led, there will be a not unnatural reluctance on the part of the manufacturer to follow.

The Author has a firm belief in the value of soil stabilization in Great Britain as a means of providing sounder roads more economically, and if this Paper does no more than encourage potential users and manufacturers to discuss their problems, he considers that it will have served its purpose.

ACKNOWLEDGEMENTS.

The Author wishes to express his thanks to Mr. H. E. Aldington, C.B., M.I.C.E., Chief Engineer, Ministry of Transport, for permission to publish the Paper and for the loan of the film used in its introduction. Thanks are also due to Mr. H. Stanley Keep, M.C., M.I.C.E., for much helpful comment and criticism.

The Paper is accompanied by three photographs, from which the Figures in the text have been prepared.

Discussion.

The Author introduced the Paper with the aid of two films. He said that road engineers were often inclined to talk of the miles of stabilized road foundations which they hoped to construct in the near future, but, when it came down to details, the questions arose of what plant was needed, whether it was available, and where it could be obtained. Unfortunately the answer usually had to be that the plant was made in America and would have to be brought over, so that it could not be obtained at present. An excellent opportunity existed for British manufacturers to take advantage of the growing market; but an assurance that it was a growing market would have to come from civil engineers in general and from road engineers in particular. The experience in America should afford some assurance, and he saw no reason why similar success with soil stabilization should not be achieved in Great Britain and in the Dominions and Colonies.

He wished to express his thanks to Mr. Gough Cooper for permission to reproduce *Fig. 1*, and to the Director of Road Research in respect of *Figs. 2* and *3*.

The Chairman observed that he could assure the Author that every effort was being made in the proper quarters to encourage British manufacturers to produce the machinery required, not only for soil stabilization, but also for general engineering work, and there was no stronger supporter of those efforts than the Chief Engineer to the Ministry of Transport, who was doing all he could to encourage manufacturers in Great Britain to proceed with its production.

Sir George Burt observed that the necessity of covering the sub-grade as quickly as possible, in order to obtain a good foundation for a road, could be inferred from the Paper, but he considered that that point might have received a little more emphasis. The Author had mentioned the blazing of trails in countries under development and had referred politely—or possibly a little sarcastically—to " the road builders of those days " ; but the simple facts that he had set out were too often ignored to-day. Sir George believed that the sub-grade should be covered quickly, and that in the old type of contruction that was better done than it was to-day. On the good old water-bound macadam roads, the covering up was automatically done much more quickly. In those days 5-ton loads had not to be dealt with ; horses brought 1½ ton along at a time, and the sub-base could therefore be covered up much more quickly.

The Author had stressed the necessity for soil stabilization methods to be directed to ensure that the soil had the best water-content after compaction ; but, apart from the base, in the British climate a similar condition of the sub-grade was equally important and was extremely difficult to obtain. Under the present specifications and the present supervision, a perfectly good concrete top was too often laid on what was really little better than an inch or two of mud. Sir George could not imagine any engineer allowing the foundations of a bridge or any other structure to be laid under conditions similar to those in which road surfaces were frequently constructed. That applied not only to road making but also, unfortunately, to buildings, unless an engineer was in charge of the foundations. It did not seem to be recognized that, in the case of a clay soil, it was vital that the sub-grade should be covered quickly.

The Author had suggested that a priming coat should be applied to a stabilized road before the wearing surface was put on. Sir George was not convinced that, in the case of a clay soil, that should not go on to the sub-grade as well. He did not mean that it was unimportant to seal the base, but he felt that the sub-grade should receive consideration.

He considered that the Author had not stressed the advantages of the mix-in-place method sufficiently—and especially the important advantage that that method enabled the sub-grade to be covered up much more quickly than was possible by any other method. Sir George wished to lay stress upon the sub-grade because he felt that many road failures were caused by foundation failures, and not by a failure of the concrete or other surface. It was not an exaggeration to say that, under present conditions, the sub-grade was often exposed for days, and sometimes for weeks, before it was sealed. That would not be allowed in the case of any engineering structure.

