On its discharge into the mixer the mineral aggregate should be at a temperature of between 300° and 350° F. As soon as the whole batch is in the mixing chamber, bitumen at 350° F. is to be added to it at the rate of 8 to 9 gallons per ton of stone. Mixing must continue till every particle is uniformly coated with the hot asphalt—the time varies with the size of the batch and the character of the particular stone being mixed—but usually one minute is sufficient after the addition of the bitumen.

When tar is used the required temperature is only 260° to 280° F. and the quantity of tar to one ton of stone would be 9 to 12 gallons.

The bitumen kettles shall be of ample capacity for a complete day’s run of the plant and so designed as to give uniform heating of the bitumen.

The bitumen bucket for measuring the bitumen and applying it to the mixer must be balanced on a suitable scale to ensure exact weighing of the bitumen. This scale is to be provided with an adjustment to compensate for any solidified bitumen which may accumulate on the bucket.

The bitumen kettles are to be provided with suitable thermometers for recording the temperature of the bitumen and the plant is to be provided with at least two protected thermometers for testing temperatures of stone, sand and mixture.

The different kinds of sand, stone, etc., are to be stored separately and precautions taken to prevent these materials becoming mixed.

Preparation of Mineral Aggregate.—Coarse and fine aggregate may be fed at the same time into the drier but after heating the coarse aggregate must be separated from the fine by means of screens and stored in separate bins. The plant must provide suitable arrangements for screening and storing before weighing and mixing.

The different grades of fine aggregate should be correctly proportioned before being fed into the drier.

Mixing.—The mixer shall first be loaded with the full batch weight of aggregate, the mineral filler shall be added and the whole thoroughly mixed before the bitumen is applied.
The bitumen shall be poured into the mixer in such a way that a thin stream the full width of the mixer falls on the mineral aggregate.

The minimum period of mixing shall be as follows:

- **Binder course** .... 40 seconds.
- **Coarse graded asphaltic concrete** .... 40 "
- **Fine graded asphaltic concrete** .... 60 "
- **Sheet asphalt** .... 60 "

**Transporting the Mixture.**—The mixed batch should be discharged into a sheet-iron lined cart or motor truck. It will usually be found that one ton motor trucks are best for hauling the hot mix from the plant to the site of the work. These one ton loads arrive hot and keep the spreaders and rollers steadily employed. Heavy loads are likely to arrive below the required temperature for easy handling partly because of the time required to mix sufficient batches to make up the load and partly because the first batches into the truck are the last batches to come out on the road. In addition large loads leave the spreaders unoccupied between loads and overwork them when the load is delivered. The men hurry to get the material spread, while it is hot enough to handle and uneven spreading usually results. It is an advantage to have the mixing plant as near the work as possible, but hot mix can easily be carted up to 12 miles and in the tropics probably up to 20 miles or more and still arrive hot enough for easy spreading. The mix should be at 225°F to 325°F, when delivered to the spreaders (with tar macadam the mix need not be laid hot).

**Laying.**—Each load should be discharged on to an iron plate and lifted from this by means of heated shovels, dropped into place by a turn of the shovel and raked to a uniform layer of the required thickness with heated rakes.

**Rolling.**—Rolling should be done by a steam or motor roller of 6 to 10 tons weight, the wheels and drums of which should be kept damp with either water or oil to prevent any sticking to the material. Where this type of mix is to be used as a base coat for two coat work, the top coat should be laid direct on to it. Where it is
intended as single coat work, the surface should be sealed with bitumen applied as a squeegee coat and blinded over with \( \frac{1}{2} \) inch stone chippings which should then be rolled in.

Quick reverse tandem rollers are the most suitable for this type of work, as they do not push the material up in front of them, as the ordinary three-wheel roller does.

**Supervision.**—The asphalt manufacturing plant shall be under the supervision of a competent and experienced superintendent capable of discriminating between essentials and non-essentials. He must have a practical knowledge of the details of asphalt plant operation and the value of specification requirements and preparation of mixtures.

He must have experience in making sand, bitumen and pat tests and be able to correct inaccuracies disclosed by those tests.

He must be a capable organizer of labour and be able to keep in close touch with the spreading.

He must make daily screen and sieve tests on each mineral aggregate, including stone and sand, and record these tests on a daily report sheet.

He must make daily penetrometer tests of the bitumen from the kettles and record these tests also.

He must see that the constituents of the mixtures are correctly proportioned to produce material in accordance with the specifications, to which he is working.

He should personally check all weighing and measuring devices at frequent intervals daily, particularly the bitumen weighing bucket.

He must above all appreciate the necessity of ever present watchfulness, exactitude and care.

**Spreading and Rolling Supervision.**—A thoroughly experienced overseer must be in charge of the spreading and rolling. He must be a good organizer of labour and should keep in touch with the manufacturing plant in such things as giving notice, when the plant is required to close down on binder or surface mixtures and so forth. He must refuse to accept any of binder or surface mixture, which are delivered to him below the specified temperatures or which for any other reason is not of good quality.
He must see that the materials are properly placed as described in the specifications and that rakes, tampers, etc., are properly heated without being overheated.

He must see that spreading and rolling are carried out promptly and must have all faulty work replaced as it occurs.

He must possess a good eye for levels and be able to lay and roll to any given contour and thicknesses.

He must furnish at the end of each day's work a statement of the number of loads of each material delivered and accepted by him, together with an accurate statement of the total areas of binder course and sheet asphalt laid during the day.

**Progress Reports.**—Daily reports should embody the following items:

1. Specifications of mixtures manufactured.
2. Sand siftings or sieve tests.
4. Tons of mixtures manufactured.
5. Area covered and area per ton of mixture.
6. Total area laid to date.
7. Thickness of binder and surface course laid.
8. Remarks as to weather conditions during the day.

**Testing Equipment.**—The following testing equipment is to be provided and maintained in a suitable building on the plant site:

1. Set of standard screens and sieves.
2. Laboratory sand balance of 100 grams capacity.
3. Penetrometer with needles, glass dish, pan for water and thermometer.
4. Roll of manilla paper for pat tests.
5. Protected thermometers for checking temperatures of hot sand, stone and mixtures, etc.

