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Use of Natural Rubber Latex in Road Construction

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Latex is the most effective form of natural rubber for road construction, both centrifuged latex and Revertex being used. The authors found creamed skim latex most effective for road-making. Because of its easy availability, however, field latex is more suitable for road-making in the natural rubber producing countries.

Results of laboratory studies on cationically stabilised, compounded and peroxide-vulcanised field latex are reported. The studies concerned the dispersion of rubber particles, temperature-dependent and rheological properties, ageing and stripping of rubberised bitumen and uses of rubber in mix designs.

Experimental stretches of road surfacing have been laid with bitumen containing up to 4% field latex. Further test stretches are being laid with rubber-modified pre-mix using field and creamed skim latices.

The improvement of bitumen by the addition of rubber was attempted even a century ago, but only recently it has become possible on a scale large enough to be of commercial interest (SINCLAIR AND BRISTOL, 1967). A fifteen-year co-operative programme of research on rubberised road materials has established conclusively the advantages of rubberised road materials for certain applications (THOMPSON, 1967). Rubber has been added to bitumen as powders, cements and latex. Unvulcanised rubber in latex form is more effective than others (SMITH, 1960), though the powder form has the advantage of convenience of addition. There is thus a steady drift away from the use of the Mealorub-type of semi-vulcanised powder and Rodorub, a slightly vulcanised powder to Pulvatex, an unvulcanised powder and to latex (MULLINS, 1963). Further, latex is considerably cheaper.

Natural rubber latices commercially used for road making are centrifuged latex and Revertex, the latter (STONE, 1963) giving better results. THOMPSON (1964) has recommended the use of concentrated latex at 1–1½% for surface dressings, 2–4% for rolled asphalt and 2–3% for bitumen-macadam. In the natural rubber producing countries, the simplest form of latex to be used is preserved field latex and its modifications.

Latices Used in Experiments

Latices used in the study were: *(a) Low ammonia field latex*—field latex was treated with 0.35% ammonia and diammonium hydrogen phosphate to precipitate and separate the magnesium and preserved with 0.3% sodium pentachlorophenate; *(b) Revertex*; *(c) Centrifuged latex; (d) Creamed skim latex*—skim latex was ammoniated to 0.7% and creamed for 48 hours with a 2.5% solution of carboxy methyl cellulose or hydroxyethyl cellulose at 0.25% on the latex and the ammonia content of the creamed skim latex brought up to 1%; *(e) High ammonia field latex*—field latex was treated with 0.35% ammonia and diammonium hydrogen phosphate to precipitate and separate the magnesium and the ammonia content was brought up to 1%; *(f) Compounded latex*—tetramethylthiuram disulphide, zinc oxide and zinc diethyldithiocarbamate as 50% dispersions and thiourea

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as an aqueous solution were added to low ammonia field latex; *(g) Cationically stabilised latex*—field latex was stabilised at 2 or 5% with a non-ionic stabiliser (Vulcastab LW), with cetyl trimethyl ammonium bromide (3% on latex) and concentrated HCl was added to bring the pH to 4; and *(h) Peroxide-vulcanised latex*—high ammonia field latex was treated with cumene hydroperoxide and tetraethylene pentamine.

Test Methods

The laboratory test methods used were as follows: A.S.T.M. D-5-52 (100 g, 5 seconds, 77°F) for penetration; A.S.T.M. D-36-26 for softening point (ring and ball); A.S.T.M. D-113-44 (25°C, 5 cm/min) for ductility and elasticity, toughness and tenacity for rheological properties. The triaxial machine applying a constant rate of deformation (0.1 in. per min) on samples 2½ in. high and 1 in. diameter prepared from rubberised bitumen, sand and quarry dust and mixed as shown in *Table 1* was used.

TABLE 1. GRADATION OF AGGREGATES FOR RHEOLOGICAL PROPERTIES

A.S.T.M. sieve number	Passing by wt (%)
4	100.0
8	71.0
16	50.0
30	35.2
50	25.0
100	17.7
200	12.5

Stripping tests were the boil test, the water immersion test, and the test to assess the stripping action of rubberised bitumen on limestone (Fernando, 1967). This quantitative test is based on the action of HCl on limestone, after stripping is carried out by boiling in water for 15 minutes. The mix designs were:

Hubbard field test. This test is used to help design sand bitumen mixes. These mix designs were carried out with different percentages of rubber, for various types of latices. The gradations of the sand and filler were controlled within the theoretical Fuller's curve to obtain minimum voids. This was done by blending different fractions of various sizes of aggregates according to *Table 1* (Asphalt Institute, 1956).

