Krenkler (1958) found that pitches having low benzene soluble contents and bitumen with high aromatic and asphaltene contents were most compatible and Tingle and Wright (1959) found that if "hard" bitumens were used blends with vertical-retort tars could be prepared in any proportions. Rang and Dickinson (1957) mentioned that a conditions for the preparation of stable blends was the use of a "hard" (in their case 37 Pen.)bitumen. Tingle and Wright (1959) concluded that the oils present in bitumen were mainly responsible for the instability of mixtures. (An explanation of the effects of adding non-polar petroleum oils to tar was given in Part 2, Chapter 4.). These authors prepared blends containing 35, 40, 45, 50 and 60 per cent of the 50 - 55°C Evt tar and,using a 10/20 Pen. bitumen, claimed that microscopic examination showed an even dispersion of the tar in the bitumen.

3.2.3 A comparison of the properties of tar, bitumen and tar/bitumen blends

It has often been stated that the rheological and weathering properties of tar/bitumen blends are intermediate between those of tar and bitumen and that blends have adhesion characteristics superior to those of bitumens (Wood, 1966).

3.2.3.1 Rheological properties

Unlike tars and most road bitumens the log-viscosity log-temperature relationship of tar/bitumen blends over the 15-45°C range is not completely linear. This was pointed out by Rang and Dickinson, (1957) from results obtained using the conicylindrical viscometer described by Lee et al. (1940). They interpreted this as change in the viscosity temeprature coefficient, which appeared to occur at a point between 20 and 35°C, and concluded that the temperature coefficient of viscosity at low temperatures is similar to that of the bitumen component.

The viscosities of tar/bitumen blend samples received from overseas producers* and of blends prepared locally have been measured over this range and the results are the complete converse of those given by Rang and Dickinson. These measurements were carried out using the sliding plate microviscometer. While a non-linear relationship was also found

---

* These were "Cindumix" received from the Cindu Co. Holland,in which a coke-oven tar was used, and"Gripta" from Midland Yorkshire Tar Distillers United Kingdom, in which the tar was thought to be a medium-temperature tar derived from the Rexco process.

the lines curved in the opposite direction to those shown by these authors. The results obtained using the imported samples are shown in Figure 3 - 22 and values given by locally produced blends are shown in Figure 3 - 23.

Viscosity measurements over the entire temperature range of use suggest that the discrepancy between the results of Rang and Dickinson and the author may be due to the fact that measurements were taken over slightly different viscosity ranges. The viscosity of the local blends was measured near the"spraying" viscosity region using a Haake, Viscowage viscometer (Haake) and by linking up these points with those obtained in the 15 - 45°C region (Figure 3 - 24). It is clear that at some stage in the temperature range 40 - 110°C the line may curve slightly in the direction found by Rang and Dickinson.

However, Figures 3 - 23 and 3 - 24 show that Rang and Dickinson's conclusion that at low temperatures the viscosity-temperature coefficient is similar to that of tar is incorrect and that in fact the shape of the viscosity-temperature plot is different from that of tar, which explains why tar/bitumen blends have lower brittle-temperatures than tars and a bigger Evt-brittle point temperature range, as shown by McNeil's results, (Tables 3 - 18 and 3 - 19) and by results given by locally prepared blends in Table 3 - 20.

TABLE 3 - 20

EVT BRITTLE-POINT TEMPERATURE RANGE FOR TAR/BITUMEN BLENDS AND OTHER BLENDS

Binder type	Evt-brittle-pt.
Coke-oven tar (45 - 50°C)	61,0-63,0
Lurgi tar (50 - 55°C)	60,5
PVC/tar	67,0-74,0
Coke-oven tar/bitumen blend, commercial blend ex Holland	71,2
Medium-temperature tar/bitumen blend, commercial blend ex U.K.	78,6
150/200 Pen. bitumens	82,0

This tendency for tar/bitumen blends to display unusual rheological behaviour has been noted by Walther (1950 and also by Tingle and Wright the lines curved in the opposite direction to those shown by these authors. The results obtained using the imported samples are shown in Figure 3 - 22 and values given by locally produced blends are shown in Figure 3 - 23.

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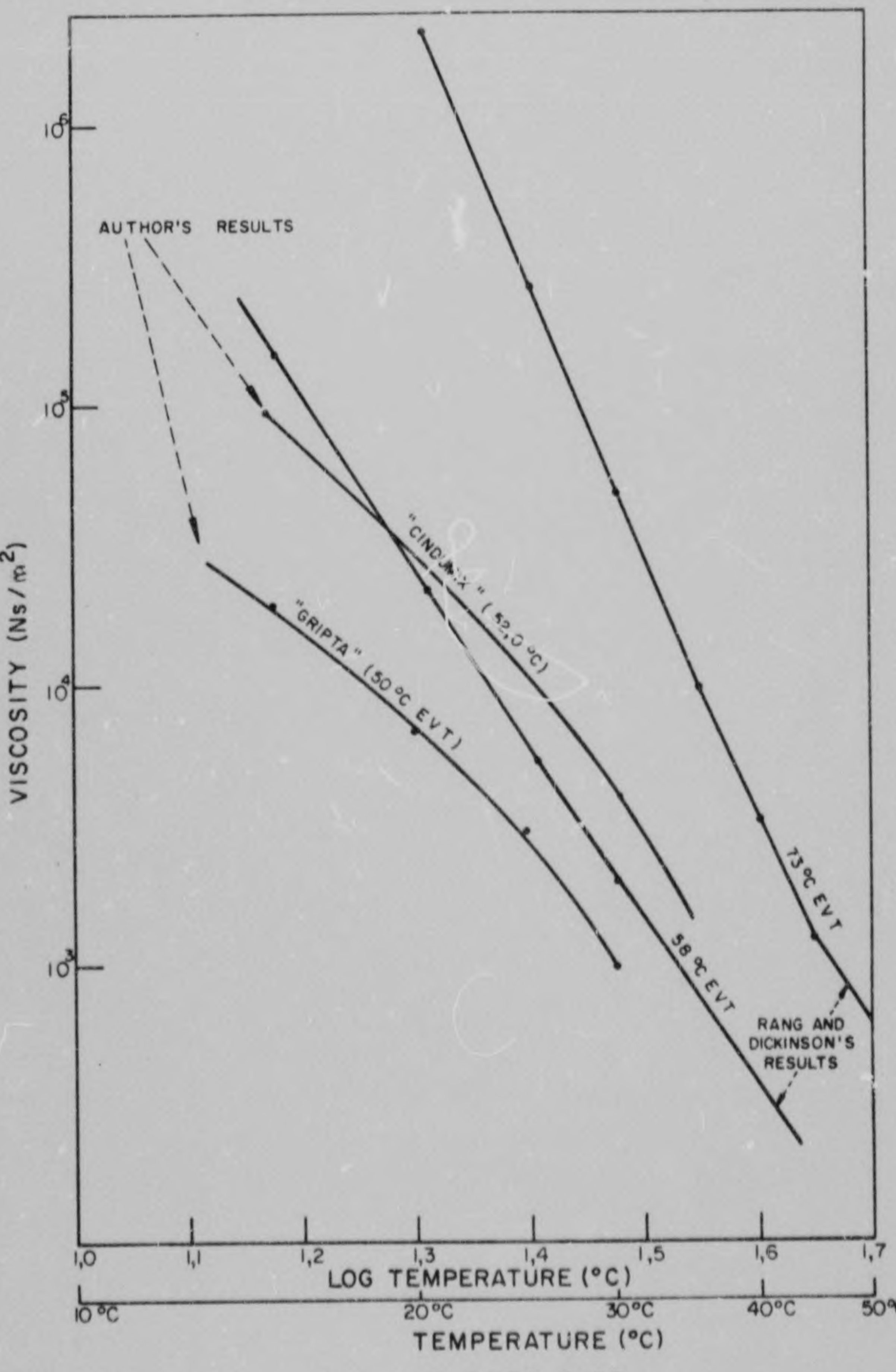

FIGURE 3-22

VISCOSITY - TEMPERATURE PLOTS AS DETERMINED BY RANG & DICKINSON (1957) USING THE CONICYLINDRICAL VISCOMETER AND BY THE AUTHOR USING THE SLIDING PLATE MICROVISCOMETER.

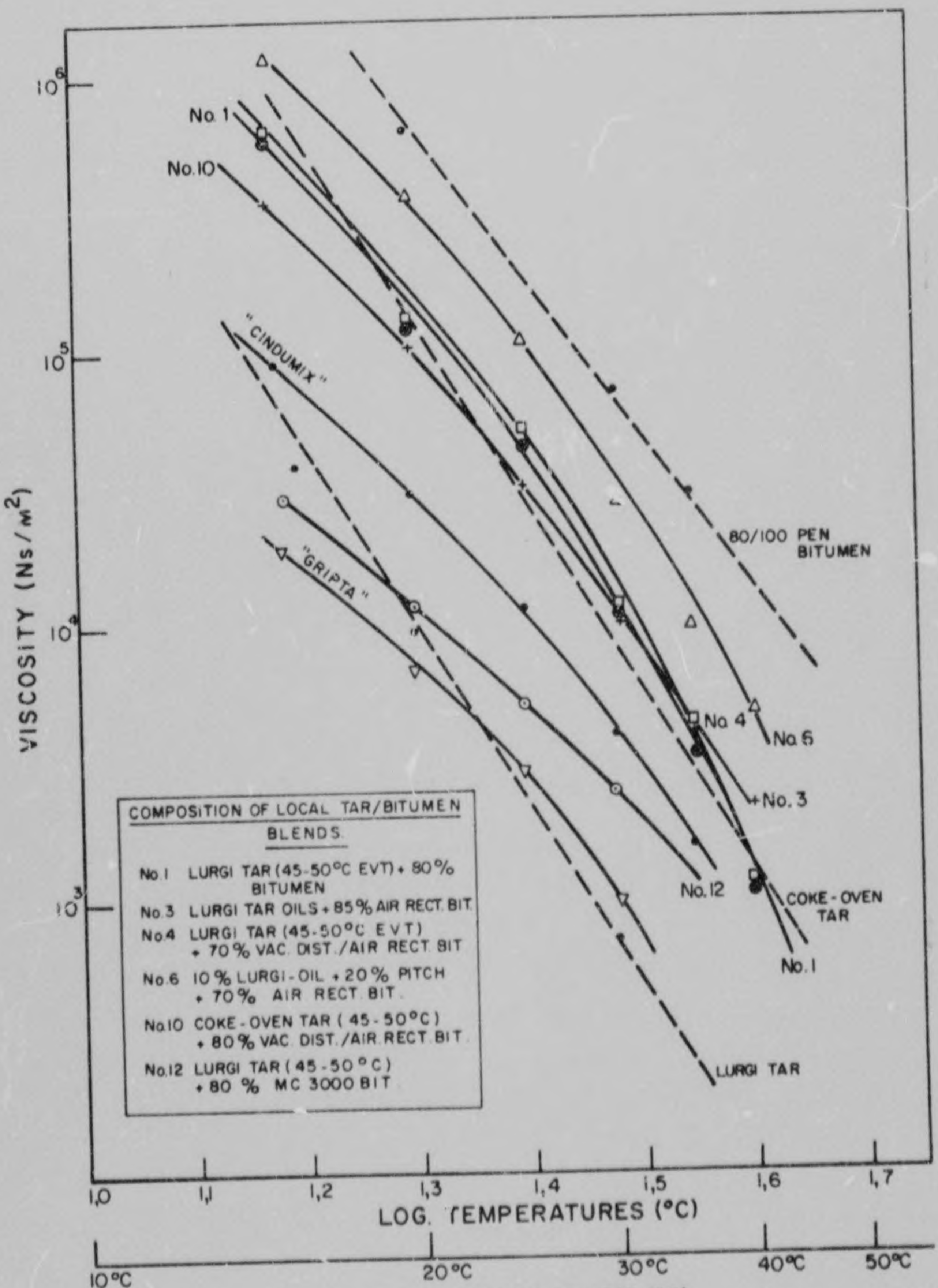

FIGURE 3-23

VISCOSITY–TEMPERATURE PLOTS (15-45 °C) OF LOCAL AND IMPORTED TAR/BITUMEN BLENDS.

