality over a period of years.

He considered, however, that the behaviour of the roads was not really remarkable, because in the dry season heavy loads could be taken with no difficulty over a farm and over downs which had no more surface than a thin layer of turf. The subsoil under the roads in a town was like soil in a dry summer and would carry loads without much difficulty. The damage which had taken place was mainly superficial, and even in the main streets of London, with concentrated periods of bus traffic, it was only at the bus stopping-places that much damage had been done to the foundations. During the war it had been difficult to maintain the surfacing without the proper means for the purpose and with heavy traffic such as had been experienced in Liverpool.

Mr. Lunn had had very little experience of the use of a thin layer of mastic asphalt to repair existing mastic asphalt surfaces, as that class of work was not one which he, as a county surveyor, could afford to undertake even if he wished to do so. Apparently the process had been successful, because the Author had repeated it, and it had not been used as a war-time expedient, because it had been carried out first in 1939. Had the existing surface of mastic asphalt been treated in any way before the thin layer of mastic asphalt had been put on it ?

The Author had said that 55 per cent. of the damage to Liverpool roads had been repaired ; did that mean that 45 per cent. of the damage was still in need of repair ? Mr. Lunn supposed that traffic was running over the damaged roads.

The experiments described by Mr. Miller were very interesting and his Note revealed considerable ingenuity in meeting the requirements with which he had been faced. Had the work been carried out after examination of the test-cubes, or had the test-cubes followed trial and error on the road ? In other words, what had made the Author decide that the maximum size of the pieces of material for his process was $3\frac{1}{2}$ inches ? He had suggested that the grout could be used for pitching, but those who came from the stone counties of the north would know that pitching was usually much larger in size than $3\frac{1}{2}$ inches, and Mr. Lunn believed that the process would be difficult to control if grout were used for that material, since the extent of the voids and the cost of the job would not be known until it had been done. There could be no doubt that the process was practical—Mr. Lunn had used it himself in an emergency, when he could not maintain a piece of road in any other way—but he still felt that it would be expensive.

Grout surfacing was a different matter altogether. Some years ago

a minor form of campaign had been initiated, mainly, he believed, by the cement interests, to persuade people that grouting work was the correct procedure—and, when carried out properly, it had its place in road maintenance. A very good bottom was required under a cement grout surface because there was no elasticity in that surface. With a good sound bottom, which, however, could not be relied upon in most country roads, it was safe to lay a grout surface. About 18 years ago he had undertaken a small job of that kind on a steep hill, about 1 in 13, near a railway station, which he found could not be maintained by the ordinary methods then in use. Omnibuses ran up the hill. He decided to roll out some granite and grout it in. Unfortunately, there was not a very good foreman on the job, which was about 30 miles from headquarters and therefore was not easy to supervise. The work was a failure in the sense that it was far too expensive. The organization was not good and the output was very small, but the road, after 18 years, was still there, although it was cracked. Electricity cables had been put through it and it had been trenched, but, except for occasional patching of the cracks with cold emulsion or bitumen, no appreciable amount of money had been spent on it since the work had been done. Possibly, therefore, the cost of the work had been justified, and its execution had saved a great deal of trouble, time, and labour in keeping the road going. Thus there was a place for the kind of work in question, and the improved technique described might be very helpful to those who might have to carry out such work.

Mr. Hussell had told a story with which some members in the south had become familiar. Considerable trouble had been experienced by those who had been charged with the maintenance of the roads in such areas. The Author had been fortunate in having asphalt plant ready to hand in his own county, for which he could find the material and which he could utilize. In Sussex the unclassified roads had just grown, like Topsy, and included more corners per mile, perhaps, than did the Author's unclassified roads in Hampshire. They were just country lanes; they had not been designed and they were not altogether capable of carrying the traffic which came upon them. The trouble was that the Army required a great deal of room when it moved; it needed roads about twice as wide as those required by civilians, and tanks did not always keep to the carriageway; but after one convoy had passed the Army expected the roads to be in good condition for the next one. The Author's experience in that respect had probably been worse than Mr. Lunn's, because the Author had had the Americans in his area, and they were so used to having everything bigger, wider, taller, and deeper than anyone else that when they wanted to move down to the coast they had to have the roads made twice as wide as the British Army would have required them. Therefore, the Author had had to get that done. Had the contract been of the " cost plus " type ? If so, Mr. Lunn imagined that the contractors had been all right from the beginning.

The work described by Mr. Bradbeer had all been done in Sussex. Reliance had been placed on surface dressing for many years, and it was that which had kept the roads together during the war. It had entailed difficulties, some of which difficulties had been set out by the Author. When complaints were made about slipperiness, as they had been from time to time, or that a road was corrugated, especially on bends, where it had an effect on the control of the car, something had to be done. In the first place, one of the enterprising divisional surveyors had started to scarify one of the smooth roads with a scarifier tine with longitudinal grooves. That gave a good grip on the road and was not entirely unsuccessful, but the road was not suitable for cyclists. It was impossible to control the depth of the groove made by the scarifier tine, and as some of the grooves made the road dangerous for ordinary push bicycles, Mr. Lunn had them filled. Later the question of burning off was considered, but the old burning-off machine was a great nuisance ; it breathed fire and smoke all over the place, and the men became very tired of it. In a town it burned the shop fronts and shop blinds, etc. In the country, however, if a planing machine were attached to it, it could do a first-class job. In comparing a piece of road which had had a burning-machine and a planing-machine over it, the difference was found to be remarkable. Mr. Lunn had been very pleased with the result of the process, which he intended to continue, and he could commend it to others. More planing-machines were needed ; he believed that there were only four in the country, and he had had two of them last year.

The Author had taken a great deal of trouble to find out how to use the chippings and other material scraped off the road. That needed considerable organization beforehand, because the material had to be used before its temperature fell below 125° F. It could be used on footpaths and byways, but after about 25 minutes' run in a lorry it became too cold to use. The Road Research Laboratory had rendered valuable help in trying to find some way of working on the material so that it could be used again after it had become cold ; but he believed the idea had been abandoned.

The work described by Mr. Lee had also been done in Sussex. The contractor to whom the Author had referred had been very helpful in the whole business. In Sussex most road work was done by direct labour, but those who directed the work knew their limitations and were always glad to receive help from contractors. When Mr. Lunn had begun to roughen concrete surfaces, and it had become known that he was doing so, a feeling existed that it must not be said that concrete was ever slippery ; but those concerned with the maintenance of roads had to be realists, and when they received complaints about slipperiness they had to consider whether those complaints were justified. Sometimes complaints were made by people who could not drive properly or whose cars or tires were not in good condition.