A supply of report forms.

**Taking Samples.**—The following quantities are required at the Plant for samples:

- Stone, 5 lbs.
- Filler, 1 lb.
- Sand, 1 lb.
- Bitumen, 1 lb.

Samples should be put into clean dry containers—preferably tin boxes or cans.
Great care must be taken to obtain truly representative samples of each material. When securing samples of stone a number of 5 lbs. samples should be taken from different points in each pile and thoroughly mixed together. The representative sample should be taken from such bulk sample. Sand samples should be taken from the interior of the pile where it is damp, and a number should be taken and dealt with in the same way as the stone. Filler samples should be drawn from several bags and mixed. Bitumen samples should be taken from the kettles with a clean dipper, after first well stirring the material.

Samples of surface mixture and binder course mixture should be taken from the wagons at the mixing plant, care being taken to secure fair average samples. These should be pressed between sheets of paper and trimmed to an even size before cooling. These samples should not be less than 3 pounds in weight.

The Plant.

There are various types of plant in use but an inspection of plants at work in various parts of England revealed that the type most in favour with road makers is, what is known as the "Cummer" type. The Cummer Plant was one of the first in the field, if not the first, and originated in America over twenty years ago. It is now known as the Marshall-Cummer and manufactured by Messrs. Marshall, Sons & Company, Limited, of Gainsborough.

The same type of plant with minor variations is also produced by Millers Machinery Co., Ltd., Stothert & Pitt and the Ransome Machinery Co., but they are all really Cummer plants and therefore a brief description of this plant will give a general idea of the various makes of this type of plant.

Sizes and Capacities.—The different sized plants are classified according to their capacity as follows:

Four-ton Plant.—This plant is capable of an output of 4 tons per hour of bituminous sand carpet or 400 square yards of sand carpet laid 2 inches thick per day of 10 hours.

This size would seem to be the most suitable for general use in Ceylon, as it is easily portable. The
erecting and dismantling are very simple and it is possible for two men to do either operation in 3 to 4 hours. Its travelling height is about the height of a London bus, and a Fordson or similar tractor would make quite a good unit for driving it or towing it along the road. The approximate cost of a complete plant including power unit melting tanks, accessories and spares would be Rs. 36,000. Plant and melting tank only about Rs. 30,000.

Eight-and Twelve-ton Plant.—These sizes would be suitable for large centres, where there is sufficient work to keep the plant employed continuously, without its having to be moved. They are portable but are cumbersome to move about and considerable labour is required in erecting and dismantling. Their capacities are 800 and 1,200 square yards of 2-inch carpet per 10 hour day respectively and approximate cost Rs. 47,000 and Rs. 62,000, including power unit.

Eighteen and Twenty-ton Plants.—These sizes can be made but are only suitable for large permanent quarries or places where a very large quantity is required daily and are not likely to be required in Ceylon.

Each plant is divided into three units:

Unit No. 1 Combined dryer and mixer.
Unit No. 2 Motive power.
Unit No. 3 Melting tanks.

Unit No. 1.

Chassis.—The chassis is rigidly built up with strong frame-work of steel sections well braced together.

The steel axle bars are of square section turned at the ends to receive the wheels. The wheels are of cast steel 2 feet 10 inches diameter by 12 inches wide and fitted with gun-metal bushes.

A draw bar is provided for haulage. The front bogie swivels on a centre pin and has an ample lock to allow the machine to be easily placed in position.

The wheels and axles are made adjustable so that the working height of the machine can be made 2 feet above the travelling height. When a still higher position is required, it can be obtained by placing blocks under the wheels for which purpose four strong screw jacks are provided.
Drying Drum.—This is the all important component of an asphalt or tar macadam plant.

The drum is heated externally and it has a number of openings or ports in addition to the large opening at its rear end. The hot gases are drawn in through these openings to be directly effective on the material under treatment. The drum interior is fitted with longitudinal bars of angle section and whilst the drum revolves, these bars lift the material and cascade it, whereby it is more effectively acted on by the hot gases. The drum is set at a slight angle and therefore the material slowly gravitates towards the discharge end.

The drum is supported at one end by a gunmetal bearing of very liberal dimensions and at the other end it works on two heavy steel rollers, the shafts of which also run in adjustable gunmetal bearings.

The housing, wherewith the drum is enclosed is lined with fire brick to conserve the heat of the furnace gases.

Furnace.—This is placed directly under the drum and is of ample proportions. The level of its grate bars ensure proper combustion and diffusion of heat. Convenient stoking doors are provided. Oil burning apparatus can be fitted if required.

Fan.—A fan is placed at the front or feed end of the drying chamber to regularly draw the hot gases through the heat ports and from the rear end. This arrangement provides the continuous draught needed to acquire equable temperature and uniformity of output.

Cold Elevator.—The bucket elevator lifts the cold undried material and discharges it into a chute, which leads directly to the drying drum. The chute is of large dimensions and well protected so that there is no risk of material getting clogged or split.

Hot Elevator.—At the discharge end of the drum a hot elevator is placed to receive the dried and heated material, elevate it and discharge it into the screens or direct to the storage bin. This elevator is entirely encased with the two-fold object of conserving the temperature of the material and preventing dust nuisance.
Screen.—This is entirely enclosed and is placed over the storage bin at the top of the plant. Any specified mesh can be supplied to meet the requirements.

The screen has a rejection spout for oversized material and a by-pass spout is also provided, so that when it is undesirable to screen the dried material, the latter can be ejected direct from the elevator to the storage bin.

Storage Bin.—This can be divided into any number of compartments up to four to accommodate various sizes of material.

Weighing Box.—This is suspended on an adjustable scale and is located under the discharge doors of the storage bin. The scale has several beams so that the materials can be weighed separately or collectively.