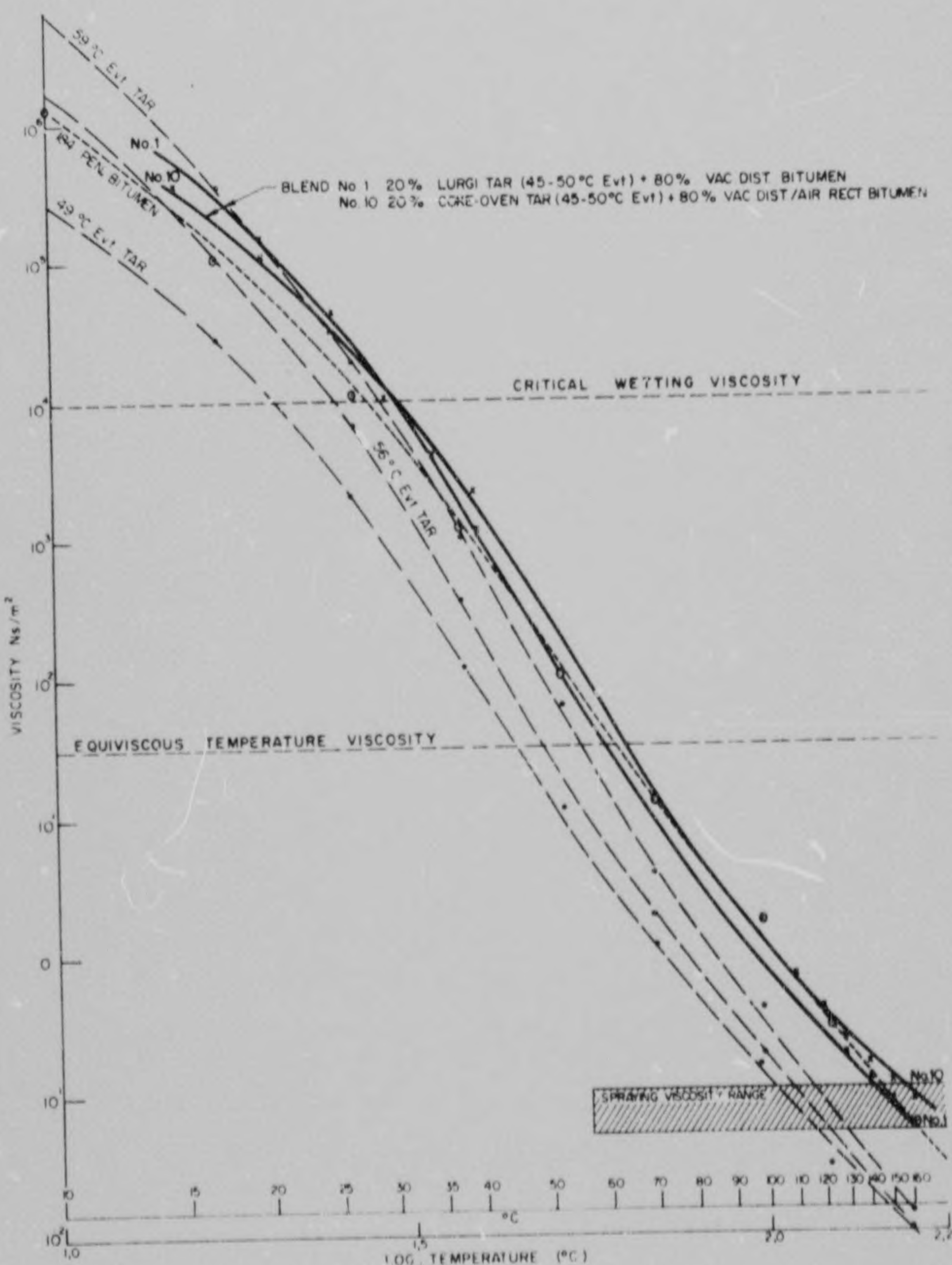

FIGURE 3-24

TYPICAL VISCOSITY-TEMPERATURE PLOTS GIVEN BY LOCALLY PREPARED TAR/BITUMEN, BLENDS, TARS, AND BITUMENS OVER THE TEMPERATURE RANGE 10°–160°C

(1959). The latter authors investigated the behaviour of mixtures of vertical-retort tars and hard bitumens and noted that whereas in blending together different consistencies of tars or even of bitumens there is a linear relationship between composition and either log viscosity, Evt, or softening point, these simple laws did not always apply when blending tar with bitumen. In particular they reported an S shaped penetration index composition curve as shown in Figure 3 - 25.

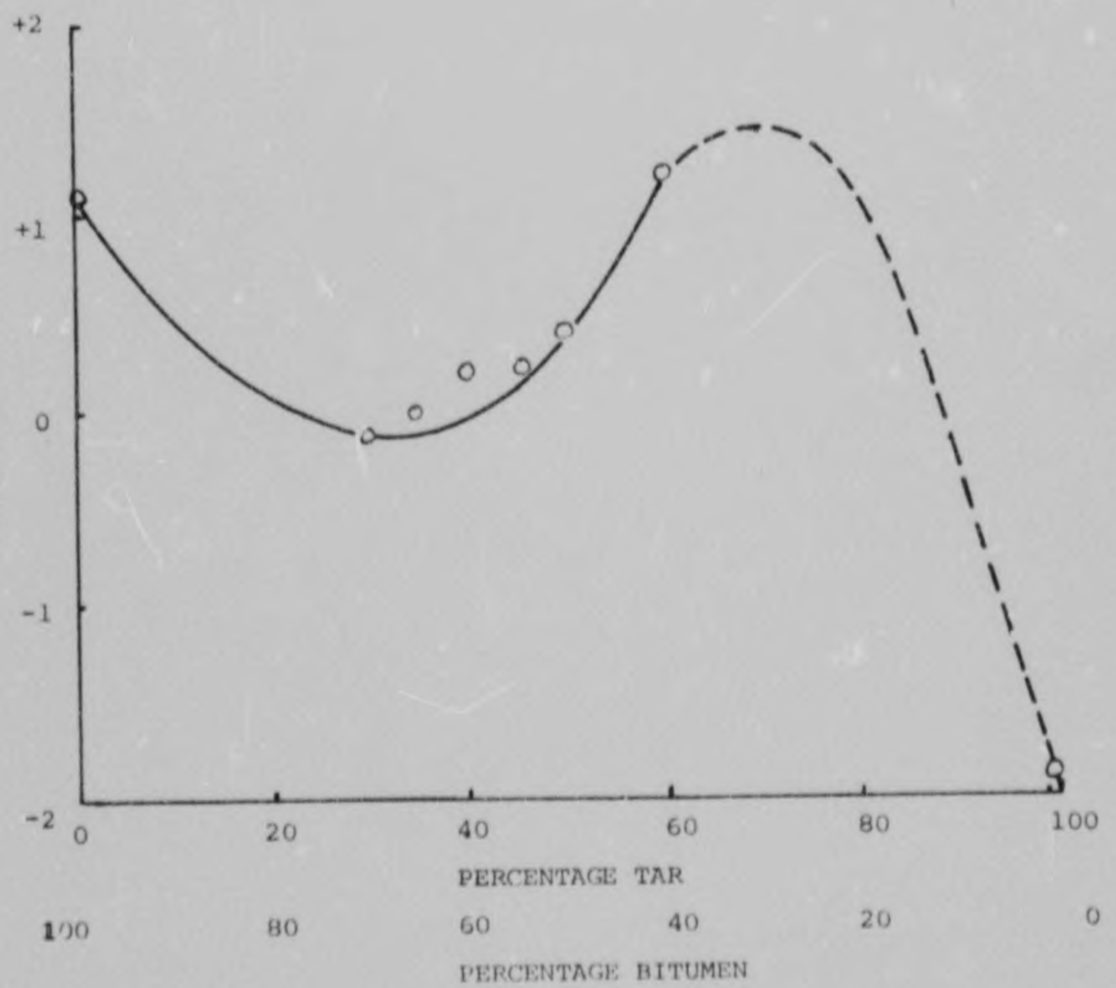

FIGURE 3 - 25 PENETRATION INDICES OF BLENDS OF 10/20 PEN. BITUMEN AND 50-55°C EVT VERTICAL-RETORT TAR (FROM TINGLE AND WRIGHT, 1959).

Bernesis and Wood (1956) found that the softening point anomalies were coincident with a sudden change in the toluene or benzene-insoluble content at about 40 per cent bitumen content. Abnormally high viscosities were recorded, at the softening point temperatures where tar was the major component, and Wood (1966) suggested that these anomalies are due to a tendency for high molecular mass components to be precipitated by oils in the bitumen.

The assumption that the rheological properties of tar/bitumen blends are intermediate between those of tar and bitumen is, in general, correct. As previously demonstrated by Daines (1972) in Part 3, Chapter 1.2 (Figure 3 - 3), this also applies to their behaviour under rapid and repeated load applications.

3.2.3.2 Weathering properties

Liversedge and Bullock (1972) have reported the results of weathering investigations and found that, while the increase in Evt of tar/bitumen blends was similar to that of unmodified tar, the increase in brittle temperature was considerably less than that of the tar. In this respect its behaviour may be equated with that of a cutback bitumen and it is apparent that this factor will depend upon the oil constituents present in the tar component of the blend.

The weathering performance of commercial blends used in Europe under the severe "Highveld" conditions was compared in weathering tests and small-scale road experiments carried out in Pretoria. In the weathering tests the samples of "Cindumix" and "Gripta" were exposed in thin films to air and sunlight on the roof of the National Institute for Transport and Road Research building. Glass Petri dishes were used to hold the binders and these were filled so that the film thickness was 1,4 mm, which is of the order of thickness of binder used in surface treatments and in small-scale road experiments. The dishes were placed in a specially constructed frame which was positioned on the roof of the building. In order to prevent dust from contaminating the samples a cover of thin polyvinyl fluoride sheeting, transparent to visible and ultraviolet light wavelengths, was placed over the frame. Samples were recovered after 6, 12 and 18 months exposure to the atmosphere and the Evt and brittle temperatures determined. The results are shown in Figure 3 - 26, and confirm that under local climatic conditions the change in Evt of commercial tar/bitumen blends is greater than the change in brittle temperature. The change in brittle temperature of