When it was found that certain sections of concrete roads were slippery, efforts were made to put them right. The first method tried was the application of hydrochloric acid, but that was a messy business, and, however the acid was applied and whatever the men were given to wear on their feet, it was an awkward material to handle. Its action on the surface helped to stultify its own effect, and it was necessary to wash it off repeatedly and start again. The result was at best only 25 per cent. efficient, although the acid was applied several times. The machine described in the Note was then tried, and it progressed from medium to efficient and then to very efficient, the surface produced becoming extraordinarily good, as was proved by the Author's statement that the coefficient on test for slipperiness had increased from 0·34 to 0·56. The latter was very good, and made driving on the road absolutely safe. The work had been limited to bends and to places where it had been complained that the road was slippery. It was not thought that the removal of the very thin hard skin on the top of the concrete would have any effect on the life of the road. Some of the roads had been down for 14 or 15 years and, as it was not possible to detect the slightest degree of wear in the roads themselves, Mr. Lunn had been naturally reluctant to wear the road down with a tool; but that had been done, and he was satisfied with the result.

Mr. Corfield's Note on post-war maintenance contained a great deal of common sense. The Author had concentrated chiefly on the preparation work that was necessary, leading up to the use of the Barber-Greene machine. The difficulty found in Sussex in the use of that machine was the considerable amount of preparation work required before it could be used, which made it impossible to provide a sufficient length of road. Mr. Lunn believed that that difficulty would be experienced by most people. The machine was ideal for use where there was a concrete foundation of some considerable length and it was desired to put a surface on it, but the inequalities of the ordinary macadam road, whether it was tar macadam or asphalt or whatever it might be, were almost unbelievable. The existence of those inequalities had been brought home to the road authorities in Sussex during the war, because they had had to strengthen the sides of some of the roads with concrete shoulders, about 18 inches in cross-section each way, and, when they had tried to lay them down to proper lines and levels and saw the result where the shoulders touched the old road, the inequalities which existed were very apparent. He did not know how the Barber-Greene machine could deal with that matter. Also, it was necessary to work to a programme. In Sussex all the drainage work was done at least twelve months, and sometimes two years, before anything was done with regard to the surfacing of a road, so that if anyone offered the road authorities a machine such as the Barber-Greene machine they would probably have to say that they would be ready for it in 1949.

Mr. R. J. Samuel observed that at the end of a long war highway authorities were faced with extraordinarily difficult problems, apart from

any question of planning or re-planning the country and the roads; and one of their main difficulties would be the maintenance and reconstruction of the highways which had been neglected for six years.

Mechanical road transport had developed since 1919 by leaps and bounds, and a large programme of reconstruction of the highways had been in progress during the years between the wars. That had suddenly come to an end in 1939, when the authorities were faced with shutting down all their works and reducing maintenance to the bare minimum. Moreover, with reduced staffs, they had been called upon to carry out considerable reconstruction, widening, and strengthening of the roads leading to airfields and other Government establishments. Very little had been said about that effort, but most of the roads in question were in remote places. Whereas previously they had carried only light agricultural traffic, they were then called upon to carry tanks, lorries, and heavy military transport of all descriptions.

Mr. Hussell had mentioned one of the most difficult tasks which the highway authorities had had to carry out. At the end of December 1943 the military, through the Ministry of War Transport, had asked Hampshire and the adjoining counties to get all the roads to the invasion hards ready by 31 March, 1944. That had involved widening and strengthening several hundred miles of roads to carry the full military traffic, including tanks. It was difficult to obtain labour, and, when men were found, they had to be housed. All those troubles, however, were overcome, and, with the help of the military, the Ministry of War Transport's labour organization, the county councils, and the contractors, the job was finished in time, in spite of the bad working conditions.

Another problem was the repair of the damage done to roads up and down the country by tanks, which did not always keep to the carriageway.

The highway authorities now were faced with six years' arrears of maintenance on the highways, they had to spend several million pounds on restoring the roads, and various improvement works were required. The labour force amounted to about 60 per cent. of the pre-war number, and there was not much prospect of many more men being available.

Many miles of roads required reconstruction. Mr. Samuel had been very disappointed to hear Mr. Lunn suggest that the Barber-Greene machine was not much good. Compared with 30 tons a day being laid by hand, the Barber-Greene machine could put down 200 tons per day. With only about 70 per cent. of the pre-war labour force, he did not see how the roads of Great Britain could be reconstructed unless mechanical means were used for the purpose. On many of the roads a thin carpet could be laid. With a machine laying 200 tons per day, at 15 square yards to the ton, 3,000 square yards could be laid in a day, and if a long length of road could be prepared the machine could resurface it at an extraordinary speed.

Two points should be borne in mind in connexion with the Barber-

Greene machine, which had been used first of all for runway construction on airfields. Firstly, it had four speeds. If the highest speed was used, a road could be re-surfaced at a very rapid rate, but the result would be poor. The machine should be run at a lower speed and should not travel more than 8–10 feet per minute. Mr. Samuel suggested that people who were going to use the machine should specify the rate at which it was to be run. Secondly, the machine had to be fed. There should be a regular supply of of material per day, and it should be mixed moderately close to the machine. A portable mixer at the roadside was the best. When the material had been brought too far the result had been poor; the material had been too cold and it had dragged.

Mr. Hussell had stated that he had used on the less important roads a certain type of surface dressing as a war-time expedient and that it was not likely to be considered in normal conditions. Mr. Samuel suggested that the Author might continue to use it for the next year or two, as he had admitted that it gave reasonably good results and that it was possible to cover a large area with it in a short time. With a small labour force he would not have many men available for use on the by-roads. It was undesirable that any of those roads should disintegrate, and it might be better to continue using the material in question until the roads could be properly resurfaced.

Mr. Samuel wondered why the Author had stated that: "It has been found from experience that asphalt for withstanding tank traffic is better than concrete." Perhaps he had had in mind the Winchester by-pass, which had a concrete dual carriageway. One of the carriageways had been closed and used as a depot for repairing Army vehicles. The other had been left open for civilian traffic, but the Army had used it for running on and at frequent intervals their vehicles had charged across the central verge into the depots on the other carriageway. The central verge and the side verges had been destroyed, the edge of the concrete had been knocked right off, and considerable damage had been done. Mr. Samuel believed that if the road had been of asphalt it would not have stood up to such treatment better than a concrete road, and the effect upon it would probably have been worse.