Bitumen Bucket.—This is a tipping bucket of sufficient capacity to hold a charge for the mixer. It is suspended on a two-beam scale attached to a trolley running on an overhead rail.

Mixer.—This is placed immediately under the discharge door of the weighing box. It is constructed on the pugmill paddle principle. It has two gear driven shafts, which rotate in opposite directions at a moderately high speed and to the shafts there are attached a series of teeth made of Manganese steel. The shaft bearings have dust proof housings. The mixer may be jacketed for steam heating, if desired, and has also adjustable wearing plates. The discharge is made by means of a sliding door in the bottom of the mixer. This door works on adjustable rollers, thereby effecting a good joint as well as an easy working arrangement.

Transmission.—The power transmission throughout the whole of the machinery is of a type calculated to be immune from derangement and is of great constructional strength. All the larger gears such as the mixer pinions, the bevel gears and transmission are made of high grade cast steel and all working parts are readily accessible.

The mixer is gear-driven. The elevators are chain-driven. All are provided with clutches so that any can be instantly put out of operation. The screen has a chain drive, motion being
impacted from the hot elevator shaft. All bearings are of ample length to ensure easy running and are provided with large grease cups.

Platforms.—Wide wooden platforms are provided which are easily erected alongside the mixer and from these platforms all operations of weighing materials, mixing, etc., are under control.

Unit No. 2.

Motive Power.—The plant can be operated by steam engines, oil engines or electric motors. The horse power required being:

- 4-ton plant: 8-ton plant: 12 & 18-ton plant

For the 4 and 8-ton plants a tractor or traction engine is desirable for convenience of removal or a steam roller may be used.

Unit No. 3.

Melting Tanks.—It is desirable to use large melting tanks with each plant. The tanks usually supplied have an internal capacity of 375 cubic ft, which is equal to 2,340 British Imperial gallons. However in normal working the tanks are not completely filled, so that the working capacity may be considered as 2,200 gallons or approximately 10 tons of bitumen.

The tanks are made of thick steel plates, flush-rivetted on the inside. The furnace firebars are sufficiently below the bottom of the tank to ensure proper combustion and diffusion of heat. The bottom of the tank itself is protected by an inverted arch of perforated fire-bricks. The fire box has a fire brick lining. Angle supports on the sides of the tank hold up, wide wooden platforms. When operating the tanks are placed alongside the main plant and the platforms are fixed at the same height so that operators can step from one to the other.

The marked advantage obtainable by the use of these large tanks is, that the complete quantity of bitumen required for running the plant a full working day can be prepared over night, thus ensuring uniform mixture for the whole output. One tank is sufficient for the plant of 4 or 8-tons capacity per hour. For the larger sized plant two or more tanks are recommended.

Melting tanks heated by steam can be supplied, but in this case the fuel bill is considerably
increased and the coal fired furnace is more generally employed, except when fuel cost is no consideration.

**Bitumen Pump.**—For lifting the bitumen a pump is recommended. After first passing through an internal strainer in the melting tank and then through an external strainer the bitumen is lifted through a pipe, leading from the lower part of the tank to a point above the bitumen weighing bucket, where the requisite quantity for each batch is drawn off by a two way valve. From this point a return pipe leads back to the melting tank. The pump keeps up a constant circulation of hot bitumen through the pipe system, so that during operation of the plant no clogging or obstruction can take place through cooling of the material. When the plant ceases work, the pump action can be reversed and the whole of the bitumen in the pipes is then pumped back to the melting tanks. Should any obstruction take place in the pipes through negligence, the pipes are so constructed that they can be easily cleared. The pump is driven from the transmission gear of the main plant.

**Choice of Plant.**—There seems little to choose between the different makes of the “Cummer” type of plant. Each manufacturing firm claims special advantages for its particular pattern, but they are mainly in minor points. The one advantage which the Marshall-Cummer has is the much longer experience behind it than the other makes, which has enabled the makers to correct defects, which experience has revealed.

There are smaller types of plant but these are only really suitable for tar macadam. The advantage of having a larger type of plant is, that it can be used for either asphalt work or tar macadam, so that when weather conditions are unfavourable for asphalt work, the plant need not stand idle, but can turn out tar macadam which can be stored and spread cold on less important roads.

If for any special reason a smaller plant is desired the Coleman Mixer has given good results. The Asiatic Petroleum Company have supplied some of their offices abroad with these plants, but while commending them as a good pattern of small plants, state that they are not to be
compared with the standard size of plant, such as the Millar or Marshall-Cummer which in their opinion is far more economical in working than the small plants.

_The Coleman Mixer._—This is of a different type from the "Cummer" and instead of the revolving horizontal pattern, the dryer is a vertical steel cylinder with a series of cones bolted on the inside. A vertical shaft runs through the centre carrying four circular plates, which revolve with the shaft. The material to be dried is fed into the top of the dryer by means of an elevator, which discharges the material near the centre of the top revolving plate. The centrifugal force set up spreads the material over the plate and throws it outward on to the cone plate fixed on the outer shell, down which it falls on to the centre of the next revolving plate. This operation is repeated until the material reaches the bottom where it falls to the discharging door.

The inlet to the furnace is below the bottom revolving plate and the gases are drawn through by an exhaust fan fixed in the top of the dryer. By this means the falling stone has to meet the hot gases the whole of the way through the dryer and with the centrifugal force always throwing a thin stream of material, practically every stone gets separate treatment.

The plant is fitted with an Armstrong-Whitworth petrol engine of 13 B.H.P. and is a neat compact little plant, but not economically suitable for coping with a large quantity of work.

_Other Makes._—Messrs. Stothert & Pitt and the Ransome Machinery Company, Limited, also produce some small simple tar macadam plants, but the results cannot be reliably controlled as they really consist only of a dryer, to the end of which is fitted a revolving mixer of the Concrete Mixer type.

_Cost of Small Plant._—These smaller plants range in price between about Rs. 15,000 and Rs. 20,000.

