Merits of Adding Natural Rubber to Bituminous Road Surfacing Materials

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During 15 years of cooperative research between the Natural Rubber Producers' Research Association and the United Kingdom Road Research Laboratory, investigations were undertaken to find the extent to which the properties of road bitumen and asphaltic materials are altered by the addition of natural rubber. The paper describes how the alterations in properties of road binders were defined initially with reference to standard tests used in the road industry. These showed that rubber addition improved the brittle properties, reduced the temperature susceptibility, and increased the softening point, and that the resultant binders were markedly elastic.

Concurrently with the laboratory research, an extended series of full-scale road experiments was undertaken to show how rubberized surfacings behaved under traffic in comparison with normal materials. The paper indicates the advantages from the addition of natural rubber, which vary with the type of surfacing laid. In surface-dressing or seal coats, rubber reduces fatting-up considerably and gives greater initial retention of chippings; in open-textured carpets, a marked increase in life was found. Both rolled asphalt and mastic asphalt are made much more resistant to cracking, and the stability of mixtures is increased by addition of natural rubber. It is also possible to increase the amount of binder by about one-eight (which in itself reduces cracking and disintegration) without impairing the stability of the mixtures.

•ALTHOUGH the study of rubberized asphalts originated in the last century, it is only in the last 40 years that serious consideration has been given to rubber-asphalt mixtures with any hope of widespread use. At this stage, part of the "rubber-for-roads" effort was engaged in developing solid rubber surfacings that, for reasons of cost and slipperiness, were not destined to be used to any great extent. Latex-cement surfacings were also investigated about the same time but, as with the earlier rubber-asphalt trials, development was slow and World War II stopped further effort.

Some work on the rheological properties of bitumen containing rubber was carried out in Holland and the United Kingdom, but most of the prewar work consisted of road trials. There are reports of road-layings in Holland, Singapore, the Dutch East Indies, the United Kingdom, and the United States. Nearly all were initiated by natural rubber interests when the price of rubber was exceptionally low. The trials established that the use of rubber as an additive had definite merit but there was little basic knowledge about why and in what circumstances it was most advantageous.

From 1947, further trials were started but it was clear that no progress would be made unless a more systematic and fundamental approach was adopted. Within a few years, investigations were started in various parts of the world, and in 1951 a joint program of both laboratory and full-scale research was started in England by the Road Research Laboratory and the British Rubber Producers' Research Association (later,

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the Natural Rubber Producers' Research Association). The present paper is concerned with the findings from this research.

In this work it was recognized that, while it was important to obtain fundamental data on the properties of rubber-asphalt mixtures and the factors influencing their variation, practical road experiments were also essential. Clearly the final acceptance of rubberized mixtures depends on the economic benefits actually accruing to the road engineer; full-scale road experiments were therefore started early in the program. It is convenient, however, to deal with the full-scale laboratory investigations separately.

PROPERTIES OF ROAD BINDERS CONTAINING NATURAL RUBBER

A number of researchers have established that the major changes in physical properties of asphalt brought about by the addition of small quantities of natural rubber are in the viscous, elastic, and brittle properties (1). Also, the quantitative change in the properties of asphalts induced by rubber addition depends on the type of asphalt, form of rubber, blending procedure, and the history of the modified binder in terms of time and temperature of storage prior to testing.

Effect of Rubber Form

Before the result of tests on the rheological properties of natural-rubber asphalts can be fully appreciated, it is necessary to understand how the form of rubber and the time and temperature of heating influence the results.

Natural rubber is blended into asphalt either in vulcanized or unvulcanized form and as a dry powder or latex. In practice, three forms are used: unvulcanized powder (containing inert filler), vulcanized powder, and unvulcanized latex (either evaporated or centrifuged).

The difference in effectiveness between unvulcanized powder or latex is dependent on the molecular weight of the rubber. This should be similar for both unvulcanized powder or latex. In practice, their long-term effects will be influenced by natural or added antioxidants present, and after blending, which involves a finite time at relatively high temperatures, differences in behavior are generally found to exist.