With regard to the travel-mix method, he was rather doubtful whether at present the plant was in a sufficiently advanced state to be really efficient. The Final Report of the British Engineering Objectives Sub-Committee (No. 918) contained a photograph of a soil-stabilization machine consisting

of a hopper for distributing the stabilizing agent, rotating blades for mixing it, and two rows of pneumatic-tired wheels for compacting the mixed soil. Apparently the consolidation was effected by rubber tires, and not by sheep's-foot rollers, so that presumably the consolidation was done from the top down, instead of from the bottom up, as by a sheep's-foot roller. The Author had stated that the machine used for the travel-mix method was not an unqualified success. Recently [1] a photograph of a very much larger machine produced in America had been published. He did not know whether any projects in Great Britain were large enough to carry plant of the size of the American tool, but he considered that at the moment those very large machines were still rather experimental, and they were certainly not yet perfect.

He agreed that the plant-mix method could be efficient; but it was more expensive and presented a less desirable alternative, principally because it was much slower than the mix-in-place method and the sub-grade could not be covered up so quickly. In the British climate,where sometimes no whole fine day occurred for weeks on end, that was a very important point.

Sir George considered that rubber-wheeled tractors were the most economical. With the plant carefully selected, it was possible to carry all the gear needed on a 5-ton lorry. With track vehicles, fairly heavy expenditure on low loaders had to be incurred, and more handling was required. The track vehicle might be suitable on a big job, but he hoped that the wheeled tractor would become general, however small the job, and he believed that it would prove the cheaper. The equipment could be, and for most work should be, kept within the limits of the Fordson vehicle.

He agreed that the ripper was necessary if the road were really hard ; but on nine jobs out of ten the roto-tiller was all that was necessary. It made a thoroughly good job, especially when it was fitted with an efficient depth-control.

At the moment application of stabilizers was probably the weakest link in the whole chain, particularly if attempt were made to stabilize with cement—which was probably the most satisfactory all-round stabilizer at present. Cement involved much greater bulk than the chemical stabilizers, such as the sodium rosinates, but the latter were not yet produced in any quantity in Great Britain. One might dislike paying too many shillings per ton for the cement, but that was better than paying too many dollars per ton for the rosinates.

The weather in Great Britain was not often dry enough for moisture control to be needed, but when it was needed it formed the greatest time bottleneck.

Sir George agreed that spare plant was essential on the job, as it was vitally important to avoid any delay caused by breakdowns. Even quite

[1] *Engng. News Rec.*, 3 April, 1947.

short stoppages, in the British climate, might have a very bad effect upon the quality of the work.

He also concurred in the necessity for good timing on the job, and he believed that when the soil stabilization method of preparing foundations for roads developed—as he hoped it would—that aspect of the matter would assume much more importance, not only from the contractor's point of view, in order to secure economy, but also in ensuring that the work was properly done, when better roads would result.

The transport of stabilizers was a serious problem, and he knew of no really satisfactory mechanical method of evenly spreading the comparatively large quantity of cement that had to be used. He believed that the only way was the mix-in-place method, namely, to spread the cement bags at correct intervals all over the site ; but on small jobs (and he wished to emphasize his opinion that that method should be used on all jobs, whether large or small) the handling of the cement presented considerable difficulty. The Author was, perhaps, rather optimistic in his reference to the use of scrapers for the importation of added soil—at all events, so far as the south of England was concerned, where either the soil was on the site or had to be carted for considerable distances.

He considered that the application of soil mechanics principles to road construction had not received nearly enough attention. Provision of the necessary equipment should present no insuperable difficulty. A good deal of equipment was available, and, although it was not as good or perhaps so cheap as it would be when further development had occurred, it would be capable of a thoroughly good job.

Finally, Sir George shared the Author's hope that the Paper would encourage further thought and experiment on the subject of soil stabilization. He had been a road builder for many years, and he believed there was considerable room for improvement on the work which was being done at present in that connexion.

Mr. Henry Grace observed that he favoured the use of cement as the stabilizer, because, as well as controlling the moisture-content of the soil, it provided additional cohesion, and ultimately produced something like a very weak concrete, which was a considerable advantage.

During the war he had been connected with a number of stabilization jobs for military purposes, such as roads to camps, parking-areas, and perimeter tracks, and he had been instructed that what was required was a bad job quickly, which was what he had managed to produce ! From the experience then gained, he could endorse most of the statements made in the Paper, and, reading between the lines, he gathered that the Author had experienced a considerable number of the difficulties which he himself had met. Had the Author found any difficulties in connexion with cement unloading, or with soft spots in the sub-grade ?