Marshall test. This is an essential test for designing asphalt concrete (pre-mix). The aggregate mix was prepared by blending various fractions of aggregate sizes according to Fuller's curve as given in *Table 2*.

TABLE 2. GRADATION OF AGGREGATES FOR THE MARSHALL TEST

A.S.T.M. sieve number	Passing by wt (%)
¾"	100.00
½"	81.5
⅜"	71.0
4	50.0
8	35.2
16	25.0
30	17.7
50	12.5
100	8.8
200	6.2

MIXING OF LATEX WITH BITUMEN

Latex was mixed with bitumen by adopting a slight modification to the method given by the Natural Rubber Producers' Research Association (1964): "Bitumen is heated to a temperature 300–325°C in a boiler, the capacity of which will allow for at least a 50% increase in binder volume. An anti-foaming agent may be added. With efficient hand stirring, a small quantity of latex is sprayed slowly using a garden watering-can. After allowing the latex to be on the surface for 20 seconds it is stirred into the binder carefully. Stirring should be continued for a minimum period of 20 minutes after the addition of rubber, the temperature being maintained between 300 and 325°F."

PROPERTIES OF BITUMEN RUBBERISED WITH LATEX

In field latex, the particle size ranges from less than 0.04 μ to about 2 μ, the maximum in the size frequency curve occurring at approximately 0.6 μ (van den Tempel, 1952). When latex is concentrated by centrifuging, the distribution curve is shifted towards larger diameters since most of the smaller particles are left in the skim. Thus skim latex would have most of the small particles, and centrifuged latex most of the large particles, present in field latex. The smaller the size of the latex particles, the less the heat required to disperse them in a homogeneous mixture and the less degradation caused by heat. In this respect, creamed skim latex and, to some extent field latex would be superior to centrifuged latex.

Figure 1 shows the particle distribution of rubber in bitumen as field latex, centrifuged latex and Revertex. In these curves, obtained by means of microphotography, it is clear that field latex in bitumen gives the highest percentage of small particles (size under) at any particle size.

The properties of bitumen with different percentages of rubber for various types of raw latices are given in *Table 3*.

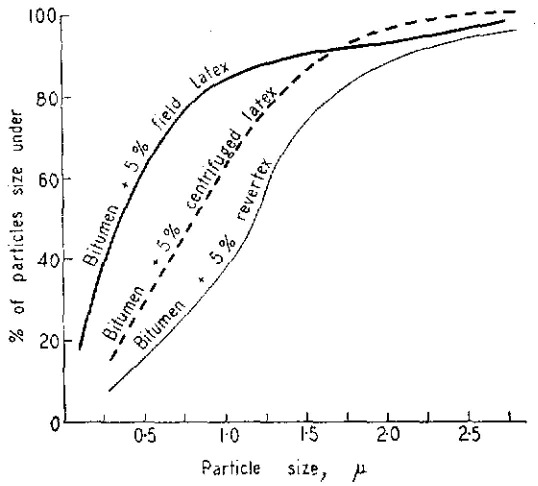

Figure 1. Particle distribution of rubber in bitumen.

TABLE 3. PROPERTIES OF BITUMEN RUBBERISED WITH LATEX

Property	Rubber (%)	Type of latex					
		L.A. field latex	H.A. field latex	L.A. centrifuged latex	Revertex	Creamed skim latex	
						C.M.C.	H.E.C.
Penetration	0	90	90	90	90	90	90
	2	74	69	71	73	70	68
	3	68	60	65	63	62	64
	4	62	58	60	53	52	60
Softening point	0	49	49	49	49	49	49
	2	53	58	54	54	58	57
	3	56	62	58	61	59	59
	4	60	63	61	67	64	62
Ductility	0	150+	150+	150+	150+	150+	150+
	2	72	55	54	72	73	58
	3	61	40	48	60	60	51
	4	54	34	43	35	45	34
Stripping on limestone	0	6.2	6.2	6.2	6.2	6.2	6.2
	2.5	2.6	4.3	2.0	1.3	1.0	2.4
Percentage increase in toughness	2.5	68	108	93	39	125	–
Percentage increase in tenacity	2.5	186	260	303	220	136	140

From these results it is clear that rubber in the form of raw latices, even when used in small quantities, is highly effective in modifying the physical properties of bitumen. The field latex (H.A.) and creamed skim latex are just as good as, if not superior to, Revertex in respect of penetration, softening point and ductility. *Figures 2* and *3* show the variation of the Hubbard field design with different percentages of rubber for creamed skim latex and field