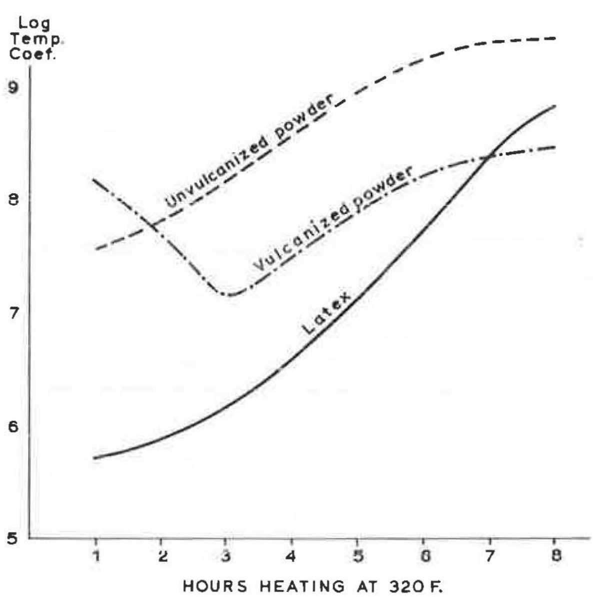

Figure 1. Change in temperature susceptibility with heating of rubber-asphalt blended with unvulcanized powder, vulcanized powder, and latex.

The difference between the properties of rubber-asphalt blended with vulcanized and unvulcanized rubber is considerably greater. Unvulcanized natural rubber dissolves readily in asphalt. In vulcanized rubber, the long-chain molecules are "welded" together into a network, and the rubber will not dissolve until the network is broken down by heating to shorter, branched chains, which are less effective.

The instrument used to measure the viscoelastic properties of the binders in the following investigations was a conicylindrical viscometer of 2 in. cylinder length, the diameters being 0.4 in. and 1.2 in. The annulus was 0.8 in. wide. A wide annulus was used to prevent interference with the results by fine particles of undissolved rubber. Full details have been described elsewhere (1).

Figures 1 and 2 show how the temperature susceptibility and change in softening point (ring and ball) of

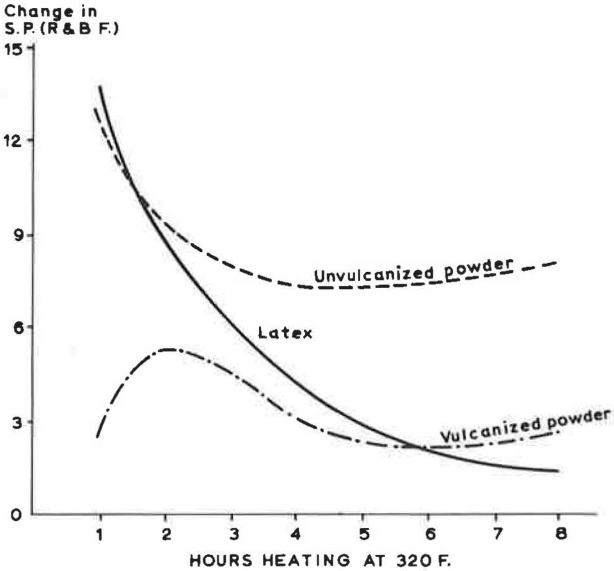

Figure 2. Change in softening point (ring and ball) with heating of rubber-asphalt blended with unvulcanized powder, vulcanized powder and latex.

rubber-bitumen blended from a Middle East bitumen alter during heating for an unvulcanized powder, a vulcanized powder, and latex. (The method of assessing temperature susceptibility is referred to later.) There is a continuous increase in effectiveness of the vulcanized rubber for the first few hours, during the time the rubber is broken down and dissolved. On prolonged heating more rubber is dissolved, but the continued breakdown of the initially dissolved rubber reduces its effectiveness.

It was recognized during the research that a single test method was desirable to assess the effectiveness of rubber in bitumen. It proved difficult, if not impossible, to assess the rubber content directly, so a method was evolved that measured the effectiveness of the rubber based on measurement of average molecular weight. The method has been published as part of the officially recommended specification for the United Kingdom (2). It depends on the recovery of the acetone-insoluble fraction of the binder on which are carried out specific viscosity and iodine value measurements. From the measurement of the specific viscosity of solution, the "effective rubber content" is calculated; the iodine value is a measure of the total unvulcanized dissolved rubber.

The effective rubber content is a measure of the useful rubber in the binder in terms of the amount of an undegraded standard natural rubber that would be required to give the same effect as the rubber actually present. It has been correlated with such properties as the change in softening point, elastic recovery, and temperature susceptibility. Figure 3 shows how the elastic recovery follows the effective rubber content. Measurements of elastic recovery were made using the conicylindrical viscometer. A torque of 10 × 10^4 dyne-cm was applied to the inner cylinder until the stress in the material at the surface of the inner cylinder was about 0.9. The torque was then suddenly removed and the elastic recovery was measured over a period of 15 min.