The Author had not mentioned the training of plant operators, which was a subject on which Mr. Grace felt very strongly. He had had to train

a new set of plant operators on every job he had undertaken. When stabilization was mentioned to the normal plant operators, they usually thought the speaker was mad ; but when the job had been done and they had been shown that something hard could be produced from something soft they began to take an interest in the subject. Unfortunately, as soon as he had succeeded in gaining their interest he had lost them, and had had to start again with new plant operators !

He considered that a satisfactory job could be obtained only by a team of skilled operators working together. Later in the war, in the Far East, he had been able to obtain a team of semi-skilled operators, who had produced much better results.

On a section of a perimeter track which he had constructed at the Kaitak aerodrome in Hong-Kong, the soil was stabilized with cement and, after ten months' operation and only a surfacing of a thin priming coat, no cracking, spalling or disintegration of the surface had occurred.

Although the Author had expressed his firm belief in the value of soil stabilization in Great Britain, Mr. Grace still felt rather doubtful. He considered that account should be taken of the very considerable difficulties and drawbacks. For example, he had found that it was possible to operate soil stabilization processes for only six months in the year ; and even in the summer—especially such a summer as that of 1946—considerable trouble was experienced. If a really wet spell should occur, water, in addition to wetting the soil which was to be stabilized, would get down into the sub-grade and weaken it, and in order to make a satisfactory job it would be necessary to blade off the soil, cut up the sub-base, dry that out, compact it, and restore the soil to its place. That needed time and added considerably to the contractor's risk, so that he would have to quote a higher price for the job than would be necessary if the British climate were more reliable.

Moreover, Mr. Grace had been informed by geologists that Great Britain included more different varieties of rocks than any other similar area in the world, and that led to very different soils, varying not only from area to area, but also from field to field. On most jobs that he had undertaken it had been necessary to haul in soil of a suitable character from some pit ; sometimes he had mixed it with the soil already on the site, but generally had used only the soil that was hauled in.

He considered that the real future of stabilization work lay overseas, especially in the Far East. Various soils in Southern China, in Malaya, and in Ceylon, were very suitable for stabilization : the soils in the tropics were naturally more friable and more sandy than those in England, labour was plentiful and cheap, and he had found that the workers understood the spreading, mixing, and watering of soils, and could produce a very fine job by hand.

Mr. H. J. B. Harding observed that in the case of soil stabilization the old question, " Which came first, the hen or the egg ? " might be varied to,

" Which should come first, the stabilization work or the plant ? " One reason why the provision of plant in Great Britain was lagging was that manufacturers could not make, nor could contractors purchase large quantities of plant until some indication was forthcoming that the people who were responsible for making roads were likely to embark on stabilization to some extent.

A few years ago he had visited an experimental road, in connexion with which the Author was one of the leading figures. Mr. Harding's firm had been able to lend one or two pieces of plant, and he had been impressed by the extraordinary and heterogeneous mixture of very heavy earth-moving and also light agricultural plant that had been collected, which included roto-tillers. That was all the plant that could be obtained at short notice during the war. Shortly after, the firm had obtained a " rote-hoe," towed by a Fordson tractor, and that had proved successful ; various investigations had been made with the object of evolving a light-weight plant for light roads and farm roads, in some logical fashion.

The original roto-hoe, by the manufacturer, was fixed to a tractor. The manufacturer did not want to go to the expense of making alterations, but Mr. Harding's firm had altered the roto-hoe so as to make it detachable from the tractor, and had also provided a gear for altering the depth of cut.

After various trials, the firm concluded that the best tractor for the purpose was a Fordson Major, and a number were obtained and the chassis lengthened in order to take a blade underneath, and adjusting gear, and a comb which could be bolted on in place of the blade, as a form of scarifier.

The Author had stated that a double sheep's-foot roller needed a heavy tractor to pull it ; but even one caterpillar tractor necessitated servicing and heavy maintenance. A single-drum sheep's-foot roller towed by a Fordson Major tractor had been tried, and in many cases had proved quite sufficient. If extra tractive effort were required, the tractor could be fitted with roto-peds. Naturally, twice the number of passes were needed with a single-drum roller, so that two tractors and two rollers were necessary to do the work of one double-drum roller, but the much cheaper form of tractor and the different type of tractor driver probably made that a practicable proposition. Moreover, the tractors would be interchangeable for towing any particular plant.