Mr. Browne had stated that the softer bitumen and tar surfaces had proved unable to withstand tanks and other tracked vehicles and that the softer surfaces on test routes for tanks had been replaced with concrete or granite sets. Granite sets could be used in Liverpool and in other big towns, because plenty of second-hand ones were available there, but they were out of the question. He hoped that it would not be necessary to think very much about tanks in future, but he did not know whether they would disappear from the roads altogether. In any case there would be a tendency for heavier traffic to use the roads. He believed that the shortage of labour would continue during the next few years, and therefore, in order to carry out the programme of reconstruction works, consideration

should be given to mechanical methods and, above all, to proper organization.

Mr. F. N. Sparkes observed that Mr. Miller had referred to the use of grouted chalk in Northern France during the early part of the war. Considerable trouble had been experienced from frost damage. The Road Research Laboratory had looked into the matter, to see whether chalk could be made more frost-resistant, and after a good deal of work it had been concluded that, if the slabs were surrounded by an envelope of mortar, about ½ inch thick, the frost-resistance would probably be improved. A short length of road had been laid in that way in Savernake Forest by a military unit, and the results had been fairly successful; but a good quality road could never be obtained with that type of material and Mr. Sparkes was sure that the Author would not wish road engineers to use it if any better material were available.

He had been rather surprised to find that the Author had referred to consolidating after grouting, by hand tamping, vibrating, or rolling. Mr. Sparkes considered that consolidation was unnecessary, as the voids in the coarse aggregate were properly filled by the mortar during grouting.

The Author had given several different types of sand grading for use with the different sizes of coarse aggregate, and had stated that the coarsest sand grading was not satisfactory for the finest coarse aggregate, namely, 1½ inch to ¾ inch. However, that size of material contained voids which were comparatively large, and Mr. Sparkes would have expected them to receive the mortar and allow it to penetrate without any serious difficulty.

He noticed that, with a mix of 1 part of cement to 1½ part of sand by weight and a normal water/cement ratio of 6½–7 gallons of water per 112 lb. of cement, a compressive strength of approximately 2,800–3,650 lb. per square inch had been obtained, whereas with that water/cement ratio a strength of about 5,000 lb. per square inch with a straight concrete would normally be expected. Similar results had been obtained at the Road Research Laboratory on cores drilled from the material in question, and it had been found that the strength of the cores was considerably lower than would be expected from concrete with approximately the same water/cement ratio. Not many results were available from which to judge, and if any further results had been obtained they would be helpful.

Mr. Hussell had stated: "It has been found from experience that asphalt for withstanding tank traffic is better than concrete," whereas Mr. Browne had remarked that: "Where test routes for tanks have been agreed with the Military Authorities and the Divisional Road Engineer (Ministry of War Transport) the softer surfaces on these routes, particularly at turning or 'slewing' points, have been replaced with concrete or granite sets". Possibly the explanation of the apparent contradiction was that either concrete or asphalt could be made considerably resistant to tank wear if a suitable specification were chosen. That subject had been investigated at the Road Research Laboratory, and the results had been published

in the *Royal Engineers' Journal*. It had appeared from the investigation that, so far as concrete was concerned, provided the concrete strength was of the order of 5,000 lb. per square inch, very good resistance to tank action (abrasion only and not the effect of tank action on road edges and kerbs) was obtained. Below that strength, the type of aggregate used had a very marked effect. Gravel gave worse results than limestone, and limestone gave worse results than granite. So far as surface was concerned, mastic asphalt could be made to give quite satisfactory resistance to tank damage.

Mr. Lee had stated that when the apparatus described in his Note was used between $\frac{1}{16}$ inch and $\frac{1}{8}$ inch thickness of concrete was removed and that in no case were large stones in the surface of the road damaged or pulled out. That might be so in the case of a particularly tough material like flint, but would the statement apply to a brittle material like gravel? Mr. Sparkes believed the disintegration might extend a little deeper in that case.

Judging by the photograph of the machine, he imagined that considerable skill was required in operating it in order to produce a uniformly level surface. He agreed that a performance test or some kind of a performance criterion was definitely required for specifying the type of surface which could be produced on a road. At the moment all that could be said was that for a good non-skid surface the variations from straight edge should not exceed about $\frac{1}{8}$ inch. He suggested that some kind of test was needed which would enable engineers to know not only how regular the road was but also whether or not the degree of roughness was satisfactory for non-skid purposes.

Mr. H. S. Keep observed that Mr. Browne had not mentioned the thickness of the veneer coat of mastic asphalt which he applied. The term " veneer " was used sometimes for a coat $\frac{1}{8}$ inch thick and sometimes for a coat nearly 1 inch thick. What thickness had been used by the Author, and what pre-treatment, if any, was given to the existing surface before the application of the new mastic asphalt?

Mr. Miller had mentioned the use of aggregate consisting of broken brick obtained from the demolition of blitzed houses. There was a danger in the use of that material, as it had been found that the plaster which might be mixed with it had a detrimental effect.

Apparently the aggregate had not been rolled before grouting; but that would probably be an advantage, in order to get as much interlocking as possible before the grout was applied.

On some work it had been found necessary to loosen the stones by forks during the process of grouting, and that did not seem a very satisfactory method. Mr. Keep wondered whether it could be avoided if the precautions recommended by the Author were adopted.

No reference had been made to the shape of the particles, either of the aggregate or of the sand. The particle-shape would have a considerable

effect upon the viscosity of the grout, and it would be interesting to know whether any data on that subject were available.

With reference to Mr. Miller's comparison of coarse and fine cements, less water made for a lower water/cement ratio, which gave a higher concrete strength. On the other hand, a coarse cement did not generally give such a strong concrete as a fine cement. The balance was rather fine, and definite information on the subject would be welcomed.

The fluidity test described had interested Mr. Keep particularly, because when he had been carrying out some experiments in 1934 a colleague had suggested and constructed a meter for the purpose, consisting of an ordinary bucket of about 1 gallon capacity, with a $\frac{1}{2}$-inch hole at the bottom, and it was found that 35 seconds gave a suitable fluidity.