By using this method it has been possible to follow the effect

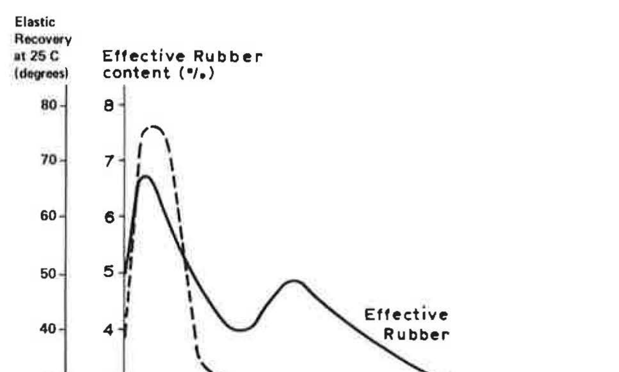

Figure 3. Relation between effective rubber content and elastic recovery during heating of rubber-asphalt.

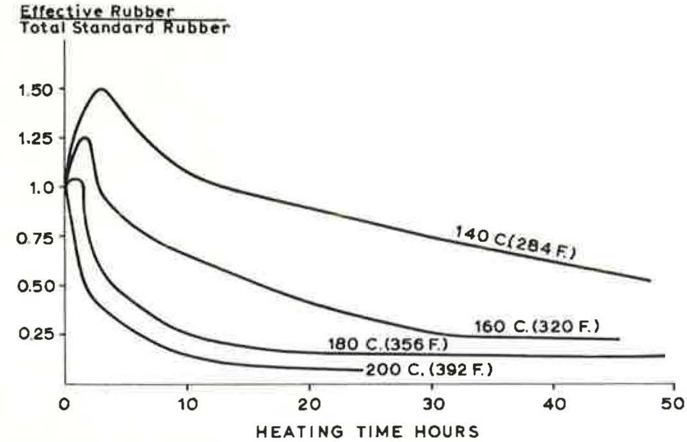

Figure 4. Variation of the effect of rubber in asphalt when heated at various temperatures.

of heating on binders containing natural rubber without carrying out a series of different tests. Figure 4 shows how the properties alter with heating at different temperatures.

The particular binder used consisted of 3¾ percent rubber (added as latex) in a bitumen/kerosene mixture. The presence of kerosene leads to more rapid breakdown of rubber than is found when either tar oil is used as a fluxing agent, or when no fluxing oil is used. The reduction in effectiveness, quantitatively, is therefore exaggerated. It can be seen that an increase in temperature above 160 C leads to a much more rapid rate of breakdown.

At the temperatures normally used for blending (around 160 C) the characteristics of rubber-asphalt vary rapidly during the first 2-3 hours. Initially, an increase in effectiveness (and, for example, elasticity) can be seen. In the first part of the heating process, which covers the normal blending time, the properties can change rapidly. This may explain some of the variability and inconsistent results that arise when different samples are compared in the laboratory. Until these changes have been explored for each type of rubber, comparisons between different rubbers may lead to incorrect conclusions. In practice, the amount of heating to which road binders are subjected before they reach the road is much greater than the period of "rapid change."

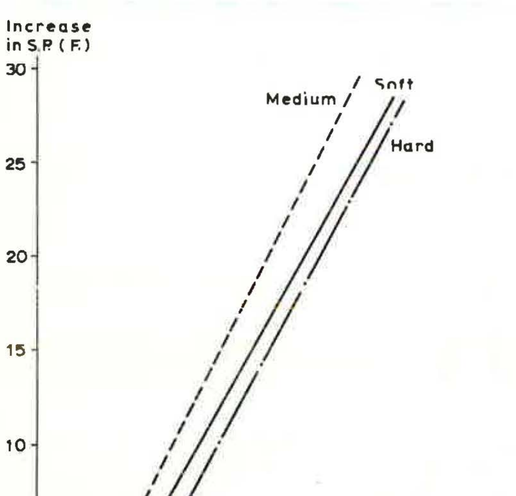

Figure 5. Effect of rubber concentration on softening point (ring and ball) in three Middle East asphalts using latex, unvulcanized rubber powder, and vulcanized rubber powder.

Influence of Base Asphalt

The sources and types of asphalts used in the United Kingdom are less varied than in many other countries, in particular the United States. For the United Kingdom there is therefore less need to establish how rubber reacts in a variety of asphalts. Smith (1) investigated the effect of natural

rubber on three different asphalts from the same source (Middle East) but varying in hardness. The viscosities of the asphalts used were 170 pen (soft), 120 pen (medium), and 55 pen (hard). Some results of this investigation are reproduced in Figure 5. It is evident that, although there is some variation in the change in softening point between the three asphalts, it is marginal. Other researches have found much greater variation. It would seem necessary, therefore, for some simple tests to be carried out in the laboratory before asphalts not previously used with rubber are modified in this way.