Mr. Harding agreed that more than the minimum number of tractors should be available on any job, so that one could be serviced, and also that plant should be augmented by trailers to carry cement ; for moving one tractor could be mounted on the trailer and towed by another tractor. A useful piece of plant was a " muledozer," consisting of a bulldozer attachment which could be fitted to a Fordson Major tractor. If something heavier were needed, a Fordson Major with roto-peds and a blade could do a considerable quantity of work.

The minimum plant for that kind of work consisted of a " rote-hoe," a

wobbly-wheel roller, and sheep's-foot rollers. It was better to have two of everything, so that perhaps four single-drum sheep's-foot rollers would be needed, with a minimum of six tractors. The single set—one rote-hoe, one wobbly-wheel roller, and one spray cart—could easily deal with 1,000 square yards per day. Such light-weight plant might be used not only for forming roads but also for sub-grade work on arterial roads. In a number of Papers discussed by the Road Engineering Division the importance of thickness of sub-base to spread the load where the ground was soft had been emphasized ; and on an arterial road it was possible to visualize the heavy plant and the caterpillar tractors, with earth-moving equipment, making the formation and moving the materials. By that time the gradient would be easy, and the light-weight plant would be able to follow behind in order to deal with any sub-grade of varying thickness, which would free the expensive caterpillar plant for its more vigorous work.

Clay was not suitable for stabilization, but a clay soil which could be worked into a tilth could be stabilized if sufficient sandy material were imported. Much of Great Britain had a clay base, and work had been done by Mr. Harding's firm in which either hoggin or sand-gravel was imported and mixed in place by the plant described above, to form a cross between a stabilized soil and a weak concrete. That formed a quick method of covering clay, especially if a hoggin could be obtained which, when spread, would allow the passage of a lorry over it. In that case lorries could back over the hoggin as it was dumped, so that they would never run on the clay, and then the hoggin could be fairly rapidly mixed in place.

Mr. H. L. Kerr agreed that the construction of carriageways by stabilization was suitable for small jobs and for jobs which had to be done quickly. He had made some experiments in that connexion, because he had had occasion to construct some estate roads quickly, at a place where the soil was very suitable for the purpose. About one mile of carriageways had had to be made with great speed, so that building operations should not be delayed, and the work had been completed in about a month. He did not know any ordinary method of road construction which would have enabled him to carry it out nearly so speedily, and he owed a debt of gratitude to the Author, among others, for assistance in that work.

With regard to the introduction of materials where the soil was too clayey he doubted whether roto-tillers would, in fact, pulverize clay soils sufficiently to enable a satisfactory material to be finally obtained. On the job to which he had referred the roto-tillers seemed to break the clay into larger or smaller lumps, but no complete pulverization was effected, and, whatever materials had been added, he doubted whether a satisfactory stabilized mixture would have been forthcoming. In fact, the section which he had constructed and which ran through a rather clayey soil, had failed completely.

Mr. Kerr thought that some consideration should be given by manu-

facturers to the provision of pulverizers that would tackle clay satisfactorily —not the very heavy Wealden clays, but the ordinary clay found in many soils throughout Great Britain.

He agreed that a ripper was necessary to start with, but he considered that some of the smaller roto-tillers of the agricultural types were not quite satisfactory for mixing soils. The larger machines, such as that illustrated in *Fig. 1*, worked at such a speed that good mixes were obtained, but his experience was that the ordinary agricultural tillers did not rotate fast enough to give satisfactory pulverization. On the job which he had done, no grader had been used, but the soil, when mixed with the stabilizing agent—cement—was rolled directly with an ordinary smooth-wheeled roller. He considered that in certain soils of a sandy and gravelly nature sheep's-foot rollers were not really necessary, but he agreed that they effected consolidation down to the sub-base. The results which he had obtained with the use of a roller only after the soil-mixer had been over the road had not been entirely satisfactory; but roads were now being used, after having been sprayed once, with a bitumen emulsion, and their riding qualities were fairly good. The roads, however, were not sufficiently even to enable the use of that method to be considered for a completed road without some kind of carpet being put on the top. Mr. Kerr had hoped that it might be possible to use those soil-stabilized roads unsurfaced, and he intended to keep them unsurfaced so long as building traffic was passing along them, because he believed that that would give some indication of the way in which they would stand up to fairly heavy traffic.