_Extra Fittings for Large Plants._

_Pyrometers, etc._—As control of the temperature of the aggregate prior to mixing is most important, a pyrometer should be installed at the discharge end of the drum to register the temperature of
the mineral matter and protected thermometers for use at storage bins and melting tanks should be provided.

_Dust Collector._—A dust collector is also advisable, as considerable dust is removed from the aggregate by the exhaust gases.

_Derrick._—A small hand operated swinging derrick is also usually attached to the platform of the melting tanks for hoisting the barrels of tar or bitumen.

_Street Tools._—The following street tools are required:—Smoother, tampers, rakes, wire push brooms, asphalt cutters, sandals, asphalt hand carts, wheel barrows and fire wagon.

_Hand Carts._—Attention is specially drawn to the very useful hand tip-carts which are now commonly used in roadwork in England. The adoption of this pattern in Ceylon in place of the present cumbersome hand cart would undoubtedly make for more economical and expeditious work.

_Lorries and Tructractors._—Each plant should be supplied with about 4 lorries for transporting the hot mix to the road. Light one-ton lorries are most suitable.

A very handy and useful vehicle for this purpose is Millar's Tructractor. It is a small sturdy, petrol-driven three-wheeled lorry. It can pull a load of 15 tons on the level, carry a 1½ ton load up a 15% grade, turn in a circle with an outside radius of 9½ feet, go where a bullock cart or ordinary four-wheeled lorry cannot go and travel at 12 miles per hour. The cost of a Tructractor is about Rs. 5,000 and this would soon be covered by economy in transport charges.

**Arrangement of Work.**

_Site._—"As it is necessary that the working of the plant and the construction work proceed more or less simultaneously and regulate one another to a considerable extent, it is desirable that the paving plant and construction work be located as near together as possible." (Goldsmith).

It is also desirable to move the plant as little as possible, as every move means fresh arrangements for the supply of the necessary materials and considerable delay, and increase of costs is occasioned before the work is set going smoothly again.
The most useful site is a quarry (preferably one near the road) from which the bituminous mixtures can be supplied for 10 to 15 miles in at least two directions, or better still at cross roads or centres where several roads within a radius of 15 miles can be supplied.

In view of rainy periods in most parts it is advisable in order to obtain full use of the plant to be able to continue work on tar macadam, when asphalt work is not possible. Therefore a site, from which some less important roads could be served with the tar macadam as well as asphalt mixtures for the more important roads, would be an advantage.

A quarry-site is the most economical as the stone can be fed from the quarry face to the crusher and the latter can be so located, that it delivers the stone from the screens near the paving plant.

The availability of suitable sand must also be taken into consideration in providing for asphalt work.

In regard to labour, usually 4 men will be required to handle the cold wet material and feed it into the cold elevator. Arrangements may be made to mix the various sizes of stone in the right proportions before they are fed into the plant and also the different grades of sand may be dealt with in a similar way. If this is done the stone and sand can be fed in approximately the right proportions and the screens will be so arranged that the stone and sand are delivered into two separate storage bins, from which they can be accurately measured by weight before going into the mixer. The supervisor will from time to time take samples from the storage bins and test them to see that the sizes and grades are being properly proportioned.

A fireman will be in charge of the furnace and under the direction of the mechanics controlling the plant, he will regulate the amount of material passing through the dryer. He will also watch the temperatures as recorded on the pyrometer at the discharge end of the dryer. The supervisor must also watch this and also test the temperatures of the materials coming from the storage bin from time to time.

On the control platform two mechanics will be needed, one to control the mineral aggregate and
the other to have charge of the bitumen and mixing. These men must also frequently test the temperatures.

A man will be required below the discharge outlet of the mixer to attend to the loading of the lorries.

A second fireman and another man will be needed to look after the melting tank and see that the bitumen is kept at the right temperature and properly stirred.

With a capable and well trained staff it may be possible to manage with fewer men, but the number given here is what should be allowed.

**Estimated Costs.**

*Summary of Plant.*—Crusher and screens are not included as the costs are estimated for materials delivered at the plant. The plant required is:

1. Drying and mixing plant.
2. Motive power.
3. Melting tanks.
4. Tools, accessories and spares.
5. Laboratory and testing equipment.
6. Four 1-ton lorries or tractors.

The approximate costs of these items are Rs. 60,000 for a 4-ton plant and Rs. 70,000 for an 8-ton plant.

**Labour**—The cost of the labour previously mentioned is estimated as follows:

6 Special coolies \( @ 1\text{.50} = \text{Rs. 9.00} \)
2 Firemen \( @ 2\text{.00} = \text{4.00} \)
2 Mechanics\( \@ 3\text{.00} = \text{6.00} \)
1 Night fireman \( @ 2\text{.00} = \text{2.00} \)
1 Watcher \( @ 1\text{.00} = \text{1.00} \)
1 Supervisor \( @ 5\text{.00} = \text{5.00} \)

Total per day = Rs. 27.00

For 4-ton plant per ton = 0.67 Cts.

**Fuel, &c.**—The consumption of coke for dryer and tanks works out at about 2% of output, i.e.,

2 tons of coke to 100 tons of mixture:

\[ \frac{45 \text{ ton coke}}{2 \text{ cubic yards firewood}} = \frac{\text{Rs. 24.00}}{4.00} \]
\[ \text{Oil, greases, &c.} = 2.00 \]

Per day = Rs. 30.00

Per ton = 0.75 Cts.
Asphalt and Tar Macadam Plant

Materials.—The cost of materials for the mixtures depends on the quantities of the various constituents and an estimate is here given for coarse stone binder:

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% Stone</td>
<td>16 cwts.</td>
<td>10 cts.</td>
<td>Rs. 1.60</td>
</tr>
<tr>
<td>15% Sand</td>
<td>3 cwts.</td>
<td>33 cts.</td>
<td>Rs. 0.99</td>
</tr>
<tr>
<td>5% Bitumen</td>
<td>1 cwt.</td>
<td></td>
<td>Rs. 5.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Per ton = Rs. 7.59</td>
</tr>
</tbody>
</table>

Summary of working costs:—

For 4-ton plant per ton:

<table>
<thead>
<tr>
<th>Item</th>
<th>Rate</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>Rs. 0.67</td>
<td></td>
</tr>
<tr>
<td>Fuel, etc.</td>
<td>Rs. 0.75</td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>Rs. 7.59</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td>Rs. 0.99</td>
<td></td>
</tr>
<tr>
<td>Haulage</td>
<td></td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.00</td>
</tr>
</tbody>
</table>

Per ton = Rs. 12.50

According to English figures spreading and rolling works out at about 25% of the cost of the hot mix delivered at the work and therefore is Rs. 3.72 per ton. The total cost is therefore Rs. 15.62 or say Rs. 16.00 per ton which gives a daily total cost of Rs. 6.40.