Results of Standard Tests on Rubber-Asphalt Blends

The properties of rubber-asphalts vary, depending on a number of factors, including the form of rubber and source of asphalt. Detailed results can therefore only apply to the particular circumstances of individual tests. Nevertheless it is possible to draw general conclusions from a wide range of test results, and the results quoted have been found to be typical for asphalts commonly used in the United Kingdom.

Softening Point—The softening point (ring and ball) invariably increased by the addition of natural rubber. Table 1 gives some typical results for various forms of rubber in a Middle East asphalt. On the average, the softening point of a rubber-asphalt blended with latex is raised by 3 C, with unvulcanized powder by $2\frac{1}{2}$ C, and with vulcanized rubber by $1\frac{1}{2}$ C for every 1 percent of natural rubber.

Individual tests on solid rubber (smoked sheet) dissolved in kerosene prior to preparing cut-back bitumen indicate that smoked-sheet-asphalt mixtures behave in a way similar to unvulcanized rubber powder.

Viscosity and Temperature Susceptibility—The addition of rubber has a marked effect on the viscosity of asphalt and, more importantly, on the rate of change of viscosity with temperature (i. e., the temperature susceptibility). At high road temperatures rubber increases the viscosity while at low temperatures the viscosity is reduced by rubber addition.

The method used for assessing the temperature susceptibility of rubber-asphalts (1) was that described by Lee et al (3), termed the logarithmic temperature coefficient. This is defined as

$$\log (\text{temp. coef.}) = \frac{\log \eta_1 - \log \eta_2}{\log T_2 - \log T_1}$$

where η_1 and η_2 are the viscosities measured at temperatures T_2F and T_1F.

As with the other rheological properties of rubber-asphalts, the temperature susceptibility varies with the amount of effective rubber in the binder. Figure 6 shows the progressive increase in susceptibility with reduction of effective rubber for latex and unvulcanized rubber blended into a 300-pen asphalt.

Elasticity—The most obvious change in asphalt when rubber is added is the marked elasticity that results. Asphalts (apart from blown asphalt) do not normally exhibit

TABLE 1

AVERAGE INCREASE IN SOFTENING POINT (RING AND BALL) IN °C WHEN 2 PERCENT AND 4 PERCENT OF DIFFERENT FORMS OF NATURAL RUBBER ARE ADDED TO A MIDDLE EAST ASPHALT

Asphalt	Latex		Unvulcanized Powder		Vulcanized Powder	
	2 Percent	4 Percent	2 Percent	4 Percent	2 Percent	4 Percent
300 pen.	$8\frac{1}{2}$	—	7	—	3	—
150 pen.	5	13	4	9	2	4
100 pen.	7	15	5	12	3	9
50 pen.	4	12	5	12	4	8
Average	6	13	5	11	3	7

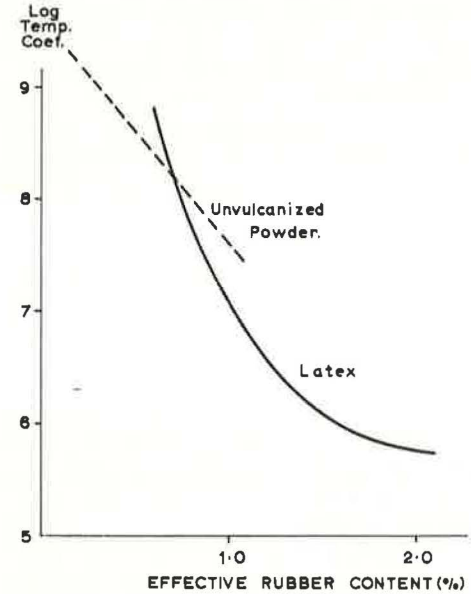

Figure 6. Variation of temperature susceptibility and effective rubber content of rubber-asphalt — with latex and unvulcanized-rubber powder.

noticeable elastic properties. With even small amounts of natural rubber (less than 1 percent), it often possible to see the elastic recovery when a sample is deformed at room temperature. Figure 3 shows how, even after two days heating at 140 C (284 F), the elastic properties are still appreciable. The very high values recorded when latex is used is accentuated by a gel structure that does not disappear until some time after initial dispersion of the rubber at normal blending temperatures.