He agreed with the Author as to the difficulty of dealing with the addition of water, and he considered that it was desirable that manufacturers should try to devise some plant which would be easily obtainable and would enable large quantities of water to be added to the soil-cement, or other stabilizing agent, by some means which would not necessitate the machine having to go on the carriageway at all. It was very difficult to get rid of wheel tracks in the soil-cement when a heavy machine had passed over the road after the cement or other stabilizer had been added and the soil-mixer had gone over it. A machine with an arm at one side, which would enable water to be distributed from the side of the road, would be advantageous.

The Author's remarks about timing were worthy of careful study.

Mr. Kerr was interested in the suggestion that soil-mixers should be used in agriculture. If a demand by farmers and agriculturists arose for the type of machine that could be used for a soil-mixer manufacturers of such machines would have an assured market for their products. There could be no doubt that soil-mixers gave a wonderful tilth.

Mr. Kerr advocated more contact between road engineers and research workers. The experimental section of the Ministry of Transport and the Road Research Laboratory had been of the greatest assistance to him and he was sure that they would be of similar assistance to others who

approached them on the subject. He considered that the average road engineer did not make nearly enough use of the experimental work which had been done by those two bodies.

Mr. L. R. Robertson observed that it was very refreshing to have a Paper dealing with the practical details and problems of soil stabilization, and it would be very helpful in framing specifications.

He considered that it was definitely advantageous, in most of the operations involved, that a certain ratio should be maintained between the forward travel of the plant and the number of revolutions of the mixer or other item. The way to deal with the problem was to have an auxiliary gear-box in one of the drives, and make use of the power take-off in the tractor, thus saving an extra engine and the maintenance and stock of spares which would be required for it.

Curing was a nuisance, because the engineer had already enough operations to keep him more than busy, and, as stabilized soil was cheaper than concrete, the proportionate expense of the curing was greater. It would seem to be ideal if the curing, the priming, and the first surface dressing could be combined into one operation, perhaps by spraying with bituminous emulsion immediately after the final consolidation of the soil cement and then spreading $\frac{3}{16}$-inch chippings and lightly rolling at once. Did the Author think that it would be possible to develop that method successfully ?

With regard to watering, Mr. Robertson wished to emphasize the very drastic effect of a drying wind combined with sunshine. It was essential that the water-spray should have a high capacity, as possessed by the modern type of spray. On a sandy soil especially, drying-out occurred, and it was essential to consolidate as soon as possible after the final mixing in of the water. The smooth roller presented a definite advantage in that connexion over the sheep's-foot roller, which was slower and left the surface of soil loose. In the plant-mix method, even if excess water were added in the mixer to allow for drying-out, such drying-out would occur only at the surface of the soil while it was being transported and dumped, and an even water-content as finally consolidated could not be obtained unless the soil were mixed again in situ.

On the question of plant Mr. Robertson felt strongly. It seemed that for certain types of civil engineering plant the ordinary laws of supply and demand did not operate quickly enough, and he considered that closer touch between road engineers and the industry would be helpful. He suggested that a specification might be issued to manufacturers from the Road Engineering Division for the new types of plant which were required, together with some indication of the probable demand for them, instead of the matter being left to ordinary supply and demand.

Mr. D. J. Maclean observed that in the past, whenever a Paper had been submitted on the subject of soil stabilization, questions had been asked whether it could be used in Great Britain, what applications it had,

and, particularly, what was done in the case of clay soils. Great Britain was predominantly a clay country and it was known that it was very difficult to stabilize that type of soil. Another frequent question was what should be done when the soil was too wet, at it often would be, owing to the British climate.

He wished to advocate the wider use of cement stabilization in the preparation of the sub-base of arterial roads.

Under efficient laboratory conditions, if a medium clay were stabilized with 10 per cent. of cement, the compressive strength of that soil could be increased from about 10 lb. per square inch to about 100–150 lb. per square inch. Assuming that the same could be done in the field, a tenfold increase in the strength of clay foundations would mean that a much cheaper form of top surfacing could be constructed ; its thickness and quality could be reduced and the overall result would be an economy.

It should also be borne in mind that a clay formation had to be prepared a good way ahead of the surfacing and that often it became very weak owing to its being subjected to rainfall. The stabilized material would have an added resistance to the effect of rain, and that would present a further advantage. Therefore, the difficulty with clay soils was not that they could not be stabilized, that was, increased in strength and made more resistant to moisture, but that in the field difficulties were encountered which were not apparent in the laboratory. That was because the processing of the soil in the field was much more difficult. The essential requirements were to pulverize the soil, mix the cement into it very thoroughly, and finally adequately to compact the processed material. Compaction was fairly well understood and the equipment was available for carrying it out, but mixing was more difficult, usually because it was very difficult to pulverize the soil. In the past, when it had been necessary to use agricultural equipment to pulverize the soil, failure had sometimes resulted, but with the introduction of plant such as the Siemen pulverizer and the rote-hoe, an entirely different outlook on the situation had appeared. With those pulverizers it should be possible to approach the strength of soil-cement that had been obtained in the laboratory. He hoped that the Paper and the discussion would encourage manufacturers to produce machines which would pulverize soil still more effectively than had been possible so far.

