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ROAD PERFORMANCE STUDIES AND AN INVESTIGATION OF SOME PROBLEMS ASSOCIATED WITH RUBBERISED BITUMEN ROAD CONSTRUCTION*

BY

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SYNOPSIS

The work on this project so far carried out indicates that:

(*i*) *the addition of 5 — 10% kerosene oil by volume of bitumen reduces the viscosity and improves the workability characteristics of an otherwise cumbersome binder;*

(*ii*) *" masterbatches " are not only convenient, but are essential to save time in blending of natural rubber latex and bitumen and in the ensuring of better quality control;*

(*iii*) *a mixture of sodium hydroxide and ammonia is a better stabilizer than either sodium hydroxide or ammonia;*

(*iv*) *better bonding was achieved with rubberised bitumen than with neat bitumen with the aggregates tested;*

(*v*) *bleeding taking place on the rubberised bitumen sections was less than in the control sections without rubber.*

INTRODUCTION

Rubber in various forms has been used in road construction work for a period of over hundred years and records of experience available indicate that rubber does modify the bitumen to give roads with better performance.

However the use of rubber as an additive to bitumen has left the engineer with the problem of handling a more viscous bitumen that makes its use very difficult and cumbersome in the field at normal working temperatures. Despite the advantages to be gained by the addition of rubber to bitumen this single factor alone may have discouraged the more widespread use of rubberised bitumen in road construction.

This research programme was therefore undertaken jointly by the Department of Highways and the Rubber Research Institute in order to investigate problems encountered in road construction using natural field latex, the cheapest and the most readily available form of rubber in Ceylon, and also to further observe the performance of stretches of rubberised bitumen road laid under controlled conditions. This led to the commencement of laboratory and field investigations with the following objectives:—

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(i) development of techniques for overcoming field problems of blending rubber with bitumen and improving the workability characteristics of the product;

(ii) investigation of the use of different stabilizers for preserving natural rubber latex;

(iii) laying of experimental stretches of road for observing field performance;

(iv) correlation of measurable physical properties of rubberised bitumen with field performance.

REVIEW OF PAST RESEARCH

In 1951 a co-operative research programme had been started between the Road Research Laboratory and the Natural Rubber Producers' Research Association and laboratory investigations and full scale road trials were carried out for 15 years (Thompson, 1967). This programme has shown that the addition of rubber to bitumen decreased its brittleness, reduced the temperature susceptibility and increased the softening point with the result that the following advantages were gained with surfacing materials:—

(i) resistance to cracking,

(ii) resistance to fatting up,

(iii) resistance to deformation,

(iv) resistance to stripping.

The data collected by Machlaclan & Morrel (1964) agree with those of Thompson (1967) in this context.

It is generally accepted that natural rubber latex with a high molecular weight is a better additive to bitumen than synthetic rubber in present day use.

In non-natural rubber producing countries concentrated latex in the form of evaporated latex (70% rubber) or centrifuged latex (60% rubber) is used. In the natural rubber producing countries however field latex is more suitable and promising results of experiments with low ammonia field latex preserved with 0·3% penta-chlorophenate and with high ammonia field latex have been reported (Fernando & Nadarajah, 1969).

Smith (1960) in his research work found that unvulcanized rubber in latex form was more effective on bitumen than other forms of rubber, although the powder form has the advantage of convenience of addition.

The field latex used in the past on road projects in Ceylon had been stabilized with ammonia. Latex thus preserved gives out a pungent smell and makes blending of rubberised bitumen unpleasant. Natural field latex has also been stabilised with sodium hydroxide which has been observed as a better stabilizer as it is non-volatile and gives a stable latex that is odourless. Also, sodium hydroxide renders the proteins in latex soluble thereby permitting closer contact between the rubber and bitumen to produce a better blend (Baker, 1941).

Fernando & Nadarajah (1969) have indicated the possibility that the interaction between natural rubber and bitumen is not only physical but also chemical. This is because the polyisoprene molecule in *Hevea* latex contains carbonyl and/or carboxylic groups. These groups under dry conditions either condense or combine with each other, inter- or intra-molecularly or combine with each other in a similar manner through polyfunctional amines or other, like molecules naturally present in latex. This reaction is catalysed by strongly alkaline substances such as sodium hydroxide (Sekhar, 1964). Since bitumen also has highly polar atoms such as nitrogen, sulphur and oxygen, and would be expected to contain aldehyde and aldehyde condensing groups, it is reasonable to expect some chemical interaction with the rubber in the dry state, and more so in the presence of sodium hydroxide and under the influence of heat.