Brittle Properties—Investigations into the brittle properties of rubber-asphalts carried out during the cooperative research program in the United Kingdom have been reported elsewhere (1). The properties were assessed by measurement of the extensibility of the binders at -10 C, and some results are reproduced in Figure 7. The extensibility measurements were carried out in a Hounsfield tensometer. The rate of extension was 0.1 in./sec. The load/extension data were obtained from photographic records of the tests at a film speed of 64 frames/sec. As with the other properties considered, the effects of unvulcanized rubber in latex and powder form are of similar magnitude. Vulcanized rubber is rather less effective. The broken lines in the diagram show linear relationships between increase in extensibility and in log (viscosity at 25 C), which are dependent on the base asphalt but independent of the form of rubber.

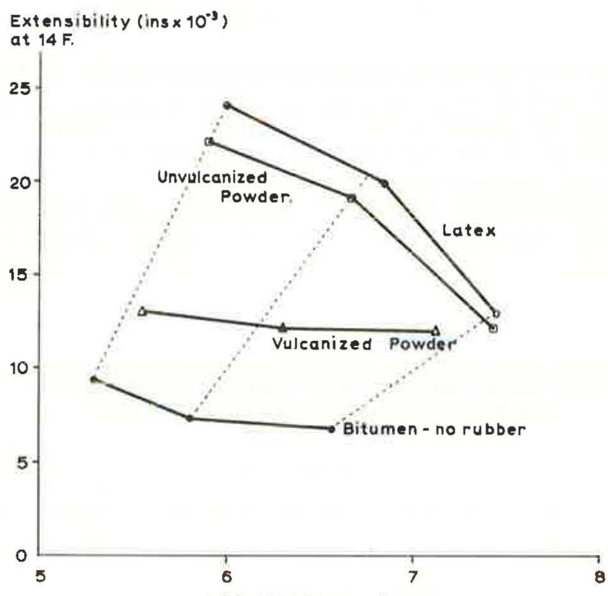

Figure 7. Relation between low-temperature (-10 C) extensibility and viscosity at 25 C after heating for 1 and 4 hours at 170 C.

Low-temperature measurements are very dependent on complete blending of the rubber. Undissolved rubber can form centers of discontinuity in the material at which stress concentrations occur, leading to premature failure.

Properties of Rubber-Asphalts

The results of the standard tests referred to indicate how rubber addition alters the properties of asphalt. The important alterations can be summed up as follows:

1. Elastic properties are imparted to asphalts resulting in considerable departure from Newtonian flow;
2. The temperature susceptibility of viscosity is reduced; and
3. Brittleness is reduced.

When the modified binders are used in surfacing materials, advantages are gained that result from these changes in properties. They are improved resistance to cracking, resistance to fatting-up, resistance to flow or deformation (i. e., greater stability), and improved adhesion and resistance to stripping (arising from the improved "tack" of rubber). Although it is possible to carry out simulative tests to show these advantages, the most convincing demonstration is one actually carried out on the road.

FULL-SCALE ROAD EXPERIMENTS

In the United Kingdom, the road experiments concerned four main types of surfacings: seal coats or surface-dressing, rolled asphalt, mastic asphalt, and open-textured carpets (bitumen macadam). Trials of other materials, such as fine cold asphalt, have been laid commercially and although successful have not been controlled systematically. The experiments carried out during the research have been reported up to 1963. They are summarized next, with additional data obtained subsequently.

Seal Coats or Surface-Dressing

Experiments using asphalt cut-backs for surface-dressing have been carried out in various parts of England (4). This treatment, in which asphalt is sprayed onto the road and covered with single-sized chippings, is vulnerable to major temperature and weather changes. Although the viscosity of the sprayed binder is generally lower in the spring and fall than in the summer, it is not changed at short notice with the prevailing weather conditions. Sudden changes in the weather, therefore, may result in serious failures. The two main causes of trouble are the onset of very hot weather and heavy rain shortly after the work has been finished. Hot weather may cause failure in months, or even a year afterwards.

Natural rubber addition to asphalt has been shown to reduce considerably the susceptibility of the seal to both these types of failure. Eleven experiments were laid using rubber-asphalt as the binder; the rubber content varied between 1 and 2 percent by weight. Most of the binders were blended with vulcanized rubber, but in the last two latex was used. Full-scale spraying trials were also carried out to determine the maximum rubber content that could be used in practice.

From the series of experiments the following conclusions were drawn:

1. Rubberized binders resist fatting-up under heavy traffic (Fig. 8 shows a marked difference in the condition of a rubberized and a normal seal after hot weather).