The Author had, perhaps, been rather too general in his statements, and had appeared to have at the back of his mind cement stabilization by the mix-in-place method. Mr. Maclean would have welcomed more details about the treatment of different types of soil and the differences in processing that had to be used with different types of stabilization. In particular, he did not believe that any one method could be laid down for the compaction of stabilized soils. The Author had suggested for that purpose the use of sheep's-foot rollers, followed up by pneumatic-tired rollers ; and that might be suitable for some soils, but not for all soils. It was important

to effect the best compaction, and the right plant would have to be used for the particular soil in question. The smooth roller was probably the best to use for the stabilization of gravels and sheep's-foot rollers should be confined to the more cohesive soils. Moreover, recent work in the study of the various types of compaction plant had shown that the sheep's-foot roller needed far more passes than the smooth roller and therefore smooth rollers might eventually be found to be preferable to sheep's-foot rollers, on economic grounds.

*** **Mr. F. W. Pearce** observed that during the recent war he had had opportunities of noting, as a pilot, the characteristics of various types of airfield surface. At one overseas station he had been able, over a period of years, to observe the construction and subsequent behaviour of a cement stabilized runway system.

The runways were constructed by removing the small quantity of vegetable soil and then tilling and admixing cement with the subsoil, which in that case was a decomposed granite. Standard agricultural machinery and native labour were used throughout, and the finished work was protected from the sun and kept watered.

The work generally proved successful, and, from the pilot's point of view, the runway system was infinitely preferable to the dusty grass surface, which was of almost concrete hardness during most of the year.

Prior to the construction of the runways the small quantity of vegetable soil present was being rapidly blown from the airfield surface into the surrounding " veld " by the slipstreams of aircraft taking off.

The chief defects appeared to be :—

(1) The appearance of cracks additional to those left as construction joints.
(2) Spalling of the surface in small localized areas.
(3) Growth of weeds up through the stabilized soil.

Mr. Pearce could well imagine that the economical form of construction was justified in view of the probably short life of the airfield, but he had no doubt that, in the absence of any regular maintenance to the stabilized soil surfaces, the rate of deterioration would be such that in ten years the condition of the runways would be little different from that of the surrounding " veld."

The Author, in reply, expressed his thanks to the contributors to the discussion, from which it was evident that a considerable measure of agreement existed on the views which he had advanced.

He had been glad to hear the Chairman's statement that the Ministry of Transport appreciated the need for stabilization plant, because not much of it was available yet.

One way of ensuring rapid covering of the sub-grade was to arrange the

*** This contribution was submitted in writing.—SEC. I.C.E.

work so that the existing soil would not be uncovered until fairly near the time when it was to be processed. By keeping its natural grass or other covering it would remain in the requisite moisture condition until just before work was started upon it.

The necessity for keeping clays open longer than was desirable could be overcome by grading the foundation 2–3 inches proud ; it might slough, but it would be satisfactory so long as it was graded off at the last moment before the stabilized base was formed.

He agreed that a priming coat between the sub-grade and the stabilized base would be useful if by that means the sub-grade could be maintained not overmoist.

The travel mixer to which Sir George Burt had referred seemed to be a machine with all the pieces of plant that were required built on to it ; he believed that it was a very large machine and he was not sure that it had been very successful. He believed, however, that the Americans had used many of the ideas embodied in it as a basis for their more recent designs of the smaller travel mixers, with which they had been more successful.

He concurred in the desirability of using rubber-wheeled tractors, and he considered that that if one or two of the tractors were fitted with roto-peds, as Mr. Harding had suggested, even a large job might be done with Fordson Majors only. Mr. Harding had relied upon the Fordson Major with about 3 feet of extra length on it for grading, but the Author did not believe that was enough. Many passes had to be made to remove a hump in the soil which a larger machine would take out at one sweep.