Although heat is required in the blending of bitumen and rubber, prolonged heating at high temperatures causes a breakdown of the rubber in bitumen and renders it less effective (Thompson, 1964). This breakdown is more severe at temperatures above 350°F so that the temperature and the duration of heating have to be closely controlled in order to obtain the maximum effect of the rubber added.

The effective rubber content has been determined by the measurement of the specific viscosity of the benzene solution of the acetone insoluble fraction of the rubber bitumen and finding the amount of undegraded rubber which will produce the same viscosity in benzene as the sample (Szatkowski, 1963). In this work, effective rubber content has been identified as the useful fraction of rubber that remains in combination with the bitumen.

LABORATORY INVESTIGATIONS

Physical properties

Investigations were carried out in the laboratory in order to determine properties of bitumen with and without rubber that could subsequently be correlated with field performance.

The bitumen used for this purpose were 60/70, 80/100 and 180/200 penetration grades, each rubberised with natural field latex stabilized with ammonia, with hydroxide and with a mixture of ammonia and sodium hydroxide respectively.

The properties determined in the laboratory were:-

(i) Penetration — Method A.S.T.M. D. 5 - 52;

(ii) Softening point — Method A.S.T.M. D. 36 - 26;

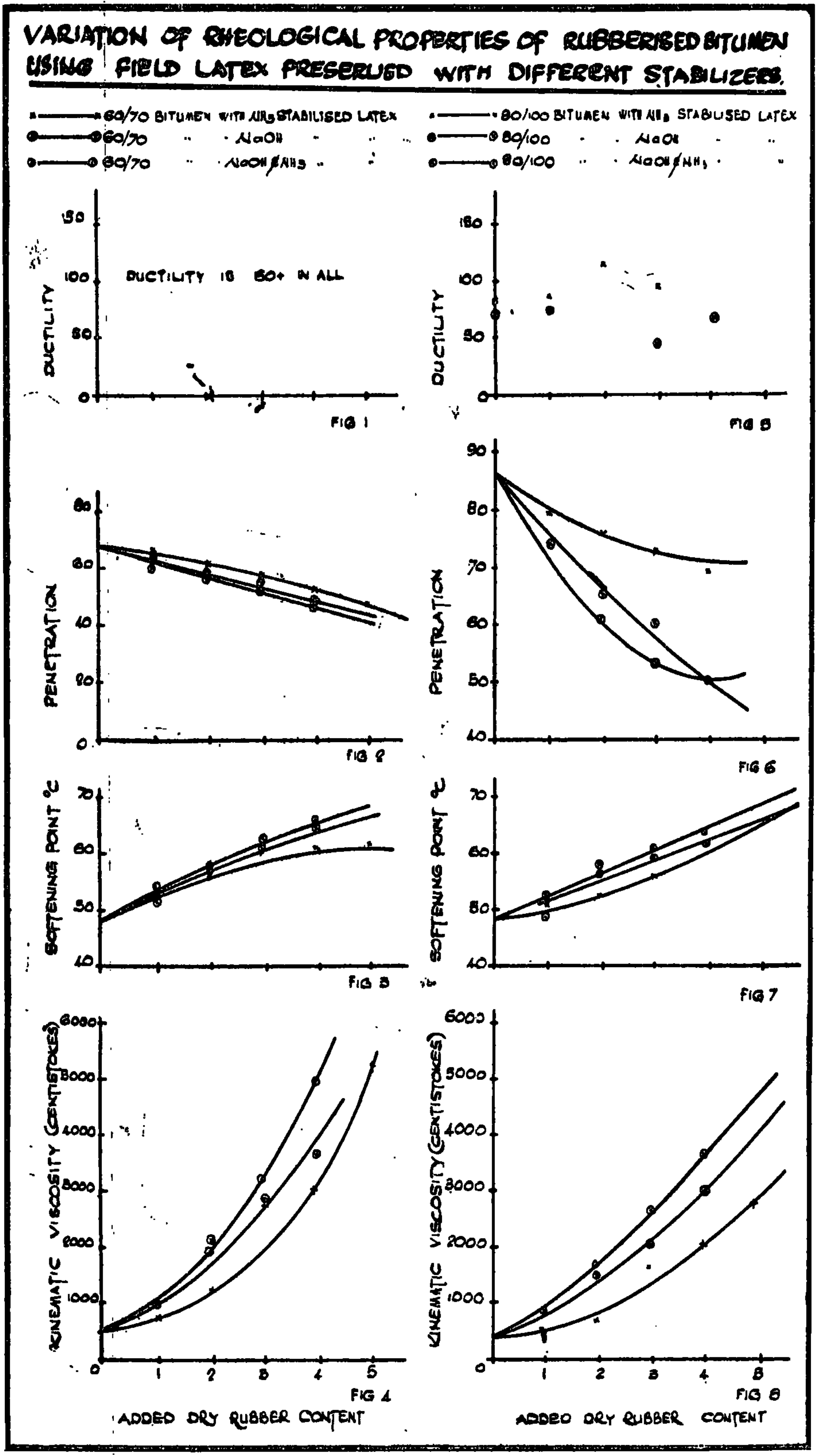
(iii) Ductility — Method A.S.T.M. D. 113 - 44;