If Mr. Miller's Table III were linked up with the diagram in *Fig. 6*, it seemed that the range of fluidity in every case corresponded roughly with $\frac{1}{2}$ gallon of water per cwt. of cement. If that meant working within 5 lb. of water, it seemed a little doubtful whether so high a degree of accuracy could be maintained with the use of ordinary sands, the moisture-contents of which frequently varied over a considerable range.

Mr. Keep presumed that, in discussing strength, the Author referred to test-cores, and not to samples taken from the carriageway or finished slab.

One difficulty experienced in the kind of grouting referred to in the Note was to prevent an excess of mortar on the surface. In many cases the mortar lasted for a few years, but it then flaked off, leaving a very uneven surface.

A practical difficulty was the limitation of supplies. In some districts large numbers of rejects could be obtained from gravel pits, and fortunately in the London area sand could usually be obtained; but in several cases his experience had been that the coarse aggregate and the sand were not found at the same place. For some work which had been carried out in Inverness-shire, it had been necessary to bring the sand a distance of 32 miles, as the sand from all nearer sources of supply did not give a good fluid grout.

He could support Mr. Lee's claim that the roughening of concrete surfaces was effective. It had been applied to a trunk road which was in excellent condition in every respect, except that it was rather smooth. It was really a fine piece of work and looked like a beautiful mosaic, but it was rather slippery. The treatment was applied with the apparatus described and illustrated by the Author. Mr. Keep considered that it would be advantageous if a third wheel—a small trailing wheel—were provided to steady the machine and give a uniform depth of cut. The possibility of a lack of uniformity of depth developed into an actuality, and the slight undulations left after the treatment were easily visible.

Mr. Kurt Billig observed that the grouting of coarse aggregate with a

cement-sand mixture had been widely used for the rapid construction of landing strips and, on the whole, had proved satisfactory.

Another type of quickly built road which had been used as a perimeter track, where no heavy excavations or fillings were required, had proved satisfactory in service, whilst it required considerably less material and labour than the types mentioned by Mr. Miller.

For the construction of that track the formation was prepared by the surface being skimmed lightly with a grader. A single layer of broken stone, ranging from 3 inches to 1 inch in size, was rolled into the prepared formation, and the stones were left standing $\frac{1}{2}$ inch proud of the earth. Special care was taken to ensure that the surface was kept clean of mud when the soil rose between the stones. The protruding portions of those " hobnails " were flushed liberally with a layer of 3 : 1 grout which covered the stones completely for a thickness of about $\frac{1}{2}$ inch over the stones. While the grout was still wet, coir matting was spread over the whole surface and was carefully stretched. The fabric was usually laid in rolls 6 feet wide, with 4-inch laps in both directions, and was immediately rolled into the grout to squeeze the wet mix up through the meshes of the matting. A final top layer of concrete, $\frac{3}{4}$–1 inch thick, was then spread, screeded, and finished with the desired surface. The mixture used for the surface was 1 part Portland cement to 3 parts crushed and washed aggregate, closely graded from $\frac{3}{8}$ inch down. To provide side support to the soil and prevent its lateral movement under load, longitudinal concrete kerbs, 6 inches wide and 18 inches deep, were placed on each side of the track. The kerb walls were cast against the soil without the use of moulds, and were used as forms to the final screeding of the road surface. French drains and agricultural pipes were laid outside those dwarf walls, to prevent access of surface water to the subsoil under the track.

The object of that track, which was originated by Mr. J. H. de W. Waller, M.I.C.E., was to make full use of the natural bearing capacity inherent in the soil itself by restraining its free movement sidewards and upwards under the application of loads. The ground formation was left undisturbed wherever possible, and the thickness of the artificial surface was reduced to the minimum.

The track consisted of a concrete skin, $1\frac{1}{4}$ inch thick, and of a $2\frac{1}{2}$-inch thick layer of broken stone embedded in the soil. The grout of the skin did not permeate the stone layer, but only covered it and adhered to it. The coir matting was completely embedded in the two coats of grout and concrete, and there was no line of cleavage between them. The matting served as a reinforcement, or rather as a toughener, of the brittle concrete. Any other material of good tensile strength could be equally well employed for the purpose, such as jute, sisal, or similar vegetable fibre. Vegetable fibre was a very suitable material for resisting tension, but it suffered from the disadvantage that elastic elongations under small loads were relatively large. The increase in the extension with greater loads was con-

siderably smaller. To overcome the disadvantage, the fabric should be stretched by hand as tightly as possible, and its porous fibres should be shrunk with water before the fabric was embedded in the concrete. While the concrete hardened, the cement penetrated into the pores of the fibres and maintained the shrinkage of the material and its tension. In that way the excessive stretch was taken out of the material.

The fabric placed in the road skin should be of fairly open mesh, so that the slurry would penetrate through the material and form a good key between the top and bottom layers. To a certain extent that vegetable reinforcement was better than a steel reinforcement, which was necessarily spaced at relatively large distances and left the intermediate parts of the concrete unprotected. The use of the loosely woven coir mat resulted in a more even distribution of the reinforcement; it was effective in all directions and had the characteristic of continuity throughout, whilst it made the thin concrete skin tough. It was not subject to oxidation, and the information available showed that it had maintained its strength in tracks laid more than 5 years ago.

In thick slabs, such as were usually employed for roads, etc., the natural tendency during hardening was for the outer skin to set rapidly, thus forming a seal against penetration of the atmosphere to the lower layers, which consequently set at a much slower pace. On the other hand, the $1\frac{1}{4}$-inch thick concrete carpet of the track described was really only an outer skin, which gained the maximum benefit from the atmosphere, with the result that a very rapid set was obtained. The carpet should be kept wet until it was well hardened, by spraying it thoroughly with water at frequent intervals. It was also essential that the minimum thickness of $1\frac{1}{4}$ inch should nowhere be undercut and that the concrete of the carpet should be of close and dense structure.

Much less material and labour were required for that road than for the types mentioned by Mr. Miller. That applied to both the ground layer of coarse aggregate placed on the soil and the cement-sand grout passed through the mixer.

Such perimeter tracks had been severely tested under repeated loads and had behaved extremely well under war-time conditions. Mr. Billig considered that they might prove suitable for cycle-tracks, footpaths, car parks, market places, playgrounds and similar works which were not subjected to severe loading at high speeds.