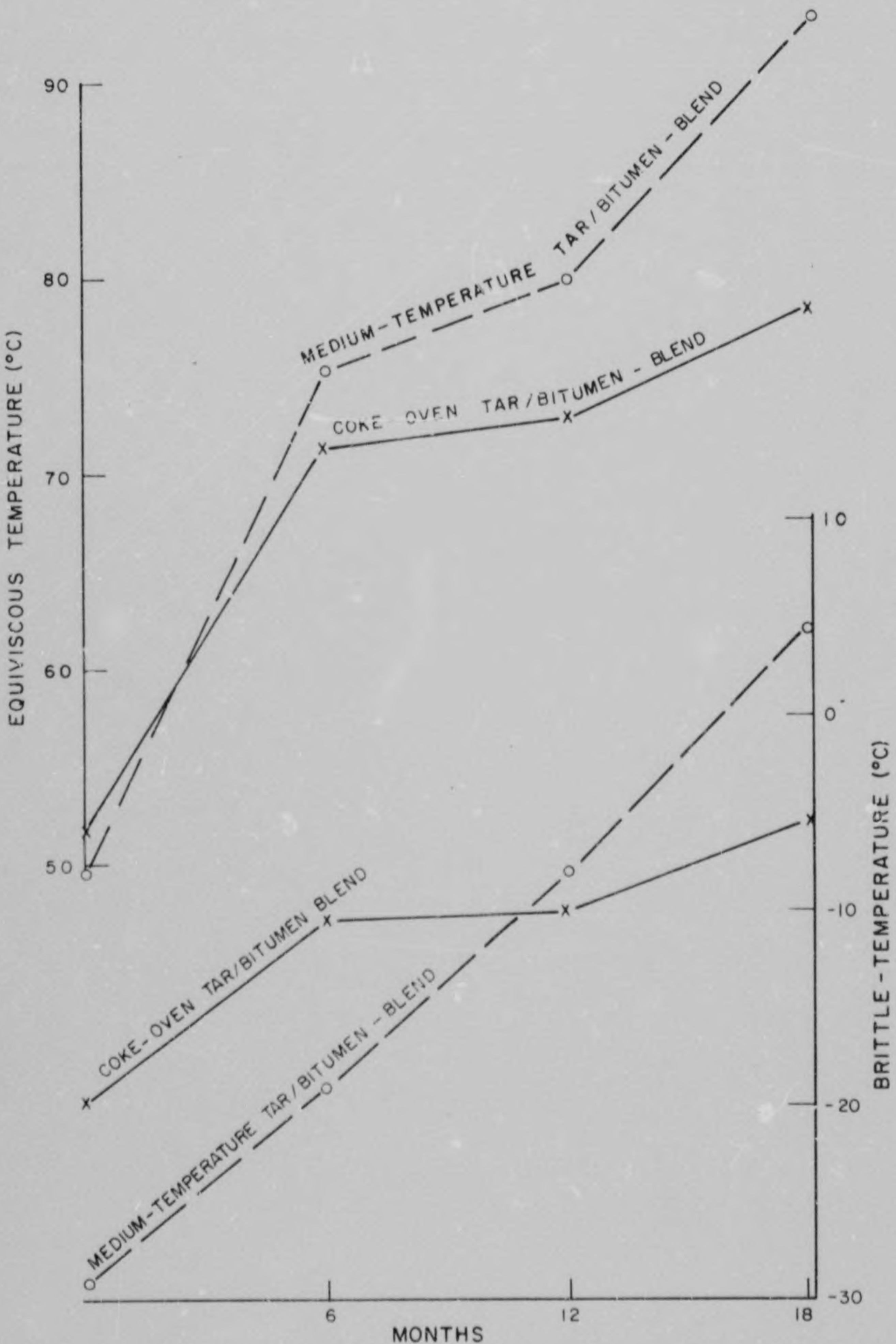

FIGURE 3-26

CHANGE IN EVT AND BRITTLE TEMPERATURE OF IMPORTED COKE-OVEN TAR AND MEDIUM-TEMPERATURE TAR/BITUMEN BLENDS IN WEATHERING TESTS the coke-oven blend ("Cindumix") diminished with time being greatest over the initial six months' exposure,but overall the change was less than in the blend containing the medium-temperature tar ("Gripta"). It was established that the tar contents of these blends were "Gripta" 32 per cent, "Cindumix" 42 per cent.

These blends were incorporated in the 1970 small-scale road experiment (Part 3, Chapter 1.5.1). Monitoring tests, in which the binders were recovered from the road after various intervals and examined in the normal manner, confirmed the main conclusions from the roof weathering tests. The results of these tests and latest performance assessments are given in Table 3 - 21 together with the results of tests on local and imported unmodified and PVC-modified tars. Despite the eventual large increase in Evt and brittle temperature in the imported tar/bitumen blends in service, these blends are still in the same main category of performance as the bitumen control sections. It has previously been mentioned that over the first year or so stone embedment and mechanical interlock are probably insufficient to withstand the disruptive effects of traffic and during this period stone retention may be largely dependent upon the binder properties. During this time the change in binder properties is a critical factor and it is significant that, as shown in Table 3 - 21, after one year the imported tar/bitumen blends (and local unmodified and PVC/tars), which performed well, had low brittle temperatures whereas the imported tars, which performed badly, had brittleness values greater than + 0,5°C at that time.

The roof weathering tests and the 1970 small-scale road experiment showed that the medium temperature tar/bitumen blend was inherently less durable than the coke-oven tar/bitumen blend and it may be thought that this augurs badly for the performance of local blends incorporating Lurgi tar. However, Accelerated Weathering Tests have shown that the hardening may be controlled by varying the proportion of tar and tar oils in the blend; a number of blends prepared for a small-scale experiment hardened by an amount lower than is normally given by tar surface treatment binders. The Accelerated Weathering Test is that proposed for future tar specifications and is fully described in Appendix L. This test gives an indication of the hardening expected after one year's exposure in a single-surface treatment. The results are given in Figure 3 - 27. Blends containing up to 30 per cent of Lurgi tar (45 - 50°C Evt) had a low Evt increase (7,2°C) and this was less than the Evt increase given by a blend which contained 20 per cent of coke-oven tar.

TABLE 3 - 21

CHANGE IN EVT AND BRITTLE TEMPERATURE AND PERFORMANCE ASSESSMENT OF IMPORTED TAR, TAR/BITUMEN BLENDS AND PVC/TAR USED IN THE SMALL-SCALE SURFACE TREATMENT EXPERIMENT (1970)

Binder type		Initial properties		After 1 year		After 2 years		After 3 years		Performance assessment*
		Evt (°C)	Fraass brittle temp. (°C)	Evt (°C)	Fraass brittle temp. (°C)	Evt (°C)	Fraass brittle temp. (°C)	Evt (°C)	Fraass brittle temp. (°C)	
Imported										
Coke-oven tar (ex U.K.)	(59)+	46,0	-14,7	69,8	+2,0	-	-	-	-	B-
PVC/tar (ex U.K.)	(61)	47,0	-20,0	69,0	+0,5	-	-	-	-	P-
Coke-oven tar/bitumen (ex Holland)	(27)	51,7	-19,5	85,0	-2,0	-	-	101,8	+25	G-
Medium-temperature tar/bitumen (ex U.K.)	(28)	49,6	<-29,5	89,5	-1,0	-	-	100	+25	G-
Local										
Coke-oven tar (low-vol.)	(21)	52,1	-10,5	67,3	-0,8	75,7	-	-	-	G-
PVC/tar (low-vol.)	(39)	51,5	-23,0	68,7	-7,0	80,7	+4,5	-	-	G-
Bitumen 150/200 Pen.	(65)									G-

*For explanation of symbols see Part 3, Chapter 1, page 105.

+Figures in parentheses are section numbers; see Appendix K (1970 experiment).

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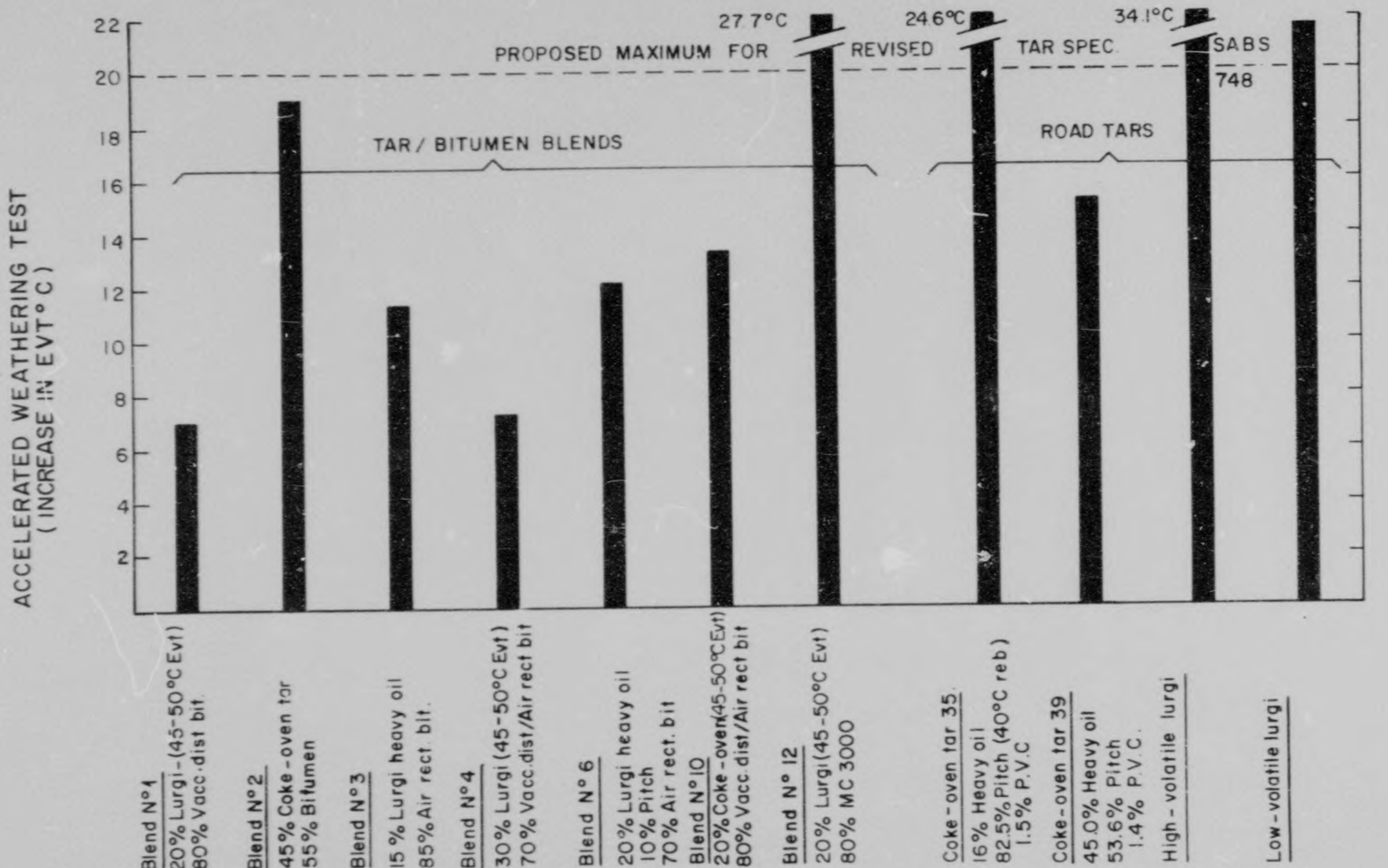


FIGURE 3-27.

THE PREDICTED HARDENING OF A NUMBER OF TAR/ BITUMEN BLENDS INCORPORATING LURGI TAR AFTER ONE YEAR IN A SINGLE-SURFACE TREATMENT (ACCELERATED WEATHERING TEST RESULTS)

3.2.3.3. Adhesion properties

The detachment test, described in Part 3, Chapter 1.2 was used to evaluate the adhesion properties of locally prepared tar/bitumen blends. As previously mentioned, the test was developed to compare the efficiency of various wetting agents and its use in this instance may be justified by regarding the tar component of the blends as an adhesion agent. The percentage stones detached after immersion in water for 12 days at 20°C is shown in Figure 3 - 28. All the tar/bitumen blends had much greater stone-retention properties than the cutback bitumen and were also superior in various degrees to a 150/200 Pen. bitumen.

3.2.4. Production of tar/bitumen blends

Possibly because of the competitive nature of the road binder industry, little has been written about the production of tar/bitumen blends. In some cases manufacturers are only prepared to supply details under a licensing agreement.

Kang and Dickinson (1957) prepared blends of coke-oven tar and bitumen in 1:1 ratios to which was added 11,5 per cent of aromatic tar-oils. A precipitated sludge was removed from the hot mixtures either by centrifuging or sedimenting and decanting. A homogeneous blend resulted which showed no sign of further precipitation and the authors claimed that microscopic examination showed a fine dispersion of tar and bitumen particles similar to that obtained in a German process, (Franck, 1955).

In modern plants continuous methods of production are used. At one such plant visited by the author (Jamieson, 1973) the bitumen was first circulated for several hours to ensure homogeneity and even temperature distribution, after which it was fluxed with a heavy anthracene-oil (from which anthracene paste had been removed by filtration) to the same viscosity as the tar component. The "fluxed bitumen" and the tar component were then drawn simultaneously through a pump, so producing a homogeneous blend. Alternatively, where"hard" high-viscosity bitumens and low-viscosity tars are used as starting products, the tar content can depend upon the required viscosity of the blend, i.e. low-viscosity blends will contain more tar than high-viscosity blends. It has also been claimed (International Road Tar Conference, 1961) that in France tar/bitumen blends can be prepared in any proportion by introducing a stabilising agent such as Buna (synthetic rubber).