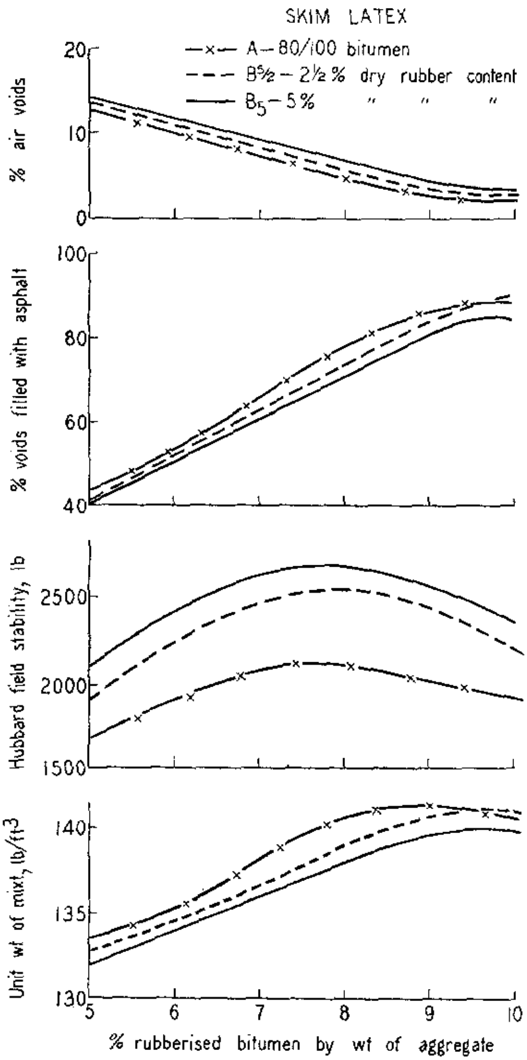

Figure 2. Hubbard field designs obtained with rubberised bitumen.

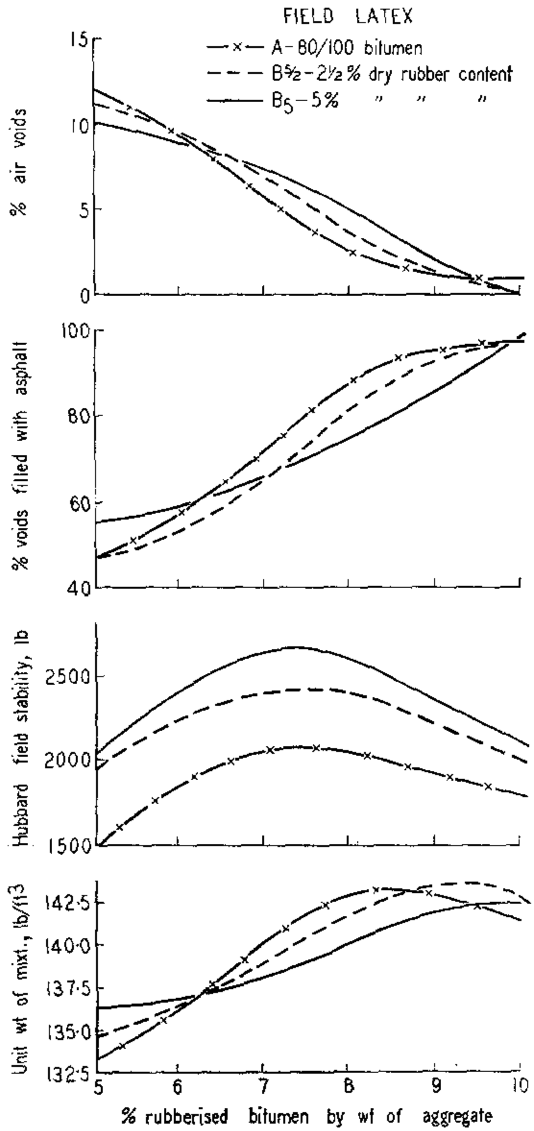

Figure 3. Hubbard field designs obtained with rubberised bitumen.

latex respectively. *Figures 4* and *5* illustrate the variation of Hubbard field stability for different types of latices with 80/100 bitumen as the control. It is clear that there is a distinct increase in the stability on the addition of rubber, keeping the percentage of air voids and the percentage filled with asphalt within specified limits. With 2½% rubber, creamed skim latex showed the maximum Hubbard field stability (24% over the control), while field latex gave an increase of 18%. Field latex as well as creamed skim latex showed a maximum Hubbard field stability of 30% increase for 5% dry rubber content (d.r.c.).