Allowing for a maximum of 300 working days for the year the cost of all charges for one year would be approximately Rs. 192,000 per plant.

Ultimate Economy.—Many asphalt and tar macadam roads have been in existence 15 years and the only expenditure on them has been minor repairs and an occasional surface dressing. For the purposes of calculation a life of 7 years is here taken and a statement is given below showing that if the Colony invested in two 8-ton plants and five 4-ton plants in 7 years' time 700 miles
of road will have been converted and the savings on maintenance estimates will then cover the cost of proceeding with the work:

<table>
<thead>
<tr>
<th>Year</th>
<th>Mileage done</th>
<th>Cost of Plant Rs.</th>
<th>Cost of Work Rs.</th>
<th>Savings on Maintenance Rs.</th>
<th>Special Vote Required Rs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st.</td>
<td>100</td>
<td>500,000</td>
<td>1,500,000</td>
<td></td>
<td>2,000,000</td>
</tr>
<tr>
<td>2nd.</td>
<td>100</td>
<td>—</td>
<td>1,500,000</td>
<td>250,000</td>
<td>1,250,000</td>
</tr>
<tr>
<td>3rd.</td>
<td>100</td>
<td>—</td>
<td>1,500,000</td>
<td>250,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>4th.</td>
<td>100</td>
<td>—</td>
<td>1,500,000</td>
<td>750,000</td>
<td>750,000</td>
</tr>
<tr>
<td>5th.</td>
<td>100</td>
<td>—</td>
<td>1,500,000</td>
<td>1,000,000</td>
<td>500,000</td>
</tr>
<tr>
<td>6th.</td>
<td>100</td>
<td>—</td>
<td>1,500,000</td>
<td>1,250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>7th.</td>
<td>100</td>
<td>—</td>
<td>1,500,000</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>700</td>
<td>500,000</td>
<td>10,500,000</td>
<td>5,250,000</td>
<td>5,750,000</td>
</tr>
</tbody>
</table>

These figures are based on a 20 feet wide road and a maintenance cost of Rs. 2,500 per mile for the present system of water-bound macadam, which should leave a good margin for minor repairs to the miles that have been converted.

If the Colony could vote larger amounts, the conversion of roads to asphalt or tar macadam could be done more rapidly and the ultimate economy would be increased.

Acknowledgements.—The author of this paper has to express his indebtedness to the firms mentioned in the paper for the facilities they afforded him to see their plants, both in manufacture and in operation and for the information supplied to him, on which the paper is based.
DISCUSSION.

4th Paper

Mr. YOUNG.—I had the very good fortune when I was at home this time to renew friendship with an old friend of mine who is an Engineer in the Ministry of Transport Department and who is in charge of large road undertakings which have been put into operation in Scotland, also very big roads in the North of Scotland and big road improvements and new feeder roads from Glasgow and Edinburgh. I was very much struck with the very scientific methods that are being employed in laying down these asphalt road makings. It was to me really a revelation to find the ordinary contractor, who before I left for Ceylon did work in a small way now taking very large contracts, demanding exact scientific research and data, and doing everything possible he could to make his road a success.

Supervision is undoubtedly a very large part of the success of these road making schemes. Each contractor for different sections, has given a guarantee to the Corporation, County or Borough as the case may be, of 7 years or so for the maintenance of each section, which means that any repairs within that period are going to be done by these contractors at their expense.

This shows with what care they have obtained data and the marked assurance with which they undertake the job. I can assure you there is no detail too small for these contractors to investigate. It is very very important from the very start of the work, that every detail has to be carefully thought out and worked out. In connection with laying bituminous or asphalt they are very particular about the exact temperatures of these mixtures. The quarries are
in most cases in convenient places and although in the tropics a distance of twenty miles (for transport) of a hot asphal tic mixture is mentioned, as possible at home; they could not take the hot mixture away successfully more than six miles. Once they got beyond six miles they could not maintain temperatures for the successful laying down of asphalt. Another important thing is that from the start each batch has its history recorded. Everything is noted down, the kind of stone, where it comes from, its temperature, its dryness, porosity, cleavage, etc., etc. They can tell exactly where each batch is put down and, in case of trouble, find exactly where it is. These roads may last as long as fifteen years or more with just a cycle of surface painting. I want to show how careful they are in every detail, and in this, really lies the crux of the question, so far as small plant is concerned, which I had the chance of visiting. The transport of the mixture was done by hand cart or lorry at the proper temperature, and never in the frosty weather. Then there is the "Colfix" of which I spoke. This is the solution for treatment in rainy weather. There is no doubt that if we could have "Colfix", for "Colas" for treatment of the roads in Ceylon and could have these two in some form, we should see very fine results.

Mr. KIRBY.—I should like to ask Mr. Stevens whether he would advise continuous or batch mixtures. It seems to me if we decide to purchase plant, that we should know whether a continuous mixture or batch mixture is better.

Mr. ROTHWELL.—One question in regard to Tar Macadam. Do you know of anything that is mixed cold, stored and utilised as required and whether we could use a cold mixture? Apparently the whole of Mr. Stevens' paper refers to a complicated plant requiring a very important point in its specification in the cardinal point viz. that it mixes hot, and material that it must be transported up to the road in an extremely hot state. I have not seen any of it myself.
Mr. BRADLEY.—I should like to ask Mr. Stevens whether any particular grade of stone is considered better than another for the correct mixing of Tar Macadam. I ask this because my only experience with this material at home was in the case of roads in the "Black Country" where an aggregate of blast furnace slag was used. This certainly did not show very satisfactory results in manufacturing towns where heavy traffic is common.