2. The use of rubberized binders is of most benefit on heavily trafficked roads. On very lightly trafficked roads, rubber addition did not extend the life of the dressing. This result is to be expected because the most important change in properties obtained by the addition of rubber affecting this treatment is the reduction in temperature susceptibility. During warm weather and under traffic the binder rises up around the stone so that individual chippings are well-embedded. Rubber-asphalt resists this action, so that, whereas on heavily trafficked roads fatting-up is resisted, on lightly trafficked roads there is little tendency for fatting-up to occur.

3. There is a noticeably increased adhesion of the stone to the asphalt with rubberized binders, giving greater stone cover. In one particular experiment in

Figure 8. Fatting-up of normal asphalt seal after a spell of hot weather; the rubberized seal in the foreground has been little affected (rates of spread 4½ sq yd/gal).

Birmingham, the rubberized sections were immediately recognizable shortly after the work was completed by the lack of stone lying in the gutter—the gutters of the non-rubber sections were filled with chippings that had been whipped off. In another experiment in Cambridgeshire, following 24 hours of rain, the cover was very much greater on the rubberized sections.

The use of rubber for this type of treatment may be regarded as an insurance against failure. It is, of course, perfectly possible to obtain long lives for normal seals, but rubberized seals are more tolerant of adverse conditions.

Results from spraying trials show that the maximum "effective" rubber content of the binder that can be sprayed is ¾ percent when whirling-spray type jets are used. Since there will be some reduction in effectiveness during the blending process, this limits the amount of rubber that can be added to about 1 percent if latex is used and 2½ percent if vulcanized rubber is added. In most countries slotted jets are normally used, and with this type of jet the figures quoted may be doubled.

As was expected, there has been no observable difference between the behavior of rubberized binders blended with natural latex and natural rubber powders, provided the binders had approximately the same effective rubber content.

Dense Mixed Materials

The two types of dense materials mainly used in the United Kingdom are rolled asphalt and mastic asphalt. Six full-scale experiments have been laid to assess the properties of rubberized rolled asphalt, and four to assess the properties of rubberized mastic asphalt.

Not all of these experiments have reached the end of their useful life, since the materials would normally be expected to last 15 years or more. It has, however, been possible to draw firm conclusions from the behavior of the materials so far.

TABLE 2

RESULTS AFTER 4½ YEARS OF A FULL-SCALE ROAD EXPERIMENT IN LEICESTERSHIRE, TO ASSESS THE CRACK RESISTANCE OF RUBBERIZED ROLLED ASPHALT OVER CONCRETE

Material	Thickness (in.)	No. of Cracks in Surfacing	Total Joints or Cracks in Concrete	Percent Cracking
Normal rolled asphalt	5	14[a]	32	44
Rubberized rolled asphalt	5	0[a]	31	0
Rubberized rolled asphalt	4	0	23	0
Rubberized rolled asphalt	3	2[b]	22	9

[a]Plus one very slight crack. [b]Plus two very slight cracks.

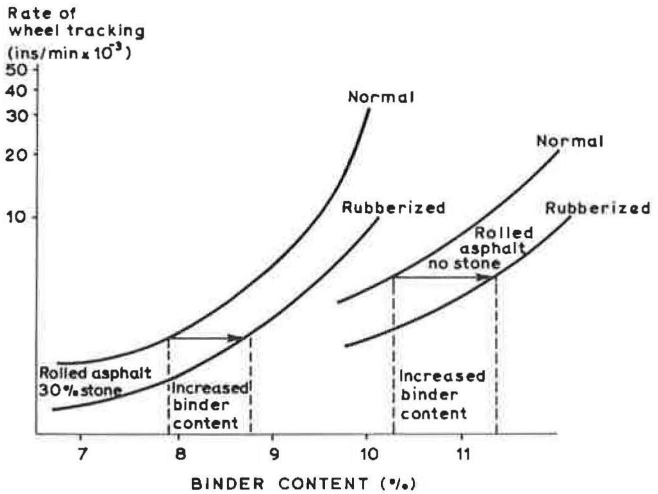

Figure 9. Rate of wheel-tracking of rolled asphalt with and without rubber.

Natural rubber added to rolled asphalt considerably improves the crack resistance of the material. As an example, the results to data of an experiment designed to assess this property are given in Table 2. In this experiment, the total thickness of the surfacing courses was varied to establish whether a lesser thickness would be successful in reducing cracking while at the same time saving costs. It is evident that not only is cracking reduced but the thickness can be reduced by 20 to 30 percent. Other experiments described previously (4) have confirmed the improved crack resistance of rubberized materials of this type.