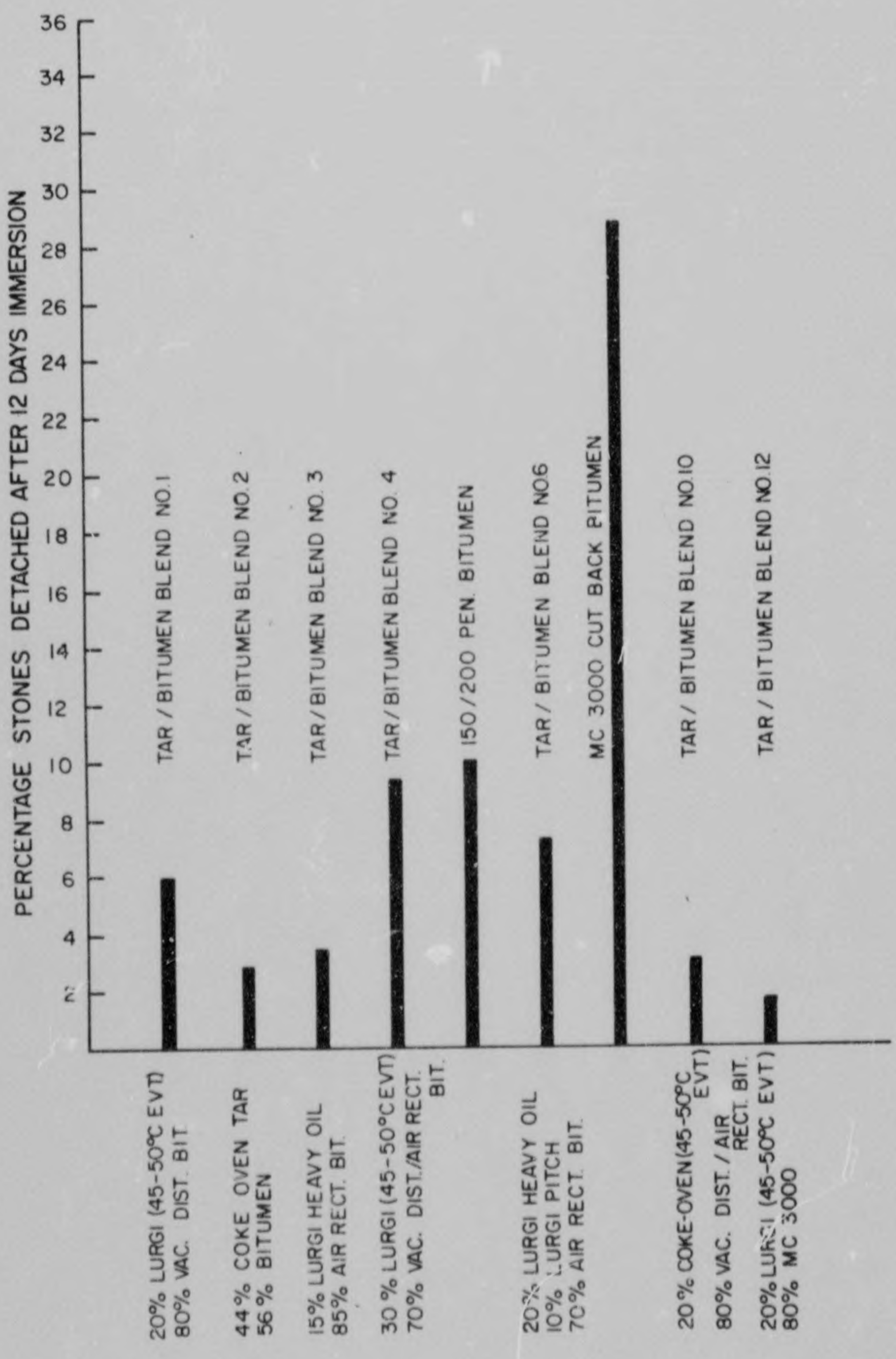


FIGURE 3-28

THE DETACHMENT OF STONE FROM TAR/ BITUMEN BLENDS AND BITUMEN USING THE METHOD DEVELOPED BY KARIUS AND DALTON (1964)

3.2.5 Control tests

3.2.5.1 Microscopic examination

It is essential that, if the full benefit of tar/bitumen blends is to be obtained without the disadvantages of sludging problems, the blends should be homogeneous. Homogeneity can be assessed from microscopic examinations. This is a universally accepted method and is included in the specifications for tar/bitumens in at least one European country (Switzerland).

Photomicrographs may be used for record purposes. Typical photomicrographs of Lurgi tar, bitumen, a non-homogeneous blend of these two binders, and of the homogeneous medium-temperature tar/bitumen blend "Gripta" imported from the United Kingdom are shown in Figure 3 - 29. Non-homogeneous blends can be detected by an enlargement and aggregation of the particles.

Photomicrographs of coke-oven tar and a homogeneous blend of coke-oven tar and bitumen "Cindumix" imported from Holland are shown in Figure 3 - 30 and photomicrographs of some local blends are shown in Figure 3 - 31.

3.2.5.2 Ductility

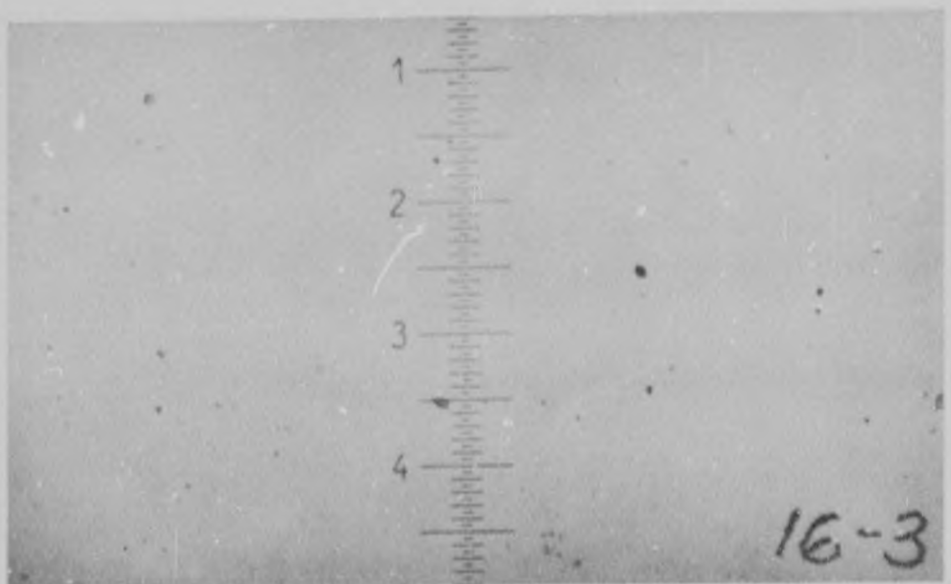
McNeil (1970) mentioned that blends which were non-homogeneous had little or no ductility. However, some authorities (Spoon, 1975) consider the ductility test to be of little value in assessing the homogeneity of tar/bitumen blends.

An advantage of the test, apart from finding the actual extension-at-break value, is that any inhomogeneity can be detected by the appearance of "lumps" of resinous material as the binder is stretched into threads.

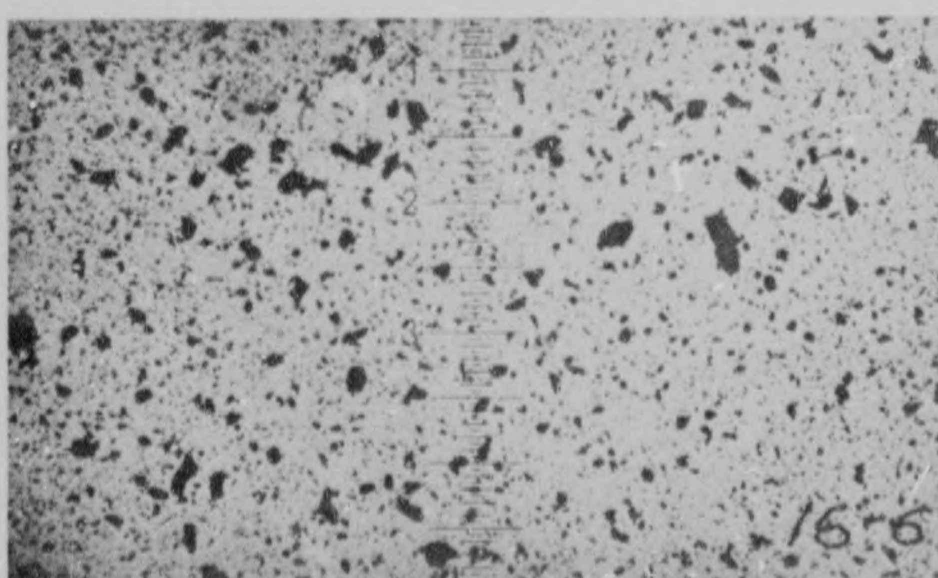
3.2.5.3 Stability on storage

In the British work on pitch/bitumen binders a stability index test was developed (Tingle, Wright and Stewart, 1962) to determine whether there was any tendency for sedimentation or "sludging" to occur during the hot storage of such blends. Investigations on the locally prepared blends have indicated that the method could be applied to these blends.

> In this test a stoppered glass tube (300 mm x 12,5 mm I.D.) is filled with the material under test and placed in a thermostatted oven at 160°C for four days. At the end of this period the tube is sectioned and the density (at 15,5°C) of the material in the bottom third is determined, and compared with the original density of the binder.