(iv) Kinematic viscosity — Method A.S.T.M. D. 2 - 63 T;

(v) Effective rubber content (7);

(vi) Anti-stripping characteristics (visual observations)

and the test results (i) - (v) obtained are presented by the graphs in Figs. 1 to 8.


VARIATION OF RHEOLOGICAL PROPERTIES OF RUBBERISED BITUMEN USING FIELD LATEX PRESERVED WITH DIFFERENT STABILIZERS.
60/70 BITUMEN WITH NH3 STABILISED LATEX
60/70 NaOH
60/70 NaOH/NH3
80/100 BITUMEN WITH NH3 STABILISED LATEX
80/100 NaOH
80/100 NaOH/NH3
DUCTILITY
DUCTILITY IS 150+ IN ALL
FIG 1
FIG 5
PENETRATION
FIG 2
FIG 6
SOFTENING POINT °C
FIG 3
FIG 7
KINEMATIC VISCOSITY (CENTISTOKES)
FIG 4
FIG 8
ADDED DRY RUBBER CONTENT
ADDED DRY RUBBER CONTENT

It is observed from the test results that field latex stabilized with a mixture of ammonia and sodium hydroxide has given the highest softening point, the lowest penetration and the highest kinematic viscosity. From the observations made on the stripping test although no stripping had occurred in any of the samples tested, it was evident that the test samples containing rubberised bitumen had achieved better bonding. These observations indicate the possibility that more rubber has effectively combined with bitumen in this case than in the other two cases. The next best stabilizer appears to be sodium hydroxide followed by ammonia.

These observations could be explained as follows. The incorporation of the latex with bitumen involves heating at temperatures around 300°F. At these temperatures ammonia evaporates in a very short time and the latex coagulates and a non-uniform mixture of rubberised bitumen is obtained.

Sodium hydroxide on the other hand being non-volatile permits more time for the latex particles to get dispersed in the bitumen on stirring thus explaining that sodium hydroxide is a better stabilizer than ammonia.

In field latex, aldehydic groups in the natural rubber molecule can condense with time with the aldehydic condensing groups in the natural rubber molecules in the presence of sodium hydroxide. This can be minimised by first adding some ammonia which reacts with the aldehydic groups rendering these temporarily inactive and then adding sodium hydroxide. In the preparation of rubberised bitumen at a temperature of 300°F, the ammonia is driven off, leaving the aldehydic group free to interact with bitumen. This reaction is accelerated by the presence of sodium hydroxide in the absence of moisture. Hence a mixture of sodium hydroxide and ammonia as the stabilizer is superior to either sodium hydroxide or ammonia.

Effect of prolonged heating on rubberised bitumen

Once the rubberised bitumen is prepared in the field, it may be necessary to keep the binder in the bitumen kettle at a temperature of 300° - 350°F up to a maximum of about 8 hr before use, during which time, degradation of the rubber can take place. In order to investigate the degree of degradation that occurs on heating, rubberised bitumen samples prepared at different added dry rubber contents were subjected to heat at 300°F and 350°F for periods of 2, 4, 6 and 8 hr respectively, and their effective rubber contents were determined. The results available up to date are illustrated by the graphs in Figs. 9 and 10.