Mr. Stanley Mehew asked whether Mr. Bradbeer had considered any type of test which would establish when the condition of a road surface was such that the planing method could be appropriately applied. Mr. Mehew had used that method in cases of palpable over-surface-dressing and it had proved very successful. He could corroborate all that Mr. Lunn had said about the excellence of the running surface which resulted from the process. As the planing-machine had a long wheel-base and planed in between two points of support which were rather widely separated, i

naturally removed irregularities. A repetition of that process produced excellent results. The machine could be used—and no doubt frequently was used—when the primary defect which the engineer wished to remedy was irregularities on the road itself rather than over-surface dressing.

Many engineers, when using the heating and planing process for the first time, might fear that the heating would result in killing the binder in the road, with the possibility of disintegration later on, when the traffic came on to the road, and Mr. Bradbeer's opinion on that would be welcomed.

Mr. Corfield appeared to have put his finger on the principal problem associated with the use of the Barber-Greene machine. Careful preparation was undoubtedly required, but Mr. Mehew considered that Mr. Lunn was a little over-apprehensive about the risks of using that class of machine. Mr. Mehew had had fairly considerable experience with it, both for laying base coats 2½ inches thick and for laying topping coats, 1 inch thick and 15–20 yards to the ton, and had been quite satisfied with the result, even though no excessive preparation work had been done. The running surface also was remarkably good. The machine was designed so that it naturally tended to improve the surface, and, if it could be used after the planing method to which Mr. Bradbeer had referred, the resultant running surface should be first-class.

The problem of supply was of considerable importance. Mr. Mehew's own area was in the Midlands, in the heart of one of the road stone counties, and even there, although the Barber-Greene machine was not yet very common, the problem of supply was a very real one. Two hundred tons of topping per day was quite a large proportion of the output of even a large plant, and the question of supply was a distinct worry to the engineer, as it was also to a supplier when two or three customers asked him for 200 tons per day. Mr. Corfield's suggestion that stocks of dry stone should be accumulated on the site beforehand was a good one. It might be possible before a job started to accumulate about half the quantity of stone that would be required for it, and the mixing could be done near the site in a portable plant, at the rate required, further supplies of dry stone being brought in as the stock was drawn upon. Had Mr. Corfield had any experience of portable plants with a capacity of 200 tons or so per day ?

Mr. Mehew had frequently told colleagues in the Midlands that if they wanted to see some really good concrete roads they should go to East Sussex. He would now be able to add that the roads in East Sussex were so smooth that it had been necessary to design a machine to make them rougher !

The cost of 2*s.* 6*d.* per yard quoted by Mr. Lee appeared high. In Mr. Mehew's area that rate would justify consideration being given to alternative means of treating a slippery road, such as carpeting with a veneer coat. Having regard to the plant and the number of men involved, he found it difficult to see how the figure of 2*s.* 6*d.* per yard was

arrived at on the output figure, the area treated per week, given in the Note, and he would appreciate further observations from Mr. Lee upon the cost.

*** **Mr. D. H. L. Keeble** observed that Mr. Miller had mentioned three methods of making grout, namely :—

(*a*) Ordinary cement grout ;
(*b*) That made with a Colcrete mixer ; and
(*c*) Cement-sand grout made with an admixture.

So far as Mr. Keeble was aware, there was only one method under (*c*) and that was a patented one and was dependent upon the use of a wetting agent and so far as was known, no admixtures of any other kind were suitable. That patented process, whereby a wetting agent was used in the grout, was fundamentally different from the processes mentioned under (*a*) and (*b*) as the addition of the wetting agent broke down the surface tension of the water and, thereby, materially assisted the grout to penetrate the voids between the stones.

Mr. Miller had stated that one of the methods of consolidating was by rolling. Whilst that might be necessary for processes (*a*) and (*b*), it was, without question, detrimental to method (*c*), as it largely defeated one of the main objects of the process, which was to have all the coarse stones lying firmly against each other without being separated by cement mortar as was the case with ordinary concrete.

Mr. Miller's tests were interesting, but he had not stated which method he adopted.

The compressive tests carried out by Mr. Miller were valuable, but his inference that concrete having a compressive strength of between 2,800 lb. and 3,650 lb. per square inch at 28 days was only fit for " light-traffic roads and paved areas " could not be regarded as seriously meant. Concrete laid by the average contractor for normal concrete roads (without high-frequency vibration) yielded test results considerably below those given by him.

It had been stated that " caking " might occur unless a high-speed mixer were used. That was not correct, as " caking " could easily be avoided with the admixture process by retaining two fair-sized stones in an ordinary tilting drum mixer, and 1 minute or less was ample time for mixing.

A major aspect of the grouting system which Mr. Keeble believed that Mr. Miller had missed altogether was that that system did not make concrete in the accepted sense ; it was merely a method of binding stones, already placed in position and in contact, with a cement-sand grout. No grout separated the stones. For that reason, it was claimed that concrete roads laid by the admixture process were not subject to the same movement due to variations of temperature and moisture as were roads made

*** This and the following contribution were submitted in writing.—SEC. I.C.E.

with ordinary concrete. That meant that joints could be spaced much more widely without cracks appearing in the concrete—a consideration which Mr. Keeble regarded as of considerable importance.

Many concrete roads had been laid with cement-sand grout and an admixture in Scotland while Mr. Keeble was stationed there. Those roads were on a tank firing range and had to stand up to 40-ton Churchill tank traffic at very short notice.

Subsequently, many other roads had been laid with outstanding success; main roads subject to concentrated bus traffic, secondary roads, housing estate roads, and farm roads.

The Building Research Station had recently carried out some practical tests with a view to making use of the large quantities of broken brick and concrete which were becoming available from demolished air-raid shelters. It was not possible to use that type of aggregate in a normal mixer owing to its size, with resulting segregation and because the brick pounded up and made a weak concrete. The slab under test was 32 feet long, 8 feet wide, and 6 inches deep. The results of the tests, which were made with a sand-cement grout with the admixture, had been summed up by the Building Research Station as follows:—

"After 24 hours the slab could be walked on without damage to the surface. The surface of the concrete was reasonably good and compared favourably with a normal concrete. Observations of the control cubes after test showed that the grout had well filled the aggregate voids and cubes removed from the actual slab on the site confirmed this. Examination of the crushed control cubes also showed that the grout showed better bond with the brick aggregate than with the gravel. This was probably due to the fact that the gravel used for the work was of smooth surface texture."

The compressive strength of the concrete was 2,800 lb. per square inch at 28 days and the density was 120 lb. per cubic foot.