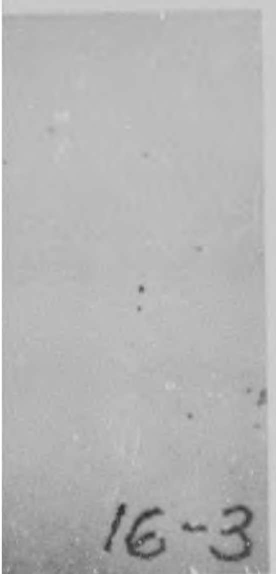
Petroleum bitumen

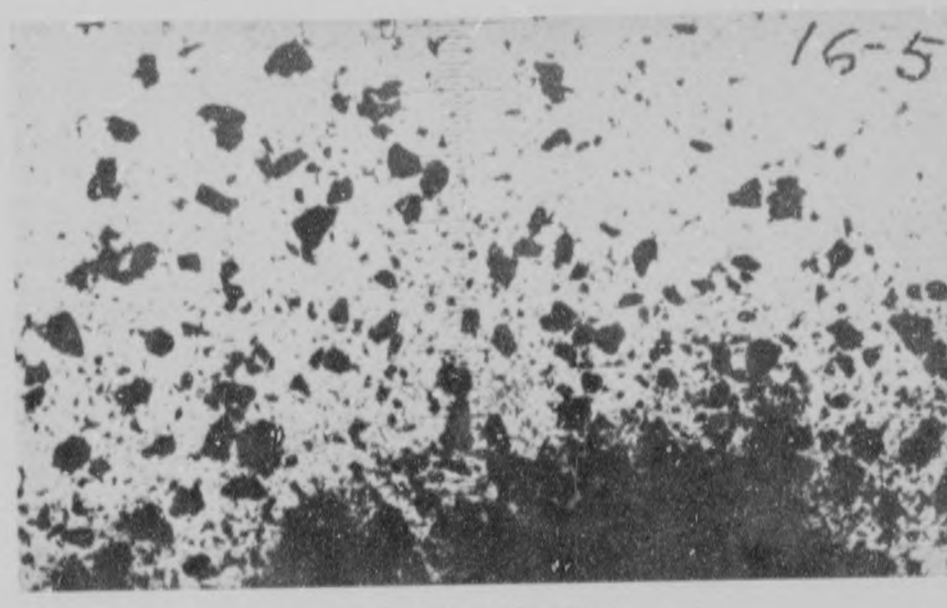


Lurgi tar

FIGURE 3 - 29: Photomicrographs of bitumen, Lurgi t

Magnification: 22 divisi

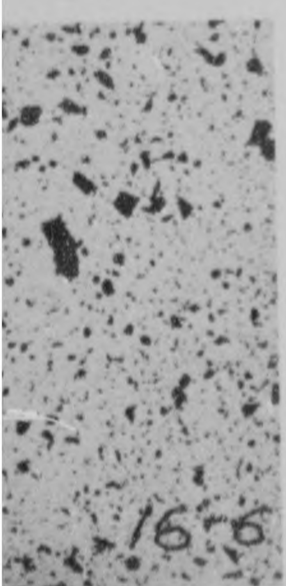


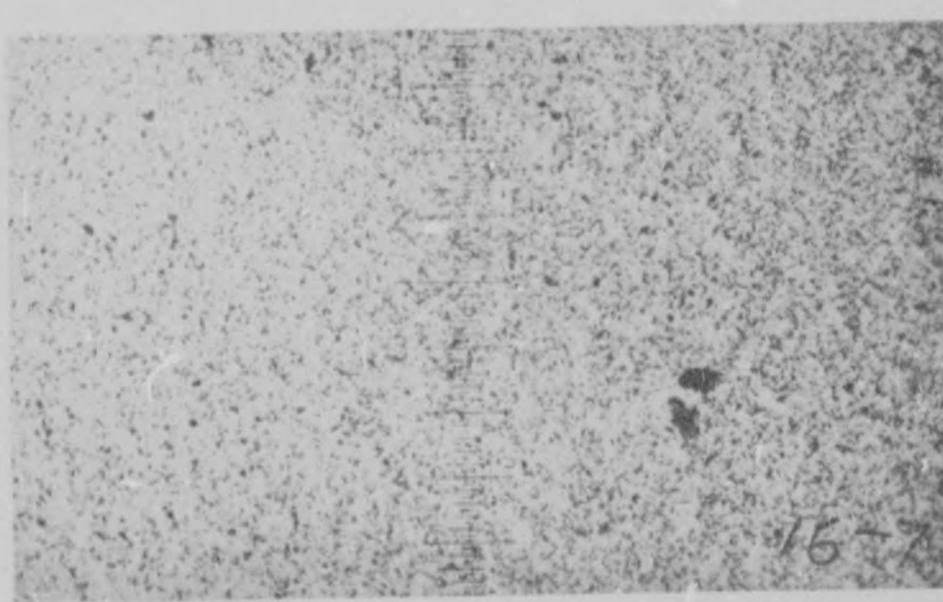


Non-homogeneous blend

20 per cent Lurgi tar
80 per cent bitumen

Stability Index: 0.9.



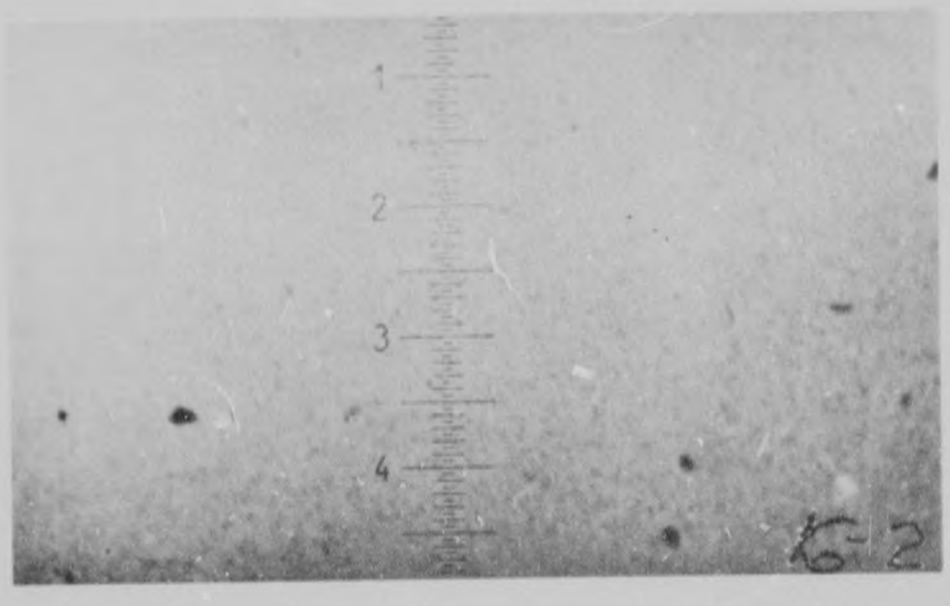


Imported blend 'Gripta' containing 32 per cent of medium temperature tar.

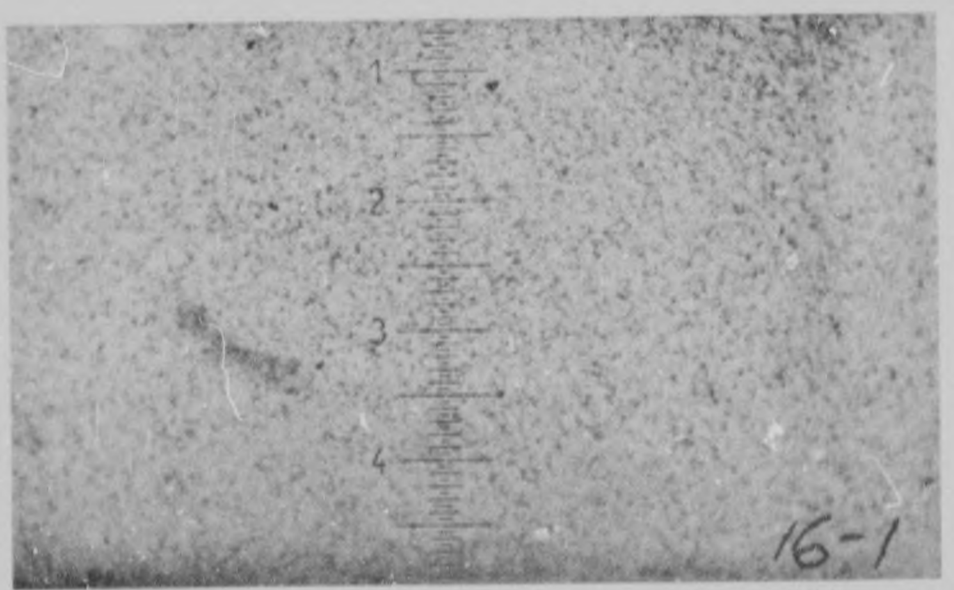
Stability Index: 0.7.

FIGURE 3 - 29: Photomicrographs of bitumen, Lurgi tar and blends of medium-temperature tars and bitumen

Magnification: 22 divisions equivalent to 1 mm)



Coke-oven tar

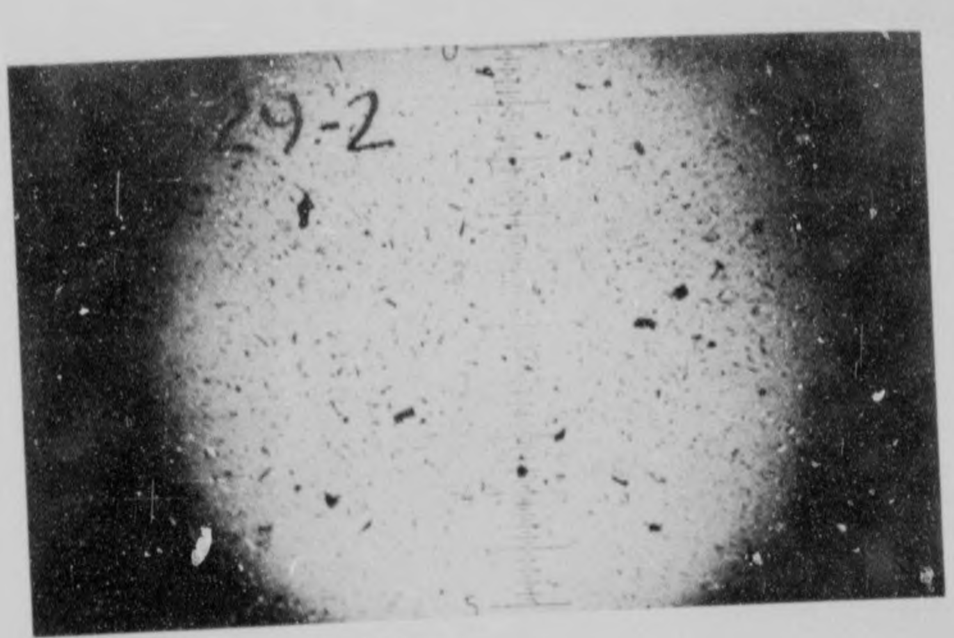


Homogeneous blend 'Cindumix' containing 42 per cent of coke-oven tar.

Stability Index: 0.8

FIGURE 3 - 30: Photomicrographs of coke-oven tar and a homogeneous blend of coke-oven tar and bitumen

(Magnification: 22 divisions equivalent to 1 mm)



BLEND No. 1

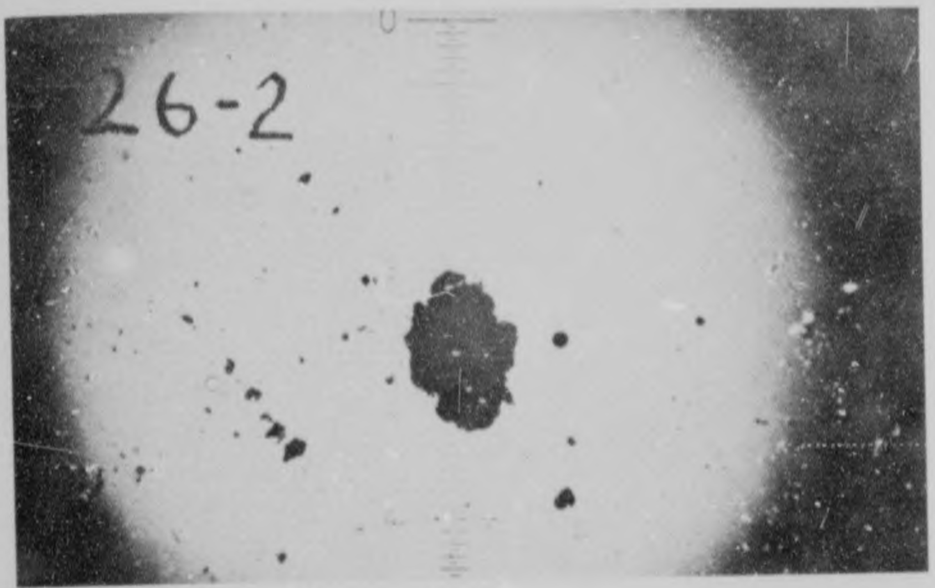
20 per cent 45 - 50° C EVT Lurgi tar
80 per cent bitumen