Lt.-Col. JONKLAAS.—The question most of our Engineers are interested is in getting something to produce sufficient grit to do our surface dressing on roads. Their present method of using sand or anything they pick up from the road drains is not the correct thing. This accounts in a great measure for our failures. Recently, I have seen work done by granulators and I have indented for one which I hope would be just the thing for us. These granulators worked with little oil engines could be drawn along the road and are capable of crushing a cube of metal into grit, 2 ins. and downwards, in about half an hour. With sufficient grit available our aim should be, after surface dressing a road, not to wait till the surfacing has been worn out by traffic but watch it carefully and as soon as you find that the dressing is giving way, renew the dressing. In doing so one would build up a surface in 4 or 5 years with an asphalt carpet. It is just history repeating itself, like in our water bound roads where we find every year a thickness of metal added on to the original surface. In the same way if we treat our water bound roads with surface dressing each year, given clean grit to build up a bitumen carpet, every road would last and improve although it would have to carry additional traffic. I think this is the best method in which we could improve our rural roads.

Just before I left England I had an interview with the Chief Engineer of the Ministry of Transport; he told me that when on inspection in one of the stations in the North of England, he asked to be shown the best road and the worst road. The best road was one built up with a bitumen dressing and grit each year. It was a very good road indeed and the worst road was a
water bound one not treated with a dressing. The granulator that has been indented for will, I hope, solve the problem of getting our grit.

Mr. STEVENS.—The only question raised by Mr. Young was the possible distance of transport for hot mixtures. The only information I have is that at one plant visited by me, in answer to a question how far the material was being transported, I was told that it was 12 miles, but no doubt the weather and other circumstances were perhaps particularly favourable. I daresay ten or twelve miles is high for England, but in a climate like Ceylon's it will be quite possible to transport the mixture that distance and have it arrive hot enough. Mr. Kirby asked about continuous and batch mixers. A continuous mixer turns out the material in batches. It is only continuous in the feeding and I do not think there is very much to choose between them. In a so-called batch mixer the material is fed in batches, and there is no gauging after drying. Each batch is dealt with separately from start to finish. The plant described is a continuous mixer and perhaps gives more accurate proportions than a batch mixer. Mr. Rothwell asked whether cold or hot tar was used. Of course it has got to be mixed hot to get Tar Macadam. It has got to be mixed hot, but I have seen tar macadam laid by, for use when they wanted it. I do not at present know which kind of local stone will give the best results. Slag is greatly used in England. They are also using limestone and granite. As to which is the best stone for us to use is a matter for further experience.

Extra Note.—In regard to the question of stone to be used, Sir Henry Maybury, when asked a similar question to that asked by Mr. Bradley replied to the effect that it depended on the quality of either of the kinds of aggregate. There were varying qualities in each kind. There was little to choose between the best qualities of either kind.
ASPHALTE AND TAR MIXTURES FOR ROAD SURFACING.

By H. N. WORTH, A.M.Inst.C.E.

The advent of motor traffic some fifteen or more years ago marked the beginning of a change which has now brought about a serious condition of affairs in the administration of our roads.

Bullock drawn traffic which has during the past few years given way in a very marked degree to the self-propelled vehicle, the range, weight, speed and intensity of traffic has considerably altered the situation all over the Island.

The problem of presenting a road surface capable of meeting all conditions of such traffic is a somewhat complex one and many factors have to be most carefully considered, not the least important one being with regard to cost.

In the early days of motor transport, it was clear that road surfaces would have to be devised having far greater cohesion than could be obtained under the so-called water-bound method wherever motor transport operated in any marked degree and it is only reasonable to think that, had the war conditions not arisen, seriously hampering all progress, that the gradual change from the water-bound surface to those of improved character would have taken effect in sufficient time to anticipate the developments of rapid transport.

Modern methods of surface treatment may be classified under three main heads:—

1. Spraying or painting a road surface with tar or asphaltic material.
2. Grouting the interstices of the upper metal layer with similar materials;
3. Treating the metal before use with these materials and afterwards consolidating with or without a final coating or carpet.

It is proposed in this paper to deal briefly with the first method only namely, that of spraying or painting, a method which is the cheapest
in initial cost, and up to a point a satisfactory one for road surfaces not subject to heavy town traffic and which constitute a considerable section of the roads in Ceylon.

The objects of surface treatment from the Engineer's point of view are:—(a) to increase the life of a road by reducing the disintegration between the metal particles; (b) to waterproof the surface and thus prevent settlement or movement in the foundations and to protect the road surface against heavy rainfall; (c) to maintain a higher standard of surface between the repair periods demanded by modern traffic; (d) to materially reduce the quantity of labour necessary to maintain a water-bound road in proper repair; (e) to maintain a road surface in good repair under adverse labour conditions and in feverish areas; (f) to reserve good quality stone for future requirements, where this is difficult to obtain.

Surface treatment has been adopted in one form or another for some years on certain sections of Ceylon's main roads but little more has been done until recent years than attempts made to overcome the excessive disintegration of metal on corners caused by fast moving traffic, chiefly owing to the totally inadequate funds at the disposal of the Engineer-in-charge.

As road making and maintenance have now become a science it is imperative that the important item of adequate and intelligent supervision should not be overlooked, as where the expenditure of comparatively large sums are involved in initial cost on an extensive programme of surfacing treatment, this will undoubtedly be a failure if the work is not carefully watched and properly supervised.