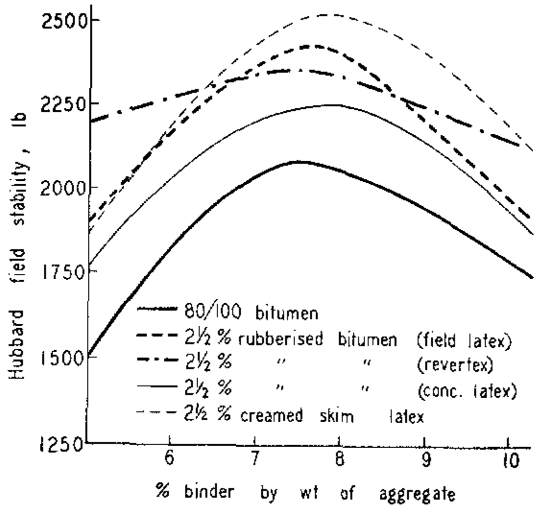

Figure 4. Hubbard field stability for different latices with 2½% d.r.c.

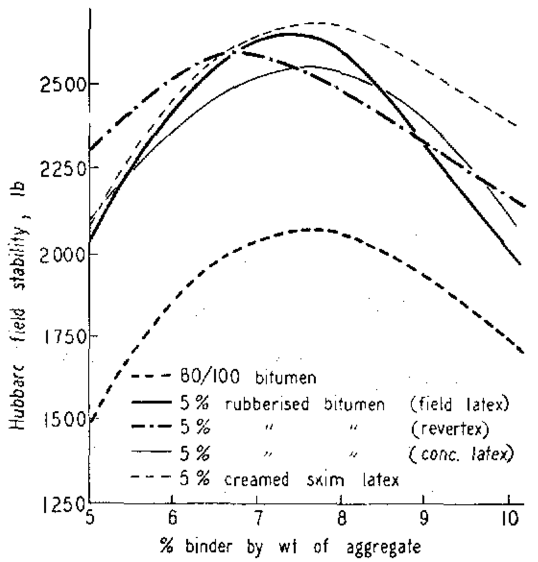

Figure 5. Hubbard field stability for different latices with 5% d.r.c.

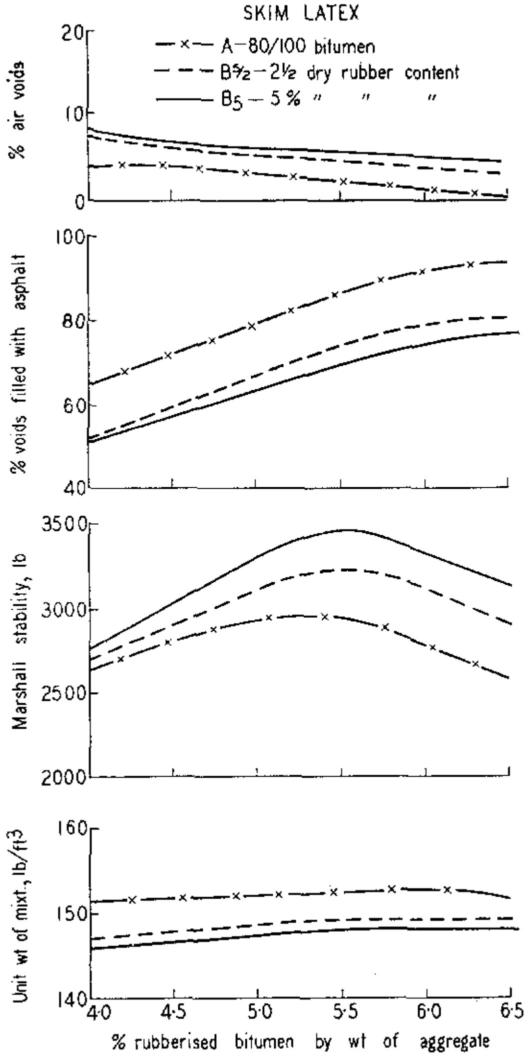

Figure 6. Marshall designs obtained with rubberised bitumen (skim latex).

Figures 6 and *7* show the variation of the Marshall design for asphalt concrete (pre-mix) with different percentages of rubber for creamed skim latex and field latex respectively. Variation of the maximum Marshall stability for different types of latices is illustrated in *Figures 8* and *9* with 80/100 bitumen as the control. A maximum increase of 12% in the stability was observed with creamed skim latex for 2½% d.r.c., whereas field latex gave an increase of 8%. With 5% d.r.c., a maximum increase in stability of 19% was observed for creamed skim latex and 11% for field latex.