Stability Index: 0.66

BLEND No. 2A

20 per cent Lurgi pitch (70° C r. & b. s.pt.)
80 per cent bitumen and slop wax

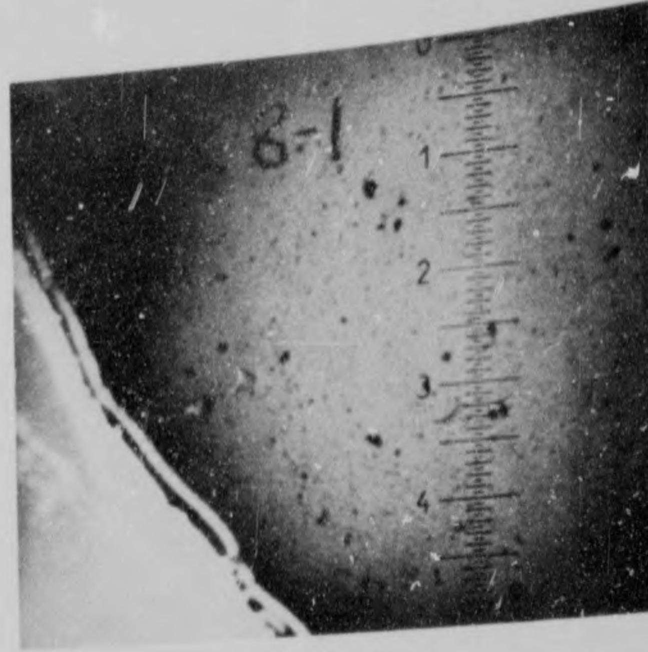
Stability Index: 1.33



BLEND No 3A

30 per cent Lurgi pitch (70° C r. & b. s.pt.)
70 per cent bitumen and slop wax

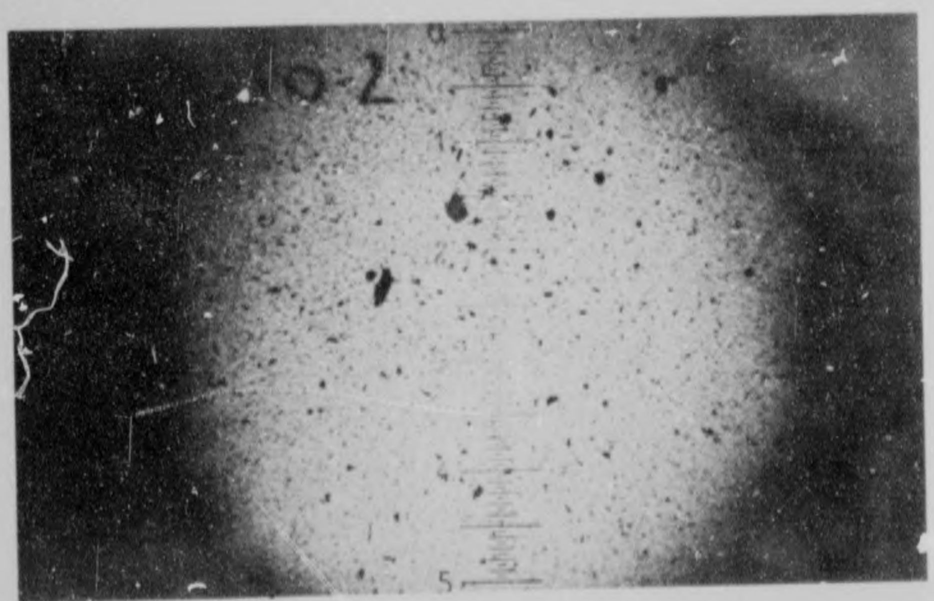
Stability Index: 0.33



BLEND No. 6

10 per cent Lurgi pitch
20 per cent Lurgi heavy oil
70 per cent air-rectified bitumen

Stability Index: 0.18



BLEND No 4

30 per cent 45 - 50° C EVT Lurgi tar
70 per cent vacc dist air-rectified bitumen

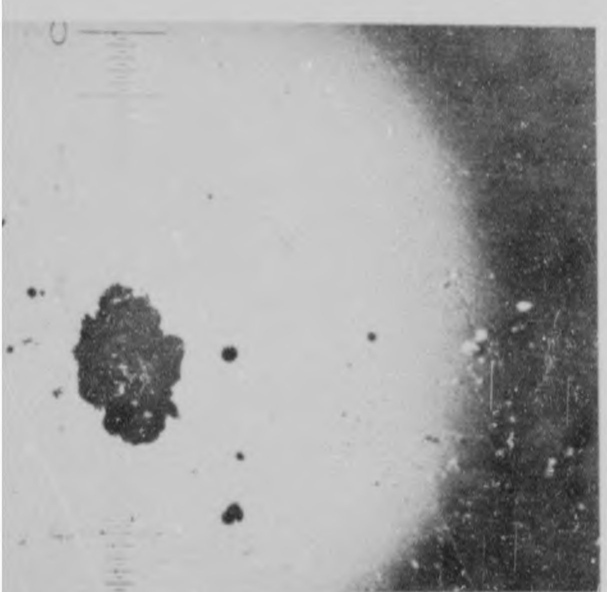
Stability Index: 0.57

BLEND No. 10

20 per cent 45 - 50° C EVT Coke-oven
80 per cent vacc. dist air rectified-bitu

Stability Index: 0.27

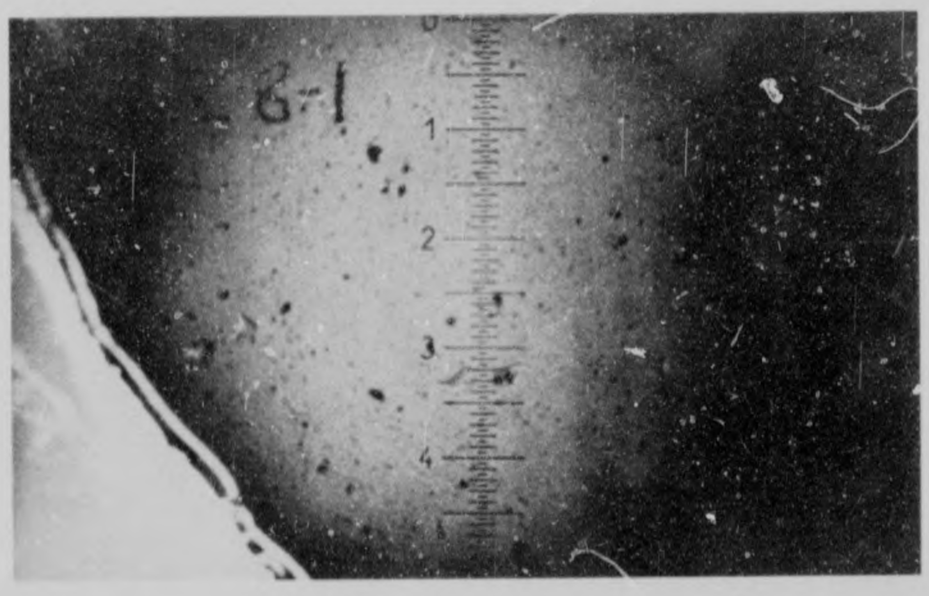
FIGURE 3 - 31: Photomicrographs of locally prepared tar / bitumen blends
(Magnification: 22 divisions equivalent to 1 mm)



END No. 3A

per cent Lurgi pitch (70° C r. & b. s.pt.)
per cent bitumen and slop wax

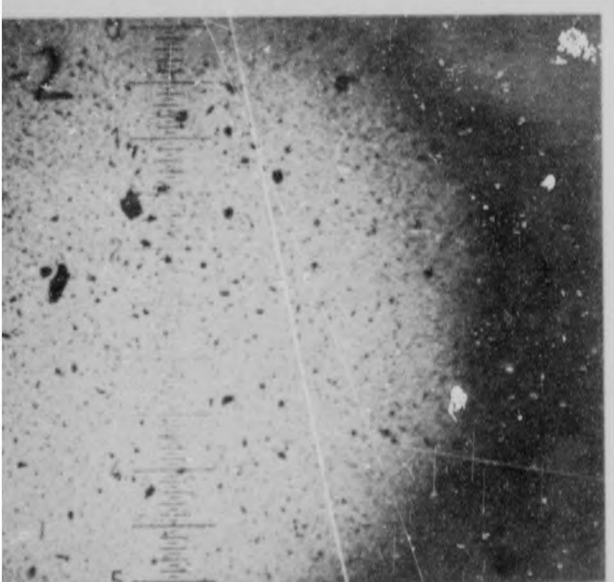
bility Index: 0.33



BLEND No. 6

10 per cent Lurgi pitch
20 per cent Lurgi heavy oil
70 per cent air-rectified bitumen

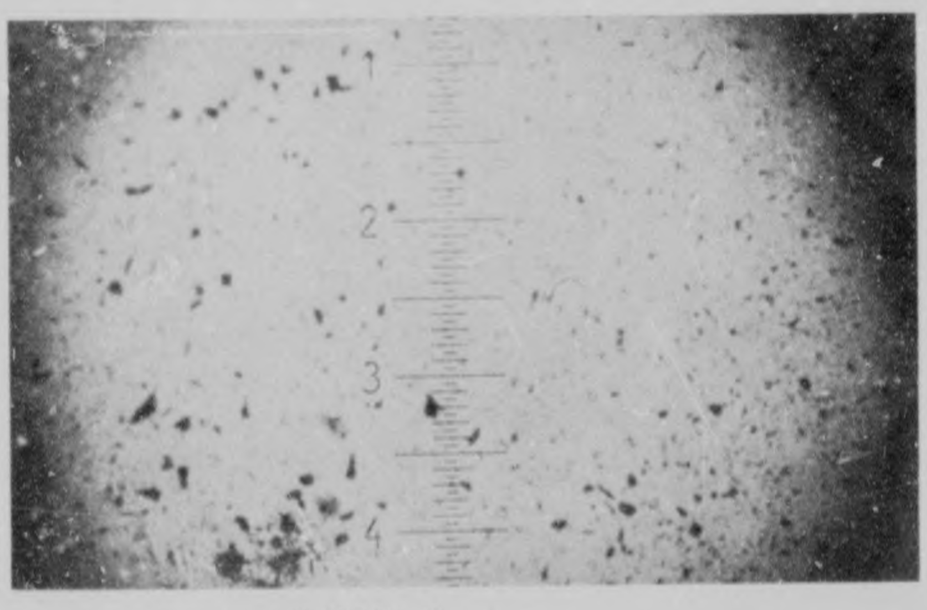
Stability Index: 0.18



END No. 4

per cent 45 - 50° C EVT Lurgi tar
per cent vacc.dist. air-rectified bitumen

ability Index: 0.57



BLEND No. 10

20 per cent 45 - 50° C EVT Coke-oven tar
80 per cent vacc. dist. air rectified-bitumen

Stability Index: 0.27

nicrographs of locally prepared tar / bitumen blends
ation: 22 divisions equivalent to 1 mm)

Stability index = (density of bottom third - original density) x 100.

It has been decided by authorities in the United Kingdom that the stability index should not exceed 1,0.

As would be expected blends which were originally non-homogeneous had high stability indices. The stability index values of imported and locally prepared blends are indicated with the photomicrographs in Figures 3 - 29 to 3 - 31. Blends which, from microscopic examination, appeared to be non-homogeneous had high stability indices. The results of a number of stability index tests are given in Table 3 - 22.

TABLE 3 - 22

THE STABILITY INDICES OF VARIOUS TAR/BITUMEN BLENDS

Blend No.	Tar/bitumen blend composition	Stability Index
1	20 per cent Lurgi (45-50°C Evt) + 80 per cent vacuum distilled bitumen	0,66
2	44 per cent coke-oven + 56 per cent bitumen	0,25
2A	20 per cent Lurgi pitch (70°C r.& b. Soft. pt.) 80 per cent bitumen and slop wax	1,33
3	15 per cent Lurgi heavy-oil + 85 per cent air-rectified bitumen	0,82
3A	30 per cent Lurgi pitch (70°C r.& b. Soft. pt.) 70 per cent bitumen and slop wax	0,33
4	30 per cent Lurgi (45-50°C Evt) + 70 per cent vacuum distilled air-rectified bitumen	0,57
6	20 per cent Lurgi heavy-oil + 10 per cent Lurgi pitch + 70 per cent air-rectified bitumen	0,18
10	20 per cent coke-oven (45-50°C Evt) + 80 per cent vacuum-distilled air-rectified bitumen	0,27
-	"Cindumix"	0,88
-	"Gripta"	0,73

It will be apparent that the lengthy duration of the stability index test is a disadvantage*. If the storage stability is related to the homogeneity of the blend, then measures for assessing the latter might also indicate the stability on storage.

* This may explain why the test has not been included in a provisional specification for tar/bitumen blends recently introduced in Britain (Department of the Environment, 1972) though a storage stability requirement is mentioned.

3.2.5.4 The Evt Brittle-point temperature range

It has previously been shown that the rheological properties of tar/bitumen blends are intermediate between those of tar and bitumen and this applies to the Evt-brittle point temperature range. Values given by imported and locally prepared blends have been determined and these are shown in Table 3 - 23.