It has also been evident that deformation is reduced by the addition of rubber. To assess the extent to which the stability of rolled asphalt is increased by rubber addition, mixtures were investigated using the wheel-tracking test (5). Test results are shown in Figure 9. Two mixtures were tested, a rolled asphalt (to British Standard BS 594) with 30 percent stone and a rolled asphalt with no stone. With both mixtures, stability was significantly increased by 3 percent natural rubber, and it was found that an extra 1 percent of binder could be used without loss of stabliity. This additional binder itself increases the crack resistance.

The improvements in properties of mastic asphalt by rubber addition are similar to those found for rolled asphalt. The full-scale experiments have again been confirmed in situations where cracking is a problem—e.g., over joints between concrete slabs.

In mastic asphalt laid at about 200 C (392 F) or more, greater percentages of rubber are used. It is normal to add 15 percent vulcanized rubber or 7½ percent unvulcanized rubber by weight of soluble binder. Table 3 gives the results of one experiment showing how resistance to cracking is increased by the rubber.

TABLE 3

RESULTS AFTER 7 YEARS OF A FULL-SCALE ROAD EXPERIMENT TO ASSESS THE CRACK-RESISTANT PROPERTIES OF RUBBERIZED MASTIC ASPHALT OVER CONCRETE

Type	Binder Content (percent of mastic mortar)	Rubber Content[a] (percent of soluble asphalt)	No. of Joints	No. of Cracks
Plain mastic to BS 1447	13½ of 65 pen.	0	9	7
	15 of 40 pen.	0	9	8
	13½ of 40 pen.	0	9	7
Plain mastic with expanded metal	13½ of 40 pen.	0	8	7
Rubberized mastic asphalt	12 of 65 pen.	16½	8	3
	12¾ of 40 pen.	17½	8	4
	15½ of 25 pen.	18	8	0
Stone-filled mastic[b]	15 of 40 pen.	0	8	3

[a]Vulcanized rubber powder.
[b]40 percent of ⅜-in. granite chippings in the mastic mortar.

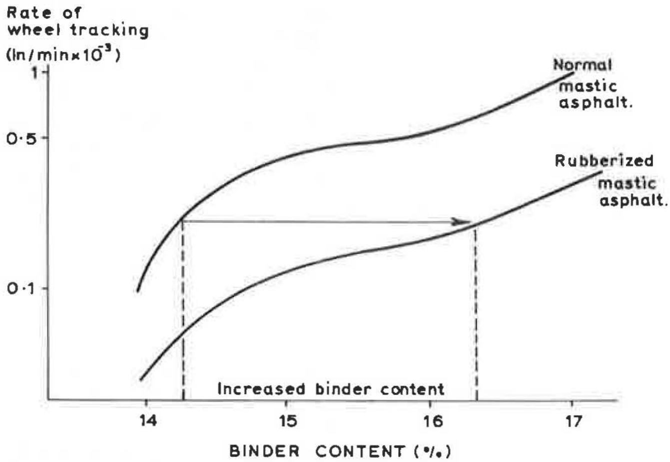

Figure 10. Rate of wheel-tracking with and without rubber.

The stability of mastic asphalt is also increased by rubber addition and an investigation using the wheel-tracking test, similar to that carried out on rolled asphalt, was made with mastic asphalt. As can be seen in Figure 10, the increase in stability of mastic asphalt is even more marked than that of rolled asphalt, and with 4½ percent unvulcanized rubber added to the binder, an increase of 2 percent in the binder content does not impair the stability of the mixtures.

Open-Textured Bitumen Macadam

The normal life of open-textured carpets of bitumen macadam is only 5 to 6 years. An increased life of only 1 or 2 years will more than justify the extra cost of adding rubber to the material. Two experiments have been started using open-textured materials. The first was completed a few years ago; the second has yet to be completed.

In the first the asphalt content of the mixed material was varied beyond the limits allowed in the British Standard (BS 1521) to see if, by rubber addition, leaner mixtures could be used. The experiment showed that, although there was no advantage with binder contents much below those allowed in the Standard, up to 50 percent increased life was obtained when 4 percent of rubber was added to the normal materials. The results of the experiment are given in Table 4. The second experiment still has a few years to run, but appears so far to confirm those results.

TABLE 4

RESULTS AFTER 8 YEARS OF A FULL-SCALE ROAD EXPERIMENT TO ASSESS THE INCREASE IN LIFE OF BITUMEN MACADAM BY THE ADDITION OF UNVULCANIZED RUBBER POWDER

Binder Viscosity	Binder Content (percent)	Useful Life (years)		Increase in Life With Rubber (percent)
		Without Rubber	With Rubber	
Asphalt cutback 100 sec. at 40 C (S.T.V.)	2.75	4	4	0
	3.0	5	5	0
	3.5	5	7	40
	3.75[a]	6	8	33
	4.25[a]	5	7	40
300 pen.	2.75	6	6	0
	3.0	6	8	33
	3.5	6	8	33
	3.75[a]	6	FG[b]	50[c]
	4.25	6	FG[b]	50[c]

[a]Only these binder contents within British Standard BS 1621.
[b]Sections still fairly good after 8 years.
[c]Life taken as 50 percent increase assuming the surfacings would be replaced the following year.