As field latex is the most easily available form of latex in the natural rubber producing countries, further work was done on it. Results on the use of rubber as field latex, on loss on heat ageing, and decrease in penetration on ageing

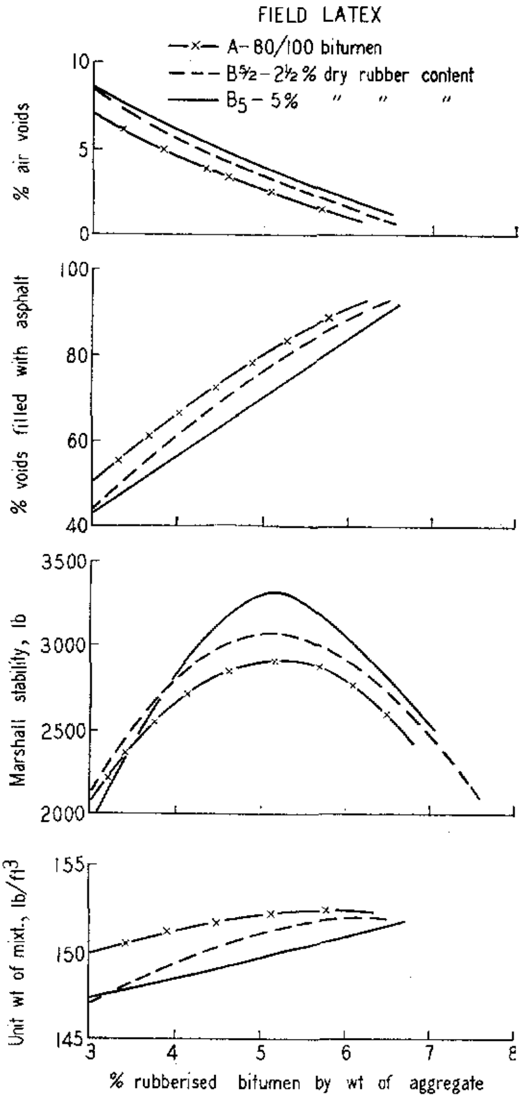

Figure 7. Marshall designs obtained with rubberised bitumen (field latex).

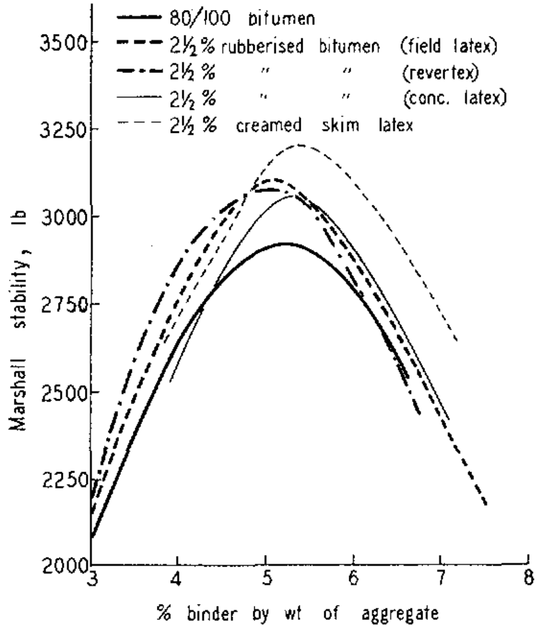

Figure 8. Marshall stability for different latices with 2½% d.r.c.

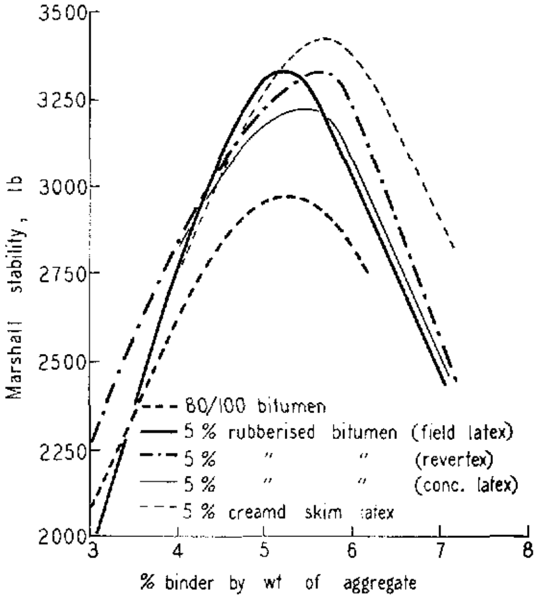

Figure 9. Marshall stability for different latices with 5% d.r.c.

TABLE 4. EFFECT ON PHYSICAL PROPERTIES OF BITUMEN RUBBERISED WITH FIELD LATEX (L.A.)