However, the Evt-brittle point temperature range is an unreliable guide to the homogeneity of a blend and values given by non-homogeneous blends may approximate to that of the bitumen component. This is shown by the values given in Table 3 - 23 and also from the results described by McNeil (Table 3 - 18).

TABLE 3 - 23

THE EVT BRITTLE-POINT TEMPERATURE RANGE FOR VARIOUS BINDERS

	Binder	Homogeneity	Evt-brittle point
	Lurgi tar	-	60,5
	Coke-oven tar	-	61,0-63,0
	Bitumen	-	84,0-89,0
	"Cindumix" (42 per cent coke-oven tar)	Homogeneous	71,2
	"Gripta" (32 per cent medium temp. tar)	Homogeneous	78,6
	Local blends		
No.1	20 per cent Lurgi (45-50°C Evt) + 80 per cent vacuum-distilled bitumen	Non-homogeneous (High.stab.index)	78,8
No.2	44 per cent coke-oven tar + 56 per cent bitumen	Homogeneous	85,0
No.3	15 per cent Lurgi heavy-oil + 85 per cent air-rectified bitumen	Homogeneous	81,9
No.4	30 per cent Lurgi(45-50°C Evt) heavy-oil + 10 per cent vacuum-distilled / air-rectified bitumen	Non-homogeneous (High.stab.Index)	82,8
No.6	20 per cent Lurgi heavy-oil + 10 per cent Lurgi pitch + 70 per cent air-rectified bitumen	Non-homogeneous (low ductility)	75,4
No.10	20 per cent coke-oven (45-50°C Evt) + 80 per cent vacuum distilled/air-rectified bitumen	Homogeneous	77,5
No.12	20 per cent Lurgi (45-50°C Evt) + 80 per cent MC 3000 cutback bitumen	Homogeneous	70,0

3.2.5.5 Determination of tar and bitumen proportions

Methods for the detection and determination of tar and bitumen in mixtures have been reviewed by Drake (1969) and more recently by Meiras (1972). At the present time no method has been accepted for all types of tar/bitumen blends. Procedures based upon the determination of the bitumen content will be considered here.

Methods which are used are specific for certain types of tar and bitumen. German and Swiss specifications make use of a sulphonation method* which assumes that all tar is aromatic and all bitumen is aliphatic (Rijkswaterstaat 1972). A correlation factor may be used as determined from results given by a mixture(of the same tar and bitumen) of known proportions. The precision of the sulphonation method has been assessed using mixtures ** of one type of bitumen with both a coke-oven and Lurgi tar. In each case the quantities of tar and bitumen used were equivalent to a blend of 75 per cent bitumen and 25 per cent of tar. The results of eleven separate tests on the simulated blends are shown in Table 3 - 24.

It was considered that an accuracy of 5 per cent would be adequate for such a method and in view of the high precision indicated in Table 3 - 24 further tests were carried out on one of the locally prepared Lurgi-tar/bitumen blends which purported to contain 80 per cent of bitumen and 20 per cent of Lurgi tar. Twelve results gave a mean result of 81,9 per cent but the scatter was high, 78 - 87 per cent (standard deviation 2,4) and it was uncertain whether this was caused by a non-homogeneous blend although tests on the "Cindumix" blend also showed a high scatter, standard deviation of 4,0 for a mean bitumen content of 62,7 per cent.

However, the method apart from being of limited precision, is arduous and the long time required to obtain a result is a further disadvantage.

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* Sulphuric acid is added to a known quantity of the blend placed in a vessel heated on a water-bath. The sulphonated and water-soluble aromatics are washed out with a 0,05 per cent solution of sodium sulphate. The mass of the unsulphonated bitumen is determined from which the percentage bitumen in the blend is calculated.

** At this stage it was decided not to use the locally prepared blends in precision tests because of doubts about their homogeneity.

TABLE 3 - 24

PRECISION TESTS ON MIXTURES OF BITUMEN

AND COKE-OVEN TAR AND BITUMEN AND LURGI TAR

USING THE SULPHONATION METHOD (RIJKSWATERSTAAT, 1972)

Blend No.	Bitumen/coke-oven tar			Bitumen/Lurgi tar	
	75 per cent		25 per cent	75 per cent	25 per cent
1	81,57		18,43	76,98	23,02
2	79,98	-	20,02	78,53	21,47
3	82,62	-	17,38	76,67	23,33
4	79,80	-	20,20	77,80	22,20
5	79,79	-	20,21	77,08	22,92
6	79,82	-	20,18	76,44	23,56
7	79,97	-	20,03	75,94	24,06
8	79,42	-	20,58	79,70	21,30
9	79,66	-	20,34	76,48	23,52
10	80,79	-	19,21	75,78	24,22
11	80,51	-	19,49	-	-
Mean	79,97	-	20,03	77,04	22,96
Std. dev.	0,43		0,43		0,96
Coeff. of variation (per cent)	0,53		2,12		4,1

In Part 2, Chapter 2 it was shown that, apart from differences in the type of hydrocarbon that comprise tar and bitumen, the compounds present in bitumen differ from those in tar in having a much higher molecular mass. This makes possible the analysis of tar/bitumen blends by gel-permeation chromatography (GPC). The principles of this technique have been explained in Appendix A.2.

A suitable method for the analysis of tar/bitumen blends was first suggested by Meiras (1973). It had the advantages of speed, simplicity and low cost. A slightly modified version was published at a later stage (British Carbonisation Research Association, 1974) and this is described in Appendix A.2.2. The bitumen is eluted from the GPC column before the tar. Typical chromatograms for a coke-oven tar, a bitumen and a coke-oven tar/bitumen blend are shown in Figure 3 - 32.

The precision of the method was established from a number of tests on the "Cindumix" blend. These results are given in Table 3 - 25.

TABLE 3 - 25

BITUMEN CONTENTS OF THE CINDUMIX COKE-OVEN TAR/BITUMEN BLENDS USING THE GPC METHOD (MEIRAS, 1973)

Test No.	Bitumen content per cent by mass	Test No.	Bitumen content per cent by mass
1	59,3	7	58,5
2	59,1	88	55,6
3	57,5	9	56,2
4	55,6	10	54,4
5	57,5	11	58,6
6	57,9	12	61,0

Mean	57,6
Std. dev.	1,80
Coeff. of var.	3,12

The method was used in an inter-laboratory testing program organised by the British Carbonisation Research Association. The author's results determined on blends of known compositions are shown in Table 3 - 26.

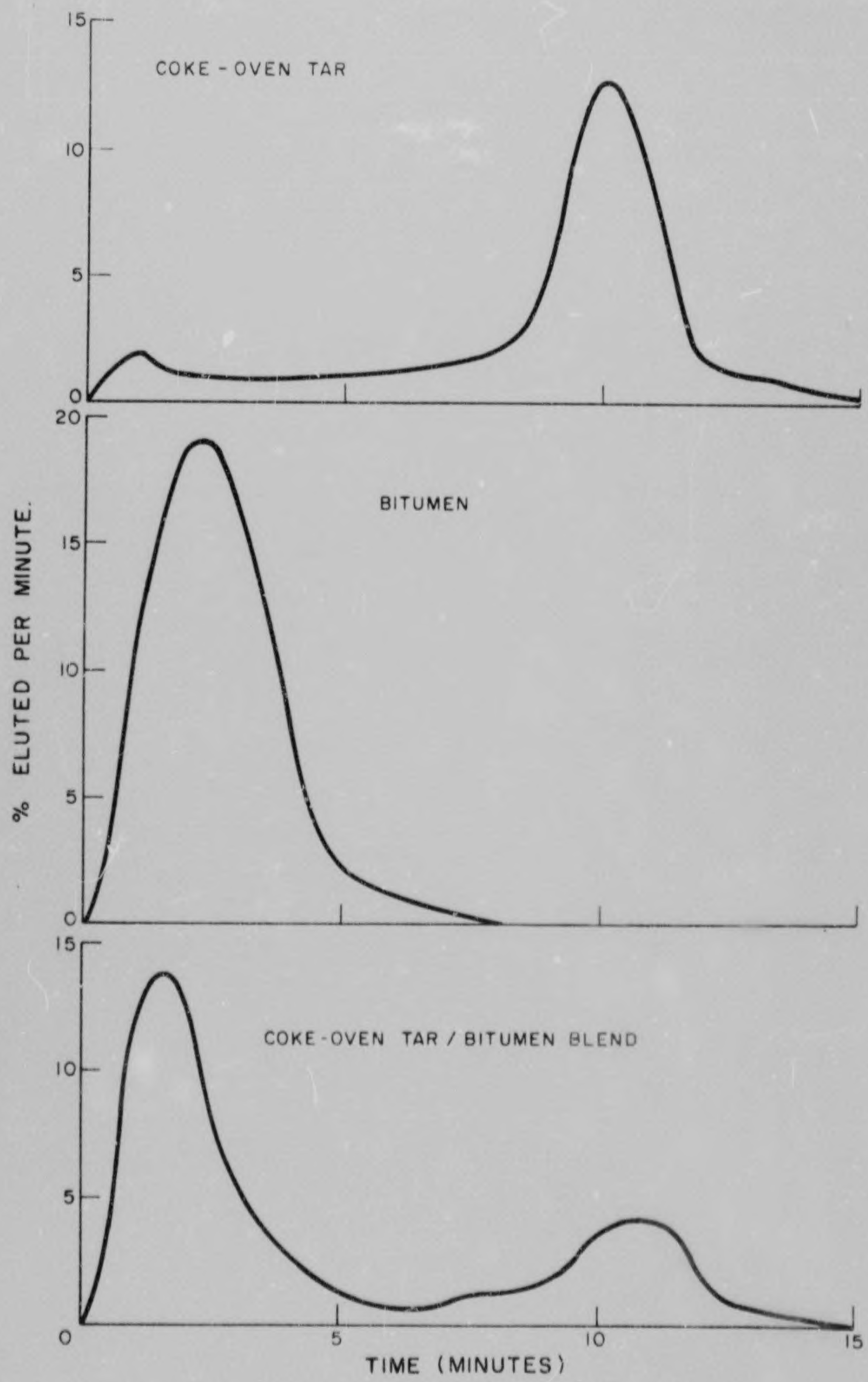

FIGURE 3-32

GPC CHROMATOGRAMS OF COKE-OVEN TAR, BITUMEN AND A COKE-OVEN TAR / BITUMEN BLEND

TABLE 3 - 26

BITUMEN CONTENT OF TAR/BITUMEN BLENDS RECEIVED FROM BCRA

Blend No.	Components	Bitumen content		
		Actual	determined* (corrected)	Error
P2	Rexco pitch and Middle East bitumen	80	84,1	+4,1
P6	Coke-oven pitch and Middle East bitumen	80	82,2	+2,2
T2	Rexco tar and Middle East bitumen	67	75,0	+8,0
T6	Coke-oven tar and Middle East bitumen	67	67,8	+0,8
T8	Rexco pitch, coke-oven oil and Middle East bitumen	67	64,4	-2,6

* See Appendix A.2.2 for determination of "corrected" bitumen content.

With one exception the method gave a result within 5 per cent of the actual bitumen content.

It is suggested that the GPC method should be adopted as a control test and incorporated in tentative specifications for tar/bitumen blends. Neither the sulphonation method nor the GPC method are entirely satisfactory but they both appear to give a reasonable estimate of the bitumen content. Their accuracy and precision are similar but the GPC method is more rapid and convenient.

3.2.5.6 Accelerated Weathering Test (AWT)

The development of this test has been described previously (Jamieson, 1974a) and is mentioned elsewhere in this thesis. The method is given in detail in Appendix L and the test is recommended for inclusion in South African tar specifications.

The method indicates the increase in Evt that may be expected after one year's exposure in a surface treatment. Wilman, (1974) considered that it may be applied to all surface treatment binders. The inclusion of the test in specifications for tar/bitumen blends may be appropriate as a means of controlling the quality of blends, the only alternative for this purpose being a distillation test. At this stage limiting criteria can only be suggested for guidance purposes using the principles which apply to the weathering of road tars.

It is suggested that the determination of limiting AWT criteria for tar/bitumen blends may be the subject of a further investigation.