Mr. A. A. Osborne observed that Mr. Hussell had commented upon the absence of any advance in road engineering (apart from some soil stabilization) as the result of the war. Mr. Osborne could subscribe to this view, as in response to an army inquiry upon the general value of a chronicle of the military roadworks in Italy, where he had been in close touch with the maintenance of thousands of miles of military routes, he had also had to point out that, in spite of the roads task being a major problem, no new technical development, apart from improvisations, could be quoted. The conditions in a theatre of operations which precluded opportunities for the Royal Engineers to contribute to post-war road problems had, however, served to emphasize the value of up-to-date road equipment coupled with good supply organizations. The vast supply of "Lease-Lend" equipment during the war had afforded British engineers an opportunity of fully appreciating the value of mechanical earth-moving plant. The improvements

in airfield runways and perimeter tracks formed a contribution to road engineering which should not be overlooked.

The success in Hampshire of asphalt for tank traffic agreed with observations made in 1944 in Great Britain [1] and the United States.[2] Was the asphalt subjected to continuous tank-track wear during hot weather? On Italian main roads it was necessary to divert *steel*-tracked vehicles to adjoining "graded" earth roads whenever possible, although it was observed that some asphalt surfacing was not seriously affected. A well proportioned concrete containing hard angular aggregate, with consequent high compressive strength, was usually satisfactory for tank traffic, but surely that problem will not arise in future, as it was hoped that tank transporters would be available for future movement on main roads.

The problem of supplying 200 tons per day to a tarmacadam laying and spreading machine, mentioned by Mr. Corfield would, in the future, be largely one of organization and suitable mixing plant.

The discussion on Mr. R. H. Law's Paper in 1944 [3] indicated that travelling mixing plants had been successful in America. The relatively narrow and winding highways in Great Britain which were now in need of maintenance presented a different problem. Carriageways should not be less than 18 feet wide to enable single-line traffic to be maintained with a laying and spreading machine in operation. A wide carriageway was necessary for the use of a travel plant for bituminous mixes on account of the road tanker, with flexible hose, which, as well as the laying machine, had to travel alongside. The aggregate had to be placed on the carriageway in the form of a measured windrow and fed into the mixer hopper by a self-propelled bucket elevator.

High-capacity central mixers required an efficient organization of supply around the plant and long haulage to the site was disadvantageous. If economical and efficient service to the high-output laying and spreading machines was to be attained, then a series of medium capacity mixers suitably situated throughout the length of the job and away from the carriageway would appear to be a desirable alternative to a travel plant on narrow roads.

The Barber-Greene maintenance plants, together with tipping lorries, would provide a speedy and flexible delivery. The plant, consisting of a single-drum dryer, a mixer, and a loading conveyor, with a capacity of from 12 tons to 25 tons per hour, depending upon the mix, was widely used for the supply of bituminous macadam for maintenance of army roads in Italy. The portable mixer could be dismantled, whilst the mixer and dryer

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[1] G. Lowe. "Observations on Tank Traffic and Carriageways." *Surveyor, Lond.*, vol. 103 (1944), p. 271. (*Road Abstracts*, vol. 11 (1944), No. 462.)

[2] "Asphaltic Concrete Tank Testing Track." *Roads and Streets*, vol. 37 (1944), p. 77. (*Road Abstracts*, vol. 11 (1944), No. 366.)

[3] "Modern Plant and Road Construction." Instn Civ. Engrs, Road Paper No. 13 (1944).

could be towed separately, by lorry, and re-erected on a new site in a few days. A road tanker had been found to be the most satisfactory method of supplying heated bitumen, as the value of the mixer's portability was wasted unless the delay in moving static auxiliary equipment were overcome.

The daily output of that plant was 120–150 tons, with a maximum of 200 tons when the dryer was not used. The need for improved methods of heating and supplying bitumen was evident, and a more mobile type of bitumen heater would increase the advantage of portable mixers.

Mr. D. Irvine Watson observed that he had been surprised at Mr. Miller's general conclusion that the grouting method effected a slight saving in cement-consumption over a nominal 1 : 2½ : 4 mix, and he had calculated the following data from the figures given in Mr. Miller's Note :—

Composition of grout : percentage by volume.

	1	2	3
Sand	38·98	37·84	35·75
Cement	21·80	21·16	19·99
Water	39·22	41·00	44·26
	100·00	100·00	100·00

Composition of concrete as laid : percentage by volume.

	1	2	3
Aggregate	51·00	51·00	51·00
Sand	19·10	18·54	17·52
Cement	10·68	10·37	9·79
Water	19·22	20·09	21·69
	100·00	100·00	100·00

Weight of finished concrete as laid.

	1	2	3
Lb. per cubic foot	154·1	153·1	151·2

Weight of finished concrete fully dried out.

	1	2	3
Lb. per cubic foot	145·1	143·4	140·4

Voids left by loss of water on drying (total absorption) calculated as percentage by weight.

1	2	3
6·21	6·72	7·69

(excluding absorption by aggregate).

Composition of dry concrete: percentage by weight.

	1	2	3
Aggregate	61·48	62·17	63·50
Sand	22·20	21·80	21·04
Cement	14·26	14·00	13·50
Water	2·06	2·03	1·96
	100·00	100·00	100·00

Weight of cement in 1 cubic yard of concrete as laid.

1	2	3
558 lb.	542 lb.	512 lb.

Approximate nominal composition of mix as usually stated.

4·6 cubic feet : 1·4 cubic foot : 90 lb.

The following assumptions had been made in arriving at the above :—

Specific gravity of limestone	2·8
,, ,, ,, sand	2·6
,, ,, ,, cement	3·1
Moisture-content of dry cement paste	14·5 per cent. of dry weight.

Mr. Browne, in reply, observed that he wished to express his thanks for the reception accorded to his Note, and also to the City Engineer and Surveyor of Liverpool (Major Herbert Hamer, M.I.C.E.) for permission to present it.

The depth of the mastic asphalt "veneer" coat to which reference had been made was $\frac{3}{4}$ inch. The temperature at which the "veneer" coat was applied (350/400° F.) was sufficiently high to melt the old surface to such degree that fusion occurred between the new and old materials. As the materials were exactly alike in composition, the process resulted merely in an increased depth of mastic asphalt—although, of course, a new roughened wearing surface was obtained.

Where the "veneer" coat was of rolled asphalt—which was manufactured at a central plant and laid at a temperature of 250°/275° F.—he understood that it was necessary to pre-treat the old surface with a "tack" coat of bituminous emulsion.