THE VARIATION OF EFFECTIVE RUBBER CONTENT WITH TIME

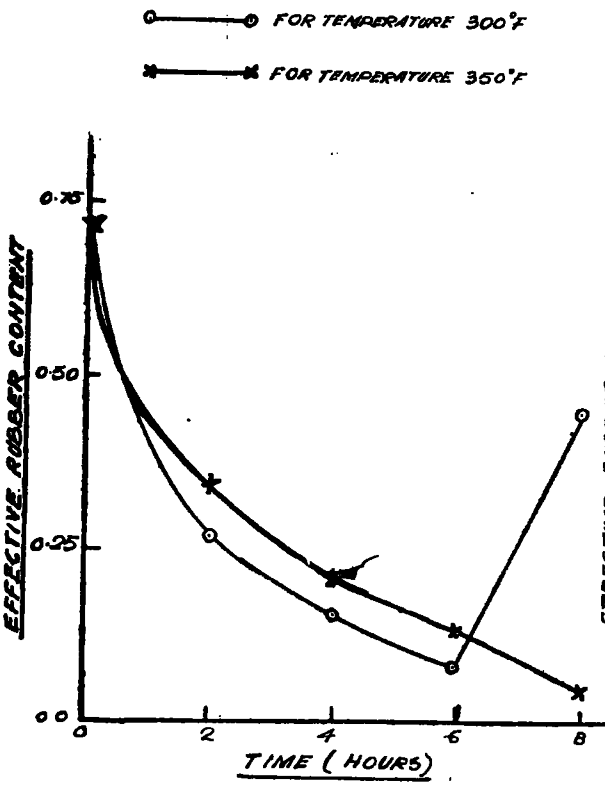


Fig. 9

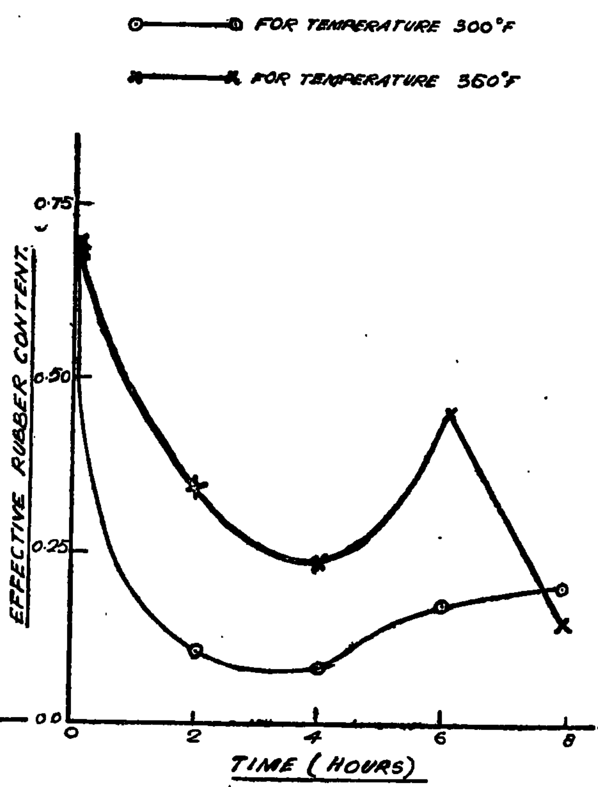


Fig 10

These graphs indicate that effective rubber content had changed on heating showing both a rise and a fall in its value. An explanation is not attempted at this stage as further work at other added dry rubber contents is yet in progress.

Masterbatches

The blending of field latex and bitumen at the work site is a time-consuming procedure that has to be carried out with the utmost care on account of the foaming that is taking place due to the presence of water in the latex. This phase of the work has been greatly facilitated in obtaining the desired rubber content by the addition of the requisite quantity of a preblended masterbatch containing a high concentration of rubber.

Investigations were carried out on the preparation of masterbatches at the Rubber Research Institute using natural field latex in order to incorporate the highest concentration of rubber in bitumen. The latex used was stabilized with 1·25% ammonium hydroxide in one case and 0·7% sodium hydroxide in the other. Masterbatches were prepared at 12%, 14% and 16% dry rubber contents and these were wrapped in polyethylene or polypropylene that would dissolve ultimately in the bitumen kettle. It was found that the preparation of rubberised bitumen with sodium hydroxide-stabilized latex was easier than working with ammonia-stabilized latex possibly on account of the better dispersion of rubber afforded by sodium hydroxide as discussed earlier (Nadarajah & Mendis, 1970).

Experience gained during field operations discussed later on in this paper, indicates that higher concentrations of dry rubber content could be incorporated, if about 5 - 10% kerosene oil by volume of bitumen is added into the bitumen prior to the addition of rubber. This aspect of masterbatch preparation is presently under investigation.