Whichever system of surfacing is adopted authorities on the subject without exception lay particular stress in the first place upon the matter of foundations—the strength of which must be adequate to stand the enormously increasing traffic, traffic loads and modern traffic conditions. A road which owing to defective foundations will not stand up to these conditions after being surface treated—apart from the general wear of the surface to be expected, is a wasteful proposition and should be put in order before any further expenditure on surface treatment is adopted.
The quality of the road metal is another important item. Stone which crumbles or crushes under ordinary traffic will do so to some extent even if protected by a resilient binder or coating and particularly so when this is thin as in the case of a tar sprayed road.

It is most necessary that good sound stone be obtained irrespective of cost before contemplating expenditure on any form of surface treatment. Heavy transport charges will in some cases have to be met in obtaining a suitable stone and this item must receive first consideration as, there is no possible chance of traffic conditions becoming less severe.

Effective drainage is more important today than ever as the water-proofing of a surface will become ineffective if provision for dealing quickly and efficiently with heavy rainfall is overlooked. The tar-spraying system is a simple one. It consists of applying by hand or by mechanical means a thin film of tar or asphaltic compound to the surface of a cleanly swept macadam road, thoroughly brushing in and finally applying small stone chippings or clean coarse gravel as a blinder to the finished surface.

The improvement to the surface is marked and immediate but unfortunately it has not the lasting qualities of the more expensive systems. A second coating should be applied after a few months' time in order to thoroughly seal the surface and prevent undue disintegration. On light trafficked roads a single coat will hold the surface for twelve months but, the life of the surface will be lengthened by not unduly delaying the application of the second coat. On a test section of road in the Koslanda District a single coat of road board tar was laid over fifteen months ago and it appears probable that a further nine months' wear will be obtainable before any breaking up of the surface occurs.

The full-life of a section treated with a particular compound under known traffic conditions has not yet been ascertained and this will undoubtedly vary considerably in different districts owing to varying local conditions. A two coat treatment of "Spramex" laid in the Haputale Bazaar has withstood heavy cart and lorry traffic for over twelve months without any appreciable signs of
wear. Asphaltum on a test section in Koslanda on a bad curve was laid over 2½ years ago and shews no signs of corrugations or wear whatever.

With the excellent materials now on the market suitable for this class of work the additional heavy cost of other methods has been found to be unwarranted on any but the most heavily trafficked roads. This method is also very adaptable to Ceylon rural conditions, and provided thorough brushing of the road surface is strictly attended to in the first place the matter of application is found to be carried out in most cases satisfactorily by the cooly of average intelligence under ordinary supervision, being applied easily and quickly at a comparatively low cost.

Tar as a liquid road binder was in the early years found to be far from satisfactory for several reasons. It was not standardized and consequently varied both in quality and density which made it impossible for continuous efficient working. It contained a considerable amount of both dangerous and useless materials and compounds which were soluble in water. It was also seriously effected by changes of temperature and weather, was inclined to become brittle and flake away in time. It did also not contain the resilient properties required to stand the strain of modern traffic.

In more recent years, however, many of its imperfections have been overcome and the tar used to-day for road purposes is of a very much higher grade. It is now standardized on the specifications laid down by the Ministry of Transport and is made principally in two grades known as No. 1 and No. 2 Road Board Tar. The chief differences being in the higher percentage of naphthalene and the lower viscosity figure in the case of No. 1 Tar.

Tar is economical both in labour and in covering capacity; it can be easily handled and can be used at low temperatures necessitating no special or expensive plant, it is moreover practically fool proof. In spite of this, however, tar cannot be compared with the lasting and wear resisting qualities of asphaltite, a product which holds such a prominent place in the road building industry of to-day.
Most asphalt compositions require careful handling and high temperatures otherwise they are not readily keyed to the metal unless these high temperatures are maintained but their durability in the prevention of surface disintegration under all conditions of heavy traffic has been thoroughly proved after many years in all climates. Asphalt is very apt to "blanket" on the surface due to condensation when being applied and to form corrugations if improperly keyed to the metal. It is also more expensive in first cost.

The tendency to-day in the manufacture of compounds for tar spraying is to incorporate a high grade petroleum asphalt with selected and absolutely uniform tar derivatives so that the good qualities of both materials are maintained and their disadvantages eliminated.

Asphalt may be classified broadly under two heads: (1) Natural asphalts occurring in nature, (2) Residual asphalts obtained from asphaltic petroleum. Asphalts are quite different from tars both in physical and chemical properties. The term "bitumen" is largely used when referring to either product and to prevent confusion the words "tar" or "asphalt" are preferable. The British Standards Association draws a sharp distinction between the two and generally speaking the term "bitumen" has been accepted to mean an asphaltic oil product substantially soluble in carbon disulphide. Pure asphalt is 100 per cent. bitumen.

Advantages are claimed by residual or what are sometimes erroneously called "synthetic" asphalts over the natural asphalts owing to the penetration value of the former being considerably higher and as its properties may be varied according to the distillate temperature of the oil and kept under control during manufacture a standard grade can be obtained for any particular class of work.

Both asphalt and tar products are now subjected to severe scientific tests before being put on the market for road purposes, but producers and users alike consider the consistency or viscosity to be the main test in the suitability of either material to meet traffic and climatic conditions.
The test for consistency or viscosity is ascertained by the depth of penetration of a standard weighted needle into a substance at a standard temperature during a fixed period of time.

Unless otherwise stated, the temperature weight and time factors are understood to be 25° Centigrade (77° F) 100 grams, and 5 seconds. The depth is expressed in units or 1/100 parts of a centimetre. Thus a 100 penetration asphalt is one in which the standard needle penetrates to a depth of one centimetre in 5 seconds. The softer the asphalt the higher its penetration.

The penetration values of asphalts for road works range between 40 and 200. Those of natural asphalts between 7 and 25.

In the case of tars a Hutchinson viscosity gauge is used. The temperature factor remains the same, the standard diameter of the container is specified but the time is a variable factor depending upon the time taken for the poise to sink from the lower to the upper ring of the gauge and is expressed in seconds.

No. 2 Road Board Tar is specified to range between 20 and 100 seconds, a much wider margin than is required by distillers for any particular specification. No. 2 Tar which is primarily used for tar macadam work in England has been found suitable for tar spraying in Ceylon owing to the difference in climatic conditions and has recently been used on a large scale.