TABLE 5

BLENDING TIMES FOR UNVULCANIZED AND VULCANIZED NATURAL RUBBER IN ASPHALT

Temperature		Blending Time	
C	F	Unvulcanized Rubber	Vulcanized Rubber
180	356	*	½ hr
170	338	*	1 hr
160	320	10 min	2 hr
150	302	15 min	3-4 hr
140	284	25 min	6-8 hr
130	266	35 min	*
120	248	45 min	*

*Not recommended.

BLENDING OF RUBBERIZED BINDERS

Although the establishment of the properties of rubberized asphalt and the advantages to be gained from their use has formed a major part of the research, devising the best methods of using rubber has also been an important part of the work. This investigation has fallen into two parts: the formulation of the best blending techniques, and the recommendation of any alterations in practice necessary for the successful laying of rubberized materials.

Rubberized asphaltic binders may either be blended prior to their use in mixed materials or, in most cases, the rubber may be added during the manufacture of the mixtures (2). For seal-coats the binder must be pre-blended. The rules for pre-blending the binders vary with the form of rubber. Rubber powders are mechanically dispersed throughout the volume of asphalt and heating is continued for sufficient time at the blending temperature for the rubber to be completely dissolved in the binder (Table 5). The time differs for vulcanized and unvulcanized rubber. It is important that all the rubber be dissolved. Undissolved rubber will not contribute to the improved properties of the asphaltic materials.

In latex form, rubber requires a slightly different technique because the relatively large quantities of water stirred into hot asphalt can be dangerous if the correct procedure is not followed. A simple method is to spray the latex onto the surface of the hot asphalt, allowing about 20 sec for most of the water to be vaporized before the rubber is drawn into the bulk of the asphalt. An antifoaming agent may be used or a tank of sufficient capacity used to allow for the increase in volume occurring when the small residual quantity of water expands as steam in the asphalt. Blending times and temperatures are the same as those given in Table 5 for unvulcanized rubber.

Both latex and unvulcanized rubber powder may be added to the mixed asphaltic materials during manufacture. Vulcanized rubber should not be added at this stage, but must be pre-blended into the asphalt. Rubber powder is poured into the mixing chamber during the injection of the liquid asphalt; latex is sprayed in as soon as the asphalt has wetted the stone. An additional mixing time of 5 to 10 sec is generally allowed for mechanical dispersion of the rubber throughout the mix, although this period will depend on the mixer. Completion of the blending process occurs during transport of the material to the site of laying. A minimum of ½ hour before laying is generally considered advisable.

Direct addition of rubber to the mixer may be used for materials mixed above about 135 C (275 F). Below this temperature, however, the minimum blending time cannot generally be guaranteed and pre-blending is desirable. At mixing temperatures below about 120 C (250 F) pre-blending is essential.

LAYING RUBBERIZED MATERIALS

Rubberized asphaltic materials are laid by the same techniques as the normal equivalent materials. The only practical difficulties that may be met arise from the

increased viscosity of the asphalt and the increased tack. Rubberized materials are "tougher" to handle. To overcome these difficulties the mixing and laying temperatures recommended are 10 to 15 C (18 to 27 F) higher than would normally be used. Rolling temperatures should also be about 10 C (18 F) higher than normal. If these rules are followed, no difficulties should be encountered.

CONCLUSIONS

The properties of asphalt are modified by the addition of natural rubber in the following ways:

1. A marked elasticity is imparted to the asphalt and there is considerable departure from Newtonian flow;
2. The temperature susceptibility of viscosity is reduced; and
3. Brittleness is reduced.

These alterations occur simultaneously.

As a result of these changes rubberized materials have shown advantages in full-scale road experiments. The advantages vary depending on the type of road surfacing. In surface-dressing or seal coats rubber prevents or markedly reduces fatting-up in hot weather and a greatly increased initial chip retention has been shown, particularly when wet weather follows shortly after treatment. In both types of dense materials—rolled asphalt and mastic asphalt—the resistance to cracking is much increased as is the stability or resistance to deformation. In open-textured bitumen macadam carpets an increased life of up to 50 percent has been found.

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