FIELD EXPERIMENTS

Whatever results are indicated in the laboratory the final test of the success or otherwise of the use of rubberised bitumen depends entirely on its performance in the field. This is because factors such as traffic volumes, wheel loads and climatic conditions experienced in the field cannot be fully simulated in the laboratory. Full scale road experiments are therefore being carried out under this programme to observe the effect of rubberised bitumen on—

(*a*) asphalt penetration macadam;

(*b*) seal coat surface treatment;

(*c*) subsequent coat bituminous treatment;

(*d*) asphalt concrete.

(*a*) *Asphalt penetration macadam*

Hotel road — Mount Lavinia — B class — medium traffic

The first field stretch of road under this project was laid on Hotel Road, Mount Lavinia where the road edges along the entire mile and sections over the full width were repaired by re-metalling. This work was carried out by manual labour using plant generally used in this type of road surfacing.

Approximately 70 gal of 80/100 penetration bitumen were heated in a 120 gal bitumen kettle to a temperature of approximately 300°F. Field latex was added into the kettle a little at a time and after about 20 sec the bitumen was vigorously stirred manually. There was a high degree of foaming due to the water present in the latex so that just the right amount of latex had to be added to prevent spilling of the binder. No anti-foaming agents were used. This method is a slight modification of that given by the Natural Rubber Producers' Research Association (1964).

When this work was in progress for a few days, it was found that foaming could be reduced if the stirring of the bitumen was started immediately after the latex was added and not 20 sec later as was done earlier. This practice was therefore adopted in all later work.

A control section without rubber was also laid on the same road.

Experimental details:

Dry rubber content	=	1% by weight of bitumen
Temperature of spraying	=	350°F (approximately)
Maximum duration of bitumen at this temperature		4 - 6 hours
Length of road surfaced	=	1 mile
Weight of roller	=	8 - 10 tons
Date of construction	=	March 1970

Remarks : Considerable difficulty was experienced in mixing and spraying the rubberised bitumen due to its high viscosity. The work had to be frequently interrupted to clean the spraying cans and the spout of the bitumen kettle.

Performance: After edge metalling on a road, it is not uncommon to find an over-bituminised section of road along the joint of the old and the new surfaces with considerable bleeding of the bitumen taking place along this joint. This effect was noticeable in the unrubberised section of road but was hardly noticeable in the rubberised section of road.

12th mile Nagoda-Kalawellawa-Bellapitiya road — B class — medium traffic

To overcome the difficulties of mixing and spraying experienced on Hotel Road, Mount Lavinia, in all subsequent experiments, a small percentage of kerosene oil by volume of bitumen was added in order to reduce the viscosity of bitumen, where the latter had reached a temperature of about 250°F. The latex was then added and mixed with the bitumen as mentioned earlier.

In some sections of this road masterbatches of rubberised bitumen were experimented with in the presence of kerosene oil.

A control section of road of length 1/4 mile was also laid.

Experimental details :

Dry rubber content	=	1·5% by weight of bitumen
Kerosene oil added	=	5% by volume of bitumen
Temperature of spraying	=	350°F (approximately)

Maximum duration of bitumen at this temperature 4 - 6 hours

Length of road	=	½ mile
Weight of roller	=	8–10 tons
Date of construction	=	July 1970

Remarks : The addition of 5% kerosene oil into the bitumen reduced its viscosity to a great extent, made the blending easier and enabled the spraying of the binder to be continued without interruption.

The use of masterbatches greatly facilitated the stirring of the binder in the absence of foaming and the presence of bitumen made this task still simpler.

Performance : The rubberised bitumen section and the control section are both performing satisfactorily. It appears too early to draw a comparison.

(*b*) *Seal coat surface treatment*

Single seal coat surface treatment using rubberised bitumen was carried on the two roads described below. The heated binder was sprayed on the road surface using manual labour and spraying cans. Stone chips conveniently piled in close proximity on the road side were spread on the road surface by manual labour. These chips were rolled with a steel-wheeled roller.

Experimental details :

2nd mile Dehiwela-Maharagama road — B class — medium traffic

Dry rubber content	=	2% by weight of bitumen
Kerosene oil	=	5% by volume of bitumen
Temperature of spraying	=	350°F

Maximum duration of bitumen at this temperature 2–4 hours

Length of road surfaced	=	½ mile
Weight of roller	=	2½ tons
Date of construction	=	March 1970

Remarks : A half mile of seal coat was laid on a road close by, to study the effect of 5 and 10% kerosene oil on the bitumen to obtain improved workability as the control section in this case.