Mr. Lunn had commented on the statement that only about 55 per cent. of the war damage sustained by Liverpool's highways had been repaired to date. The actual present position was that, whilst damage was estimated at about £206,000, the expenditure incurred on repair work amounted to £116,000. All craters in highways—and there were remarkably few—were repaired as soon as possible after their occurrence, and

most of the damage to carriageways had long since been dealt with. There were, however, a considerable number of instances of damaged footways which could not be repaired until site clearance operations, which were still in progress, had been completed. Moreover, some areas of the City had sustained such extensive damage that there was, at present, no necessity for the continued use of certain roads. In such instances only temporary repairs had been executed pending redevelopment of the affected areas.

In reply to Mr. Sparkes, it was only for the *softer* bitumen and tar surfaces on tank-testing routes, and then mainly at " slewing "-points, that concrete or granite sets were substituted. Mastic asphalt surfaces had proved capable of withstanding even the heaviest tank traffic. The concrete was manufactured with Welsh granite aggregate.

Mr. Miller, in reply, observed that the experiments referred to in his Note had been made after a certain amount of experience had been obtained on the roads, and the reason for deciding that the maximum size of the aggregate should be $3\frac{1}{2}$ inches was that it was considered that with a larger size the running surface of a road would be too rough. If hardcore were used, which was much larger, sometimes $4\frac{1}{2}$ inches or 6 inches, the surface would be very rough and therefore good riding would not be obtained. It was also considered that $3\frac{1}{2}$ inches would be about the size of quarry rejects, which it was thought might be a source of supply for the type of work in question.

He agreed with Mr. Sparkes about the damage that might be caused to a cement grouted road if chalk aggregate were used. Chalk had been used in the case referred to in his Note because nothing else had been available, and the surface was not supposed to be a permanent one. The work done in Savernake Forest, where the chalk aggregate had been boxed in with grout, appeared to have been quite successful. It might also be useful to give the surface afterwards a slight dressing of cold emulsion, which would probably increase its life.

For consolidation he had used hand tamping. The object was to shape the road rather than to consolidate it.

With a fine sand more water was needed to get the same penetration and, if it were desired to use a very fine sand with a $1\frac{1}{2}$–$\frac{3}{4}$-inch aggregate, it would be necessary to increase the water-content. Therefore a very fine sand was not recommended for the aggregate gradation from $1\frac{1}{2}$ inch to $\frac{3}{4}$ inch.

The compressive strength had been obtained from crushing the cubes mentioned in the Note, and not from cores taken from the road.

He agreed with Mr. Keep that broken brick taken from damaged houses for use as coarse aggregate should be free from excessive quantities of old mortar, which was very detrimental. If the bricks were full of mortar, it would not pay to go to the expense of having them cleaned. In any case the broken brick should be thoroughly saturated with water

before grouting was started ; otherwise it would absorb a certain quantity of water from the grout.

Rolling before grouting had been practised in America, but not in Great Britain, so he could not say whether it was effective or not. A good plan might be to pin the stones together by passing a light roller over them once or twice. That could not be done with round beach gravel or any round aggregate, but with broken stone it might be quite effective.

He had not had any experience of having to loosen the stones with a fork.

He had not yet given any consideration to the shape of the particles, but he agreed with Mr. Keep that that might have some bearing upon the fluidity of the grout.

The difference between the quantity of water required with a coarse cement and that required with a fine cement was very small, and from the practical point of view it hardly merited consideration.

His experience had been that penetration could be obtained with a fluidity of 46 seconds, but he preferred to err on the safe side on a job and therefore suggested that 29 seconds should be about the maximum.

Mr. Billig's description of another method of doing grouting work on perimeter tracks was very interesting. Mr. Miller had not heard of that method before.

Mr. Keeble's statement that there was only one kind of admixture being used for cement grouting work might be true for Great Britain, but it was Mr. Miller's impression that others were being used in the United States of America.

He could not agree that light rolling of the coarse aggregate to " pin " the stones together would be detrimental to method (c) mentioned in the Note, but it certainly was not essential either for methods (a), (b), or (c).

In his opinion, a compressive strength of 2,800 lb. per square inch at 28 days would not be considered sufficient by most engineers for main road traffic.

The method of avoiding " caking " described by Mr. Keeble, whilst being effective, would no doubt in time cause damage to the drum of the mixer.

With practically the same cement-content used for cement-grouted roads as for ordinary concrete roads, it was difficult to agree with Mr. Keeble's contention that the same amount of expansion and contraction would not occur. Any cracks which did appear, however, would not be so noticeable as in the ordinary concrete road and, owing to the large-size aggregate used, the edges of cracks had not the same tendency to " fray ". Cement-grouted roads should, in the same way as ordinary concrete roads, be inspected periodically and any cracks found sealed with bitumen.

Mr. Miller's statement that a slight saving of cement was effected by the cement grouting method, was based on his experience in carrying out a number of road jobs, and not, as Mr. Irvine Watson had assumed, upon the data from the experiments described in the Note.

Mr. Hussell, in reply, expressed his thanks for the reception accorded to his Note and to the County Surveyor of Hampshire for permission to present it. The opinions expressed in the Note were not necessarily those of the County Surveyor.

In a period of war there was usually a great development in engineering science, and the recent war had emphasized that fact, with one rather notable exception. The various Notes presented were intended to show how war-time difficulties had been overcome, but they had, in fact, revealed that during the war very little advance had been made in road-making technique. It was true that during the war a certain amount had been heard about soil stabilization, and the grouting method of making concrete roads would probably be developed in the future; nevertheless on road engineering generally the war had had no marked effect. Therefore it would seem that road engineers should look to the future, and he believed that there was a wide field to be explored, not only in the design of road foundations and surfacings, but also in the methods of laying them efficiently and cheaply. Road making was an expensive operation, and the costs would have to be reduced if road standards were to keep abreast of the improved performance of road vehicles.

The invasion contracts were not " cost plus ". He had, in fact, prepared a schedule of items on a Saturday morning and handed it to the contractors during an inspection on the following Sunday. The list consisted of about twenty or thirty items, and in the circumstances it was gratifying that so few claims had been made.

Whereas Mr. Lunn's unclassified roads appeared to have grown naturally, in Hampshire a 12-year programme had been started in 1933 in which a definite standard was set for the unclassified roads. Some were of more importance for through traffic than others, and were given a sounder construction. Many roads in Hampshire had no metal on them at all, and those were giving trouble because the mechanization of the farms was doing a great deal of damage to them. The Ministry of War Transport were making additional grants to county councils for unclassified roads, to help the local rate-payers.