Type	Ageing		Penetration at			Percentage stripped			
	Loss on heat ageing (%)	Decresae in penetration (%)	25°C	30°C	35°C	Boil test		Water immersion test	
						Granite	Charnakite	Granite	Charnakite
80/100 Bitumen	0.33	20	90	130	200	12	11	5	10
2% Rubberised bitumen	–	–	–	–	–	5	1	0	1
2½% Rubberised bitumen	0.11	12	60	81	120	–	–	–	–
5% Rubberised bitumen	0.10	5	54	77	112	–	–	–	–

given in *Table 4* confirm previous findings (LEWIS AND WELBORN, 1954) that rubber enhances the ageing properties and resistance to subsequent cracking due to brittleness of bitumen.

The results obtained on the variation of penetration with temperature, of bitumen rubberised with field latex and on stripping immersion test *(Table 4)* show the effectiveness of rubber.

EFFECT ON BITUMEN OF FIELD LATEX MODIFIED WITH ADDITIVES

Compounded Latex

It has been shown by DE MERLIER *et al.* (1964) that smoked sheet in which the rubber has a molecular weight of less than 400 000 exerts a negligible influence on the elasticity of the bitumen; above this value, the elastic recovery increases rapidly and attains 100% for a molecular weight value of about 900 000. Rubber is subject to degradation when heated and at the temperatures at which road materials are mixed and laid, *i.e.*, up to 200°C, the degree of degradation can be serious. The formula used for making compound C *(Table 5)* was that recommended by the NATURAL RUBBER PRODUCERS' RESEARCH ASSOCIATION (1961) for compounding natural rubber latex for heat resistance: natural rubber as latex 100, zinc oxide 1, tetramethylthiuram disulphide (TMTD) 3, zinc diethyldithiocarbamate (ZDC) 1, and thiourea* (TU) 1, vulcanised for 2–3 hours at 70°C. Compounds A and B were prepared by adding 25% and 50% respectively of the compounding ingredients as in C. No pre-vulcanisation was done, since vulcanisation occurred when the compounded latex was mixed with hot bitumen.

The properties of bitumen with different percentages of rubber for compounds A, B and C are given in *Table 5*. Light vulcanisation (Compound A) gave the best all-round properties.

CATIONICALLY STABILISED FIELD LATEX

Preliminary trials on bitumen rubberised with cationic perbunan C latices by ESSER AND HOFMANN (1964) have been reported by them to be interesting, as cationic latices whose rubber particles have a positive charge would promote a particularly good adhesion of such

* According to *N.R.P.R.A. Technical Information Sheet No. 93*, an effective anti-oxidant for unvulcanised latex.

TABLE 5. EFFECT OF FIELD LATEX MODIFIED WITH ADDITIVES ON PROPERTIES OF BITUMEN

Property	Rubber (%)	Type of modified latex							
		Compounded latex				Cationically stabilised field latex	Peroxide-vulcanised field latex		
		Control	A	B	C		A	B	C
Penetration	0	90	90	90	90	90	90	90	90
	2	74	80	78	75	64	69	64	56
	3	68	70	72	70	59	60	62	52
	4	62	62	68	66	55	58	58	48
Softening point	0	49	49	49	49	49	49	49	49
	2	53	53	53	52	56	58	58	59
	3	56	57	55	53	58	62	63	62
	4	58	61	57	55	61	63	64	65
Ductility	0	150	150	150	150	150	150	150	150
	2	72	60	52	50	81	55	35	22
	3	61	58	49	45	58	40	30	20
	4	51	51	40	30	49	34	26	17
Stripping on limestone	0	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
	2.5	4.0	–	2.0	–	1.3	4.3	3.0	2.9

rubberised bitumen to other materials. The results obtained by us with cationically stabilised field latex, as given in *Table 5*, show an improvement as compared with the control in penetration, softening point and stripping. It would be expected that still better results on stripping would be obtained with an acidic stone such as granite.

PEROXIDE VULCANISED FIELD LATEX

SEKHAR (1958) has stated that, during aeration of natural rubber latex, oxygen produces peroxidic centres in rubber and that while the production of these peroxidic centres causes the rubber to degrade on heat ageing, the presence of reduction activators altered the course of reaction to one of cross-linking. It may be expected that blowing of air over the surface of heated field latex in the preparation of Revertex may give rise to peroxidic cross-linking due to reduction activators present in the latex serum. BLOOMFIELD (1952) has shown that cumene hydroperoxide (CHP) and tetraethylene pentamine (TEP) can cross-link rubber molecules in latex. CHP at 0, 0.4 and 0.8% and TEP at 0, 0.1 and 0.2% were added to H.A. field latex respectively. The properties of the bitumen with different percentages of rubber and with different concentrations of CHP, *i.e.*, A having 0%, B having 0.4% and C having 0.8% CHP are given in *Table 5*. It will be seen that peroxide vulcanisation gives some improvement in the properties of bitumen over that of the control.