Performance : The metal whip-off observed with the passage of traffic was less in the rubberised bitumen section of road than in the control section. Also some bleeding was observed in the control section of road whereas no bleeding was observed in the rubberised bitumen section of road.

Hotel road — Mount Lavinia — B class — medium traffic

Dry rubber content	=	2% by weight of bitumen
Kerosene oil	=	10% by volume of bitumen
Temperature of spraying	=	350°F (approximately)

Maximum duration of bitumen at this temperature 2–4 hours

Length of road	=	½ mile
Weight of roller	=	2½ tons and 8 tons.
Date of construction	=	September 1970

Remarks : There was no control stretch of single seal coat laid on this road.

Performance : This section of road is behaving satisfactorily and no bleeding has been observed so far.

Double seal coat : Double seal coat surface treatment was carried out on a section of Hotel Road, Mount Lavinia.

Experimental details :

Hotel road — Mount Lavinia — B class — medium traffic

Dry rubber content	=	2% by weight of bitumen
Kerosene oil added	=	10% by volume of bitumen
Temperature of spraying	=	350°F (approximately)

Maximum duration of bitumen at this temperature 2–4 hours

Length of road	=	½ mile
Weight of roller	=	8–20 tons
Date of construction	=	July 1970

Remarks : There was a short stretch of a control section laid on this road.

Performance : Satisfactory performance has been observed on this road and no signs of bleeding have been visible up to date.

(*c*) *Subsequent coat bituminous treatment*

A thin coat of bitumen is generally applied on a polished road surface to restore the lost binder. This same treatment was tried out on the following road. The rubberised bitumen was sprayed by manual labour using spraying cans fitted with baffles.

Experimental details :

13th mile Panadura - Nambapana road — A class — heavy traffic

Dry rubber content	=	1% by weight of bitumen
Kerosene oil	=	10% by volume of bitumen
Temperature of spraying	=	350°F

Maximum duration of bitumen at this temperature 3–4 hours

Length of road surfaced	=	¾ mile
Weight of roller	=	8-10 tons
Date of construction	=	July 1970

Remarks : A control section of a quarter mile of road was laid along the same mile of road.

Performance : Satisfactory performance has been observed on both the rubberised bitumen and the control sections of road. It appears too early to draw a comparison.

(*d*) *Asphalt concrete*

Asphalt concrete with rubberised bitumen was prepared in a continuous mixing plant and the mix was transported two miles and spread on the road surface with a paver. The rolling was carried out with a tandem roller.

Experimental details :

60th mile Colombo-Galle-Hambantota-Wellawaya road — A class—heavy traffic

Dry rubber content	=	2% by weight of bitumen
Kerosene oil	=	5% by volume of bitumen
Temperature of spraying	=	350°F (approximately)

Maximum duration of bitumen at this temperature 1–2 hours

Length of road surfaced	=	½ mile
Date of construction	=	June 1970

Remarks : An attempt was made in this case to mix asphalt concrete with rubberised bitumen containing no kerosene oil. After 10 min of working, the bitumen pump got choked and work had to be suspended for cleaning operations. Five percent kerosene oil was thereafter added and the work was carried on uninterrupted throughout the entire half mile.

A control section of road was also laid along this mile.

Performance : Satisfactory performance has been observed in both sections of road. It appears too early to draw a comparison.

SUMMARY

In the course of this work it was found that delays and difficulties usually associated with rubberised bitumen work could be mostly overcome by the introduction of a little kerosene oil into the bitumen (5 - 10%). The kerosene oil not only facilitated the blending and spraying of the binder but also cut down on the idling time of labour and plant resulting from the delays caused in cleaning the plant. The use of masterbatches further speeded up the blending of rubber and made this work more congenial.

The laboratory investigations carried out indicated that the addition of rubber to bitumen improved its properties.

Natural field latex was preserved with three stabilizers of which a mixture of 0·3% ammonia and 0·7% sodium hydroxide was found to be the best followed by 0·7% sodium hydroxide and 1·1% ammonia respectively.

The experimental stretches of road so far laid indicate that better bonding properties had been imparted to the aggregates coated with rubberised bitumen and also reduced the bleeding.

The cost was seen to increase by about 10% for labour intensive work such as seal coat surfacing and to a lesser extent for asphalt concrete paving. However, initial cost of a road should not be taken as the criterion as the maintenance during its lifetime too has to be considered, so that if better durability is obtained this will more than offset the initial cost.

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