Asphaltes can be thinned to fluid consistency by the addition of a volatile distillate or by the addition of water and an emulsifying agent. Asphalts so treated are suitable for direct use for road work without heating, the latter is known as an “emulsified asphalt” and is now being used to a considerable extent as it overcomes the difficulties experienced and the expensive plant required in the application of hot asphaltes.

These asphaltes harden on exposure due to the evaporation of the solvent and are claimed to more thoroughly bind the aggregate together and so prevent disintegration owing to their more liquid consistency and greater penetration. Condensation defects are overcome and being applied cold during wet or fine weather progress is being made in the right direction which should
show a considerable saving in time and labour costs. Preliminary patching which is generally required should be also unnecessary; in that the surface treatment may follow directly the newly metalled surface has been completed.

"Colas" one of these emulsified asphaltes is now being used in Ceylon on a more extensive scale than hitherto and it is probable in the near future that these asphaltes will be obtainable delivered direct to the spot and applied to the roads by motor pressure tanks as is done in other countries avoiding all transit losses, the cost of drums and considerably reducing the cost of handling. This would undoubtedly solve to a great extent the labour problem in the outlying districts and allow of more extensive widening and improvement programmes to be taken in hand with the available labour.

Hot asphaltic compounds, such as "Spramex" and Asphalum, have been extensively used throughout Ceylon and have given good results.

The annual cost of maintaining the surface of waterbound roads is approximately Rs. 1 to Rs. 1.50 per square. In the Koslanda District over a 98 mile section of main roads the average cost is Rs. 1. This figure represents the cost of all metal, consolidation, gravelling and general surface maintenance which would ordinarily be discontinued if the surface were treated with an asphaltic or tar compound.

The cost of surface treatment varies between Rs. 2.50 and Rs. 3.25 per square for first coat work according to the composition used. The cost of second coat being between Rs. 1.35 and Rs 2.

If the life of a treated surface be based between 3 and 4 years it will be seen that except as an initial cost there is no great difference, when the cost of water-bound surface is allowed for over this period. Whereas the treated surface has every point in its favour.

It would appear desirable to the interests of our roads that larger sums be allotted over a few years for surfacing until the general standard is materially improved and such work if carried out on a more extensive scale would tend to reduce the cost of both labour and materials in the future.
DISCUSSION.

5th Paper

Mr. WORTH.—I think what really is required is a systematic check of the traffic on the surface painted sections throughout the Island. Once in six months at least a record should be made and that information could be collected every year. It would do a great service in fixing upon the best method of treatment to be adopted, and as to whether certain roads require anything more than surface painting would I think be more readily ascertained.

Lt.-Col. JONKLAAS.—We have been dealing a good deal with the “hot mix.” I have a sample here of this absolutely cold mix (the sample block produced was from Stoke Road, Guildford). I got it just before I left London. It is mixed absolutely cold and once it is mixed you can put it down. I have seen it done in Bristol in a shower of rain.

Mr. KIRBY.—That is an excellent suggestion to have a census of traffic over sections, whether surface painted, grouted or sprayed. The results will indicate the effect of what is actually being done on various roads.

Mr. ROTHWELL.—Officers of the Public Works Department are really somewhat deficient in information as to really what are the best materials to use. But I understand the Head Office have circularised Engineers throughout the Island asking them for particulars of the different materials and tar mixtures used, and what is the approximate cost. I would appeal earnestly to the officials at the Head Office dealing with this, not to put the information received into the files, but to publish it say in pamphlet form, so that we, who are interested in improvement of
roads, may read and know what is going on in
different parts of the Colony instead of being (as
it were) watertight compartments. It is
information in book form that will be most useful
to enable an officer in one district to compare
his work with what happens in the next province
or district.

Mr. YOUNG.—I should like to ask Mr. Worth
something about the bleeding of surface asphalt.
How was this bleeding stopped in Haputale
Bazaar? We have heard so much about it. We
want to think out a solution and try to get some
condensed ideas before they are put in the Head
Office to be filed. In connection with Col.
Jonklaas' cold mix and "Colas" for surfacing,
I think undoubtedly the solution of Ceylon's
water-bound road is to be found in "Colas" or
as I said before in "Colfix" application.

Mr. SCOTT.—As regards Colas my experience
has been that it is a very good mixture for grouting
during wet weather. But considering that you
have about 50% water and pay about 50% more
for it, I think it is waste of money. I do not
think it is any use at all without a seal coat. It
is far better to have a sealing coat of Asphaltum
or Spramex.

Mr. GROOCOCK stated that he was not in favour
of Colas except as the first coat to be used—con-
tinued wet weather after consolidation or as a
grouting mixture during consolidation. The
mixture contained about 50% of water, and was
about 50% dearer per gallon than asphalt and as
a sealing or surfacing coat one did not get value
for money as compared with Asphaltum or
Spramex.

He stated that records were being asked for
from the Provinces of the most successful examples
of painting, grouting, carpeting, etc., undertaken
up to date, with probable costs of each system
from a cycle of years as compared with the yearly
maintenance costs which would ensue if the
work were sanctioned without treatment.

Mr. ALLEN.—In connection with records of
experiment with regard to road work, I
should like to mention that some years before
the war, when tarring of roads was first begun,
a road in the Birmingham District, twenty miles.
long, was experimented on by the County Council. Different materials were used on various sections, Tarmac, tar-painting, asphalt, etc., and small white boards were set up by the side of the road to indicate the material used on that section and the date it was laid. It would be well to try that method on some of the Main Roads of Ceylon to find out from actual trial and observation how different materials behave under similar conditions.

Mr. WORTH.—In regard to the question of bleeding raised by Mr. Young I may say that this Spramex was put down early in 1925 and nothing whatever has been done since, the small patching in places required was possibly due to improper sweeping. I attribute " bleeding " to underheating and have had no serious trouble due to this cause.