CHEMICAL INTERACTION OF NATURAL RUBBER WITH BITUMEN

Elastomer and bitumen technologists have generally held the view that the effect of rubber on a bituminous material is physical rather than chemical. KALIN (1967) investigated the use of SBR (styrene 23%, butadiene 77%) latex in rubberised asphalt and is of the view that the effect of the rubber in bitumen is purely physical.

However, this may not be so in the case of natural rubber latex. SEKHAR (1961 and 1963) has shown the presence of abnormal groups in rubber namely about 9 to 35 aldehydic groups and about 100 to 420 aldehyde condensing groups per polyisoprene molecule, assuming a molecular weight of 1 000 000. Since bitumen has also 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, when mixing natural rubber latex with bitumen. This may explain the somewhat varying results obtained in the properties of bitumen rubberised with field latex. Thus if there is a long interval between tappings because of rain interference, if the latices are from different clones or if the tapping intensity varies, then all these factors may affect the amount of abnormal groups in rubber and hence the properties of the bitumen rubberised with field latex. The results obtained for the properties of bitumen rubberised with (a) high ammonia field latex from clone Tjir 1, and (b) high ammonia field latex from clone RRIM 501, given in *Table 6*, confirms this view.

Further it is known that hydroxylamine condenses with the aldehyde groups present in the natural rubber molecules and renders them inactive. The H.A. latex from RRIM 501 was treated with hydroxylamine at 0.34% on the latex and the properties of bitumen rubberised with this latex are also given in *Table 6*. It will be seen that the properties of the hydroxylamine-treated latex are inferior to that of the non-treated H.A. latex from RRIM 501 in penetration and softening point. Hence the aldehyde groups in natural rubber latex in the unreacted state have a chemical influence in improving the properties of the bitumen.

TABLE 6. CHEMICAL INTERACTION OF NATURAL RUBBER LATEX AND BITUMEN

Property	Rubber (%)	Type of latex: Tjir 1 H.A. latex	RRIM 501 H.A. latex	RRIM 501 latex treated with ammonia (0.5%) and then with NH_2OH (0.34%)
Penetration	0	96	90	96
	2	77	70	80
	3	74	67	76
	4	70	62	67
Softening point	0	48	49	48
	2	56	56	54
	3	60	58	55
	4	60	61	57
Ductility	0	150+	150+	150+
	2	46	76	60
	3	41	58	56
	4	36	43	49

FIELD EXPERIMENTS

An experimental seal coat was laid on one mile of road with rubberised bitumen at the 9th mile, Nagoda–Matugama–Agalawatta road about two years ago. The work consisted of sections of single seal coat using 1, 2, 3 and 4% rubberised bitumen. A short section was also given a double seal coat using $\frac{3}{4}''$ metal for the first seal coat. Some sections were treated with plain rubberised bitumen containing 2 and 3% dry rubber content and blinded with sand.

The control and the 1% rubberised bitumen single seal coat section have shown some cracks already. However, the 2% rubberised bitumen single seal coat section is behaving well. Therefore a rubber content of 2% should be the minimum to be used for road work.

The section dressed with plain bitumen and blinded with sand has already started pitting up, while the rubberised bitumen sections blinded with sand has as yet shown no signs of pitting at all.

Half a mile of road is being laid with rubber modified pre-mix (4% d.r.c. on bitumen), the rubber being in the form of field latex (L.A.), field latex (H.A.) and creamed skim latex.

More and more field trials must be carried out to study the potentialities of rubberised bitumen in other forms of construction such as asphalt concrete and sand asphalt carpets where little work has been done.

For convenience in field work, a 16% rubberised bitumen masterbatch is recommended.

DISCUSSION

To improve the stability of field latex, it was treated with diammonium hydrogen phosphate, to precipitate the magnesium. According to *N.R.P.R.A. Technical Information Sheet No. 93*, diammonium hydrogen orthophosphate is an effective inhibitor in oxidative breakdown of unvulcanised latex rubber. Hence it would be advantageous if an excess of diammonium hydrogen phosphate is added so that after being used for precipitating the magnesium up to 1 p.p.h.r. of it is left in the field latex. It is during the process of dissolving the rubber in bitumen that it is liable to get degraded. Once the rubberised bitumen is laid, the rubber is protected by the surrounding mass of bitumen and further oxidation of the rubber is unlikely to occur to any significant extent.