The war-time method of supplementary surface-dressing in Hampshire was not a very good method, but it had certainly met the war-time difficulties. It would have been better to employ automatic sprayers, spreaders, and so on, than to put down something which was not entirely satisfactory; but during the war it had not been possible to procure sprayers for all the roads in Hampshire, and execution of the work by hand machines, was necessarily slow. The method described in the Note had therefore been chosen as the quickest one in the circumstances.

He had expected that his observations about asphalt and concrete roads would arouse some comment. He agreed that it was not fair to take the Winchester by-pass as an example of the way in which concrete roads stood up to traffic, as it had been treated very badly by tanks, but other concrete

roads in Hampshire had been subjected to what he might call normal tank traffic, and there was no question that they had not stood up to that traffic so well as had the asphalt roads. In fact, he thought there was no doubt that the concrete by-passes would have to be resurfaced within a year or two. The asphalt roads in Hampshire, on the other hand, had never given the road authorities a moment's anxiety during the war.

Mr. Osborne had inquired whether asphalt roads had been subjected to continuous tank traffic in hot weather. The answer was that they had been used by continuous tank traffic in all weathers and the only permanent indentations were those made by stationary tanks immediately after coming to rest. The indentations were presumably caused by the heat of the tracks rather than by the weight of the vehicles.

Mr. B. F. J. Bradbeer, in reply, observed that a decision whether planing was necessary or not could be made only as a result of practical observation and the knowledge of the surveyor of how many times he had surface-dressed the road. Another point of practical observation was the particular type of creep and corrugation which an experienced man knew could only come from an accumulation of dressings. The combination of a polished surface and corrugations was the worst possible condition; it caused the wheels of a car to bounce and made the car much more prone to skid than it otherwise would be.

The effect of heat upon the material which was scraped off the road was to reverse approximately the tar-oil : pitch ratio. In fresh tar the ratio of tar-oil to pitch was about 40 : 60, and those proportions were very roughly reversed, so that the material became far less ductile and more brittle. He did not think that effect penetrated very deeply into the surface of the road, because as the heat penetrated it fell off very rapidly. Considerable heat was required to affect an appreciable thickness of the road, and one of the problems of the operation was to apply sufficient heat per unit area of road. In cold weather the large heater had to pass over a single area two or three times, whereas in very hot weather it could go forward continuously, so that the work could then be carried out very much more expeditiously and cheaply. In cold winter weather the output might fall to very nearly half the output on a warm summer day.

One practical effect required watching. The tearing off of the softened surface (it was called planing, but it was really only shearing or tearing off) appeared to call for the healing action of the rolling tires of traffic in warm weather to restore the surface of the road and so prevent it fraying out. If the work was done late in the autumn there was a risk of the surface ravelling before an opportunity occured to protect it by a further dressing. The ideal time for the treatment was obviously the spring and early summer. If it were done then, the application of another surface dressing after a few weeks or months of traffic under the best conditions would give the desired result.

He agreed that the laying of carpets with a machine such as the Barber-

Greene machine should be preceded by heating and planing. On many roads which suffered from an excess of surface dressing planing was a *sine qua non* in order to obtain the full benefit of the carpet. He knew of roads on which carpets had been laid, and the surveyor had endeavoured to produce an open texture surface, where within a year or two the open texture had disappeared, because of the welling up of the surplus tar from underneath, which would not have occurred if the surface had been planed first. A direct economy might be effected in the thickness of the carpet laid if it were certain that the same net thickness would exist over the whole surface. It was reasonable to say, he thought, that after planing the resurfacing could be done at 16 yards to the ton instead of 12 or 14 yards to the ton and another saving thereby effected.

He agreed with Mr. Corfield that the supply of material to the Barber-Greene machine at the rate of 150–200 tons per day was a very real problem, especially in those counties which were not naturally stone-bearing and had not facilities, such as, he believed, were enjoyed in Hampshire, for producing material for themselves. In Sussex it was not possible to obtain sufficient material from one supplier to keep a Barber-Greene machine in operation, and it was quite impossible to mix supplies from two different sources, as the setting of the machine depended upon the consistency of materials fed to it. He believed that the protagonists of the Barber-Greene machine had the difficulty of supply well in mind and that a subsidiary firm was being formed—it might be in existence by now—which would accompany the Barber-Greene machine with portable mixing-plant. If the surveyor responsible would accumulate stocks of dry stone at a suitable place near the work the portable mixing-machine would come with the Barber-Greene machine, pick up the dry stone, and make what the road engineer wanted, to his own specification.

Mr. Lee, in reply, observed that he wished to express his thanks for the reception accorded to his Note.

All the surfaces in Sussex were granite, but he had experimented on a surface consisting of 4 : 1 beach concrete and the result had been perfectly satisfactory. A certain number of whole stones had been removed, but only to the extent of about one per square yard.

The production of a level surface with the machine described in his Note was a matter of skill, but after a test on some thousand square yards he had been perfectly satisfied with the result and the contractors had been given orders to carry out considerably more work. He agreed that if some method of controlling the machine could be devised it might be an advantage, but the contractors had told him that they could control it to quite fine limits. In Sussex a section of a concrete carriageway on an embankment collapsed to some extent, and the concrete road sank 7 inches. The concrete was pumped up to approximately its original level by the cement grout process and it had now settled with certain of the joints with an upstand of perhaps 1 inch. The contractors had inspected the site

and had told him that they were quite prepared, by using the machine in question, to produce a good surface which would conform to within $\frac{1}{4}$ inch on a straight edge, and he would be interested to see that done.

The cost for the work given in his Note referred to about seven or eight months ago; he believed that since then both wages and plant costs had increased.

In comparing the cost of the work in question with the cost of curing slipperiness by other methods, the probable life of the concrete road when it was roughened should be taken into consideration. Plenty of concrete roads in Sussex were 20 years old and were as good to-day as when they were put down, in so far as the actual concrete was concerned, and he saw no reason why they should not last another 20 years, or even much longer. If they did so, and if the roughening process lasted for a considerable number of years, as indications at the moment appeared to show that they would, the method might prove cheaper than putting down a carpet. Since the Meeting information had been received regarding the treatment of concrete roads with a gravel aggregate. Upwards of 10,000 square yards had been treated in one county with satisfactory results; very few stones had come out, and there was no appreciable corrugation.

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