With regard to the film showing of soil-cement and the advantages of the extra cohesion, after even a slight shower of rain about 2 inches of soil stuck to one's boots, whereas after the soil-cement work had been done the whole of the concrete for the bays which went in on the top was hauled over that length without any impression being made on the base, and no hold-up occurred owing to wet weather ; the hauling could be done under any conditions.

He agreed with Mr. Grace and thought it was very desirable to keep a trained gang to operate the plant, going from job to job.

Mr. Grace's statement that the British weather made it possible to work during only six months of the year might be a difficulty in some ways ; but on the job to which Mr. Kerr had referred the work had gone on steadily, mixing being done in the rain, and no trouble had been experienced. The work had been quite successful, admittedly with a sandy soil.

There seemed no reason why good work should not be done in the Far East by hand, so long as the men were given levels to work to and enough labour was available. In Great Britain there was not sufficient labour, and it was necessary to think more in terms of mechanical plant.

Mr. Harding had evidently devoted considerable thought to obtaining a proper outfit of plant, and the Author wished to emphasize the value of that plant ; the plant should be a coherent whole. The Fordson Major

with a blade down in front of the rubber-tired roller was a very useful device. If the Fordson Major were used for towing the roller, the blade could be touched down on the ground at the same time, and as the roller made its ridge and furrow markings those that had been made on the last trip could be graded out.

With regard to Mr. Harding's statement that the tractor operator could operate the spray bar from his driving seat, the Author could not understand how the tractor operator, who was in the front, could see what was happening to his spray gear while he was driving.

Several speakers had referred to the problem of heavy clay soils. If the clay were of such a kind that sand could be mixed with it, soil cement could be made, using some of the clay; but if the clay were of such a difficult type that it could not be pulverized with the equipment available, it would be necessary to grade the clay down below the finished surface and import something better and, if necessary, put the cement into the imported material; in other words, it would be necessary to blanket the clay with soil which one could deal with in practice.

If only for the protection of the soil-mixer, which was a fairly expensive machine, the ripper should be run through first, because on nearly every job it was impossible to tell what might be found—brickbats, the remains of old temporary roads, or even electric cables.

The Author agreed that sheep's-foot rollers were not needed on sandy soils. That had been borne out on the job to which Mr. Kerr had referred. Effort should be made to effect compaction without sheep's-foot rollers, because, as had been mentioned in the Paper, it was possible to deal with much more ground in a day if the rollers could be put on immediately the soil-mixers had finished.

Soil-mixers would probably be found useful in agriculture, but he believed that farmers liked to plough, then leave the land to aerate for a time, then cultivate, and then disk; whereas, if the soil-mixer were used, all of the work could be done at once and the soil left on the top would be aerated, but there might be a depth underneath which would not obtain the benefit of the air to the same extent. He agreed, however, that if a case could be made out for using soil-mixers in agriculture they should be made in large numbers; that would help the road engineer.

In reply to Mr. Robertson, the curing was normally done with water; but it could be done with bitumen, if a grade of bitumen could be obtained which would be suitable for priming and would soak into the soil to a certain extent; probably if it were desired to spray it afterwards a heavier grade of bitumen would have to be used, so that it would hold the chippings. It might be better to cure with water for a day or two, and put on the priming afterwards.

In reply to Mr. Maclean, the Author had considered it preferable to give a more or less general picture of what could be done in the way of

soil stabilization, and he had stressed the use of cement because he had done more work with cement than with other materials.

The surface cracking referred to by Mr. Pearce was not regarded as a serious objection in soil-cement, especially if the soil could be given a surface seal soon after construction. Weed growth could be prevented provided that a road carried sufficient traffic; the problem would be greater in the case of airfields. Had the airfield in question been a permanent one, a substantial surfacing would doubtless have been specified and that should have prevented deterioration of the soil-cement base.

The Chairman announced that the constitution of the Divisional Board for session 1947–48 would be as follows :—

Mr. W. H. Morgan (*Chairman*)
Mr. H. E. Aldington.
Mr. Arthur Floyd.
Dr. W. H. Glanville.
Mr. A. C. Hughes.
Mr. Joseph Rawlinson.

Elected by the members present at the Meeting, in accordance with Rules 10 to 14 :—

Mr. B. F. J. Bradbeer.
Dr. A. R. Collins.
Mr. R. R. W. Grigson.
Mr. E. B. Hugh-Jones.
Mr. F. N. Sparkes.

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