The use of a non-volatile preservative may be an advantage, as it is less likely to be affected by heat during the mixing process; hence our experiments with L.A. field latex. According to DE MERLIER *et al.* (1964), rubber in the form of latex takes several weeks to swell and distribute itself uniformly throughout the bitumen. It is therefore necessary that a certain waiting period should be allowed for the elastic properties of the bitumen to reach a maximum. This period may vary with various types of latices and may be why L.A. field latex behaves less efficiently in laboratory experiments than H. A. field latex and Revertex in rubberised bitumen *(Table 3)*. According to THOMPSON (1967), it has been established conclusively that the rubber must be dissolved in the binder since undissolved rubber makes no contribution to the improvement of surfacings.

It is well known that skim rubber because of its high protein content shows some undesirable properties when compounded in the normal way. An alternative use of skim latex would be the use of creamed skim latex with bitumen in roads.

The observations made by the authors on the experimental roads laid recently confirm the view that the temperature-dependent properties, elastic properties and stripping action due to monsoon rains and traffic are improved considerably.

At the present prices for rubber, the cost (in Ceylon) of a single seal coat increases by $2\frac{1}{2}\%$, double seal coat by 3%, asphalt concrete (pre-mix) by $4\frac{1}{2}\%$, and sand asphalt carpet by 6% for rubberised bitumen using field latex or creamed skim latex for road work. Other countries have claimed large savings by using rubber in roads, with the life of the road increased by 25–40%. In effect, it is not the initial cost of the road but the cost per square yard per year of its total life including repairs and renewal that decides the economy of road construction. Thus, the additional cost of using rubber in road work is negligible in view of the longer life it gives to the roads.

The natural rubber producing countries are now faced with the problem of obtaining reasonable prices for their rubber. Wide-scale use of it in roads in the natural rubber producing countries themselves would not only help increase rubber consumption but also give them better roads. Bitumen imports could also be reduced considerably.

There seems to be a bright future for the use of rubber in roads in Ceylon. Certainly rubber will play a very important part in all the desired properties of a binder for a road engineer to give more durable, better and cheaper roads.

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DISCUSSION

Chairman: Dr. J-P. Poliniere

Mr. K.M. Philip asked if the authors had tried 'reclaimed rubber' in roads. Mr. Fernando replied this had not been done yet. Mr. R.A. Billett noted the use of anti-foaming ingredients in some trials and enquired if these decreased the surface tension of the bitumen, leading to reduced adhesion and greater stripping. Mr. Fernando said no stripping had been observed. In reply to Mr. Billett's further question, he said the cost of the rubber required was 2% of the cost of the bitumen and aggregate used in the top surface; it was not 2% of the total cost of road construction.

Mr. J.E.A. Slootman asked about safety on roads incorporating rubber, especially when wet. Mr. Fernando said that many countries had reported improved resistance to skidding. He had investigated the index of retained strength under wet conditions (which is the ratio of these values expressed as a percentage of control) by preparing specimens of pre-mix cured in the oven and duplicates cured in water; the tests indicated improved strength even in the wet. Mr. R.W.J. Gouldbourn said his experience in England was that rubber gave a rather bad skid surface. Compounds of nitrogen influenced the adhesion of bitumen with certain types of aggregates. He enquired if latex had been mixed with emulsions of bitumen especially with a view to protecting the sides of canals. Mr. Fernando said most work had been done with penetrating types of bitumen, but emulsions of bitumen had been found very useful on a small scale to patch pot-holes, when it was necessary to have a small supply with good storage properties for occasional use.

Dr. B. Saville drew attention to the temperature of 325°C at which the latex was added to the molten bitumen and asked if there was any hazard from the steam evolved. Mr. Fernando said it was necessary to take precautions, but the workers had been trained to add the latex carefully in very thin streams and small quantities and to allow time for dispersion; anti-foaming agents should be used when necessary. Mr. A.D.T. Gorton asked if the rubber dissolved in the bitumen, what the role of the aldehydic groups was and how this was affected by the use of peroxide-cured rubber or of vulcanised rubber powder. Although the rubber must be dissolved in the bitumen, Mr. Fernando thought that it was broken down to some extent by the heating; therefore, moderate vulcanisation to raise the initial molecular weight was beneficial. According to their theoretical model, the aldehyde groups at intervals along the hydrocarbon chains gave points of anchorage for the bitumen and for cross-links and this resulted in flexibility.