3.2.6 Determination of viscosity grades suitable for use in South Africa

In order to determine suitable viscosity grades for use on South African roads, cognisance must obviously be taken of typical annual road temperature cycles. As explained in Part 2, Chapter 4, at the time of application the viscosity should be low enough to ensure adequate wetting of the stone and high enough to ensure stone retention.

Williamson (1972) gave the annual variation in road surface temperatures for the various climatic regions in South Africa. Data obtained in the Highveld and Natal is most appropriate for this purpose, because as previously explained it would be expected that tar products would be used mainly in these regions. In these areas the daily minimum road surface temperatures range from -2°C to + 26°C and mean daily road surface temperatures range from 5 - 53°C. From this information it is possible to compute the range of Evt's applicable throughout the year using Briggs's method described in Part 3, Chapter 1.6.2, and this Evt range may be arbitrarily divided to give four distinct grades.

From Briggs (1970), and as previously described, the maximum Evt for a surface treatment binder is calculated from the minimum road surface temperature + C, where C varies according to the type of binder. Briggs assigned a value of 40°C to C in the case of tar/bitumen blends. However, the author's viscosity-temperature plots for local and overseas tar/bitumen blends (Figure 3 - 33) show that the temperature at which they intercept the critical wetting viscosity (10^4 Ns/m^2) may lie between 32,5 and 37,3°C below the Evt. It is apparent that the C value depends upon the type and quantity of tar and bitumen in the blend, and it is suggested that a value of 33°C should be used until it is found that the products of local suppliers have values consistently greater than this figure. Thus the range of Evt's of tar/bitumen blends to be used in South Africa can be estimated* and it is proposed that these should be 35** - 60°C and that this range be divided to give the following grades:

---

* Maximum Evt = minimum road temperature + C.
Lower limit = -2°C +33°C = 31°C
Upper limit = +26°C +33°C = 59°C

** A minimum Evt of 35°C is proposed (as is the case with unmodified tars) although according to the calculation this should be 31°C.

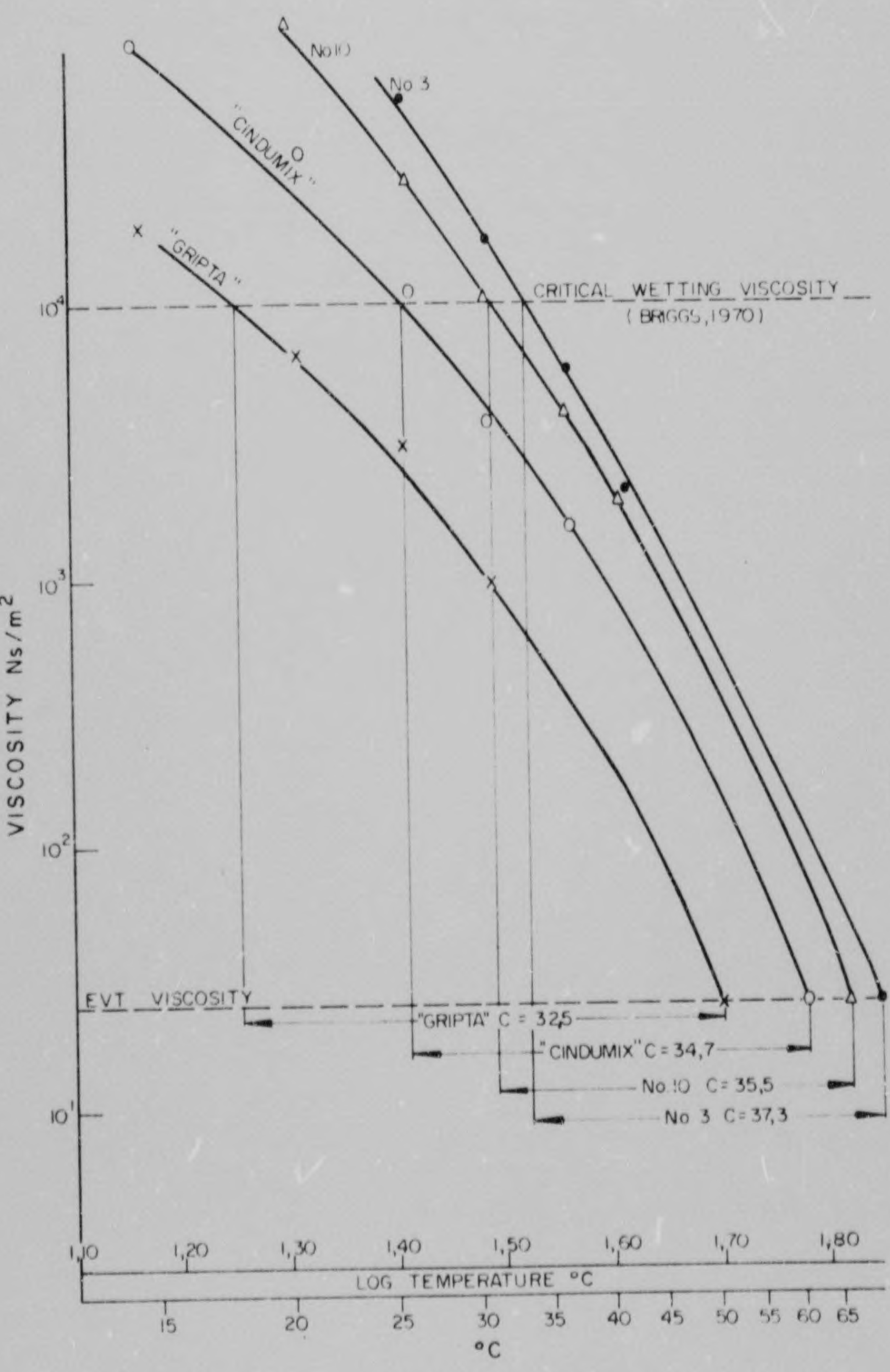

FIGURE 3-33

THE INTERSECTION OF VISCOSITY - TEMPERATURE PLOTS FOR VARIOUS TAR/BITUMEN BLENDS WITH EVT AND CRITICAL WETTING VISCOSITY LEVELS.

35 - 42°C

42 - 48°C

48 - 54°C

54 - 60°C

However, it is suggested that as in most European countries their viscosity should be expressed in seconds efflux from the standard tar viscometer (STV) at a temperature of 40 or 50°C. There are distinct disadvantages in expressing the viscosity of tar/bitumen blends according to the Evt scale and Wilman (1974) mentioned that road engineers had assumed incorrectly that road tars and tar/bitumen blends of the same Evt would have the same viscosity over the entire road surface temperature range. As shown in Figure 3 - 24 this is not so and one important consequence of this wrong assumption could be the use of an incorrect spraying temperature (typical tar spraying temperatures would be too-low for spraying tar/bitumen blends.).

Accordingly the above Evt ranges may be converted to STV seconds at 40°C from a plot of Evt versus STV seconds, at 40°C, prepared by the author (Figure 3 - 34) in a manner identical to that described by Wilman (1974). The corresponding viscosities in STV seconds (40°C) of the four grades of tar/bitumen blends are:

25 - 75

75 - 180

180 - 410

410 - 1 000 (110 - 260 at 50°C)*

These grades are proposed for the initial development of tar/bitumen blends in South Africa, It could be that in some cases the range is too great to guarantee successful application, and for this and other reasons, (e.g. a change in the value of C for commercial blends) these ranges may have to be redetermined at a later stage.

* Because of cooling effects such long efflux times may lead to substantial errors and it may be preferable to use a test temperature of 50°C for specifying the most viscous grade.

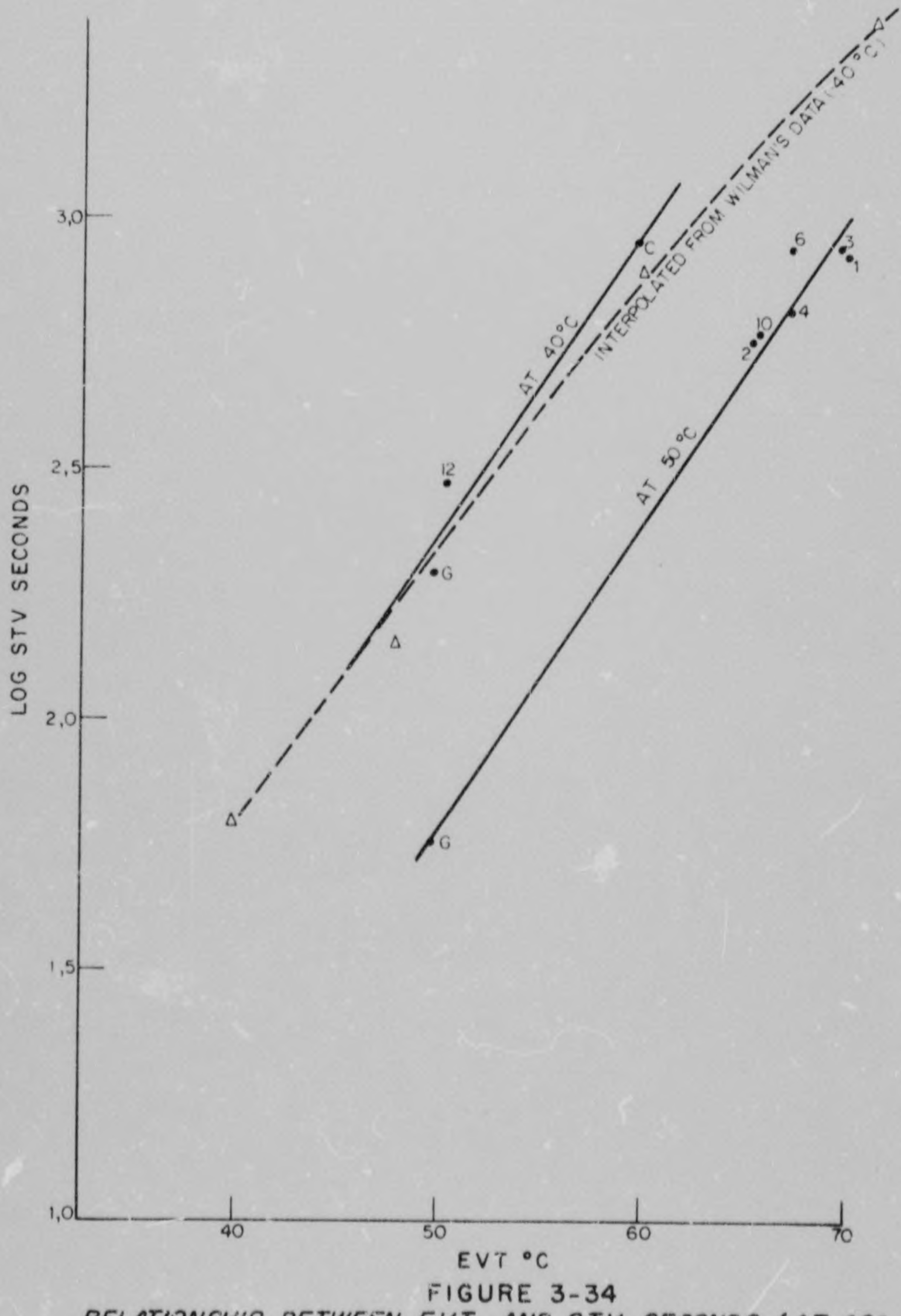

FIGURE 3-34
RELATIONSHIP BETWEEN EVT AND STV SECONDS (AT 40° AND 50°C) FOR TAR/BITUMEN BLENDS.

3.2.7 Specifications for tar/bitumen blends

From the accumulated information given above, recommended specifications for bitumen-rich blends are given in Table 3 - 27.

TABLE 3 - 27

TENTATIVE SPECIFICATION REQUIREMENTS FOR TAR/BITUMEN BLENDS

Property	TB 25/75	TB 75/180	TB 180/410	TB 410/1 000 (or 160 - 260)+	Test method
Viscosity (STV, S., 10 mm cup) at 40°C	25-75	75-180	180-410	410-1 000	STPTC RT 2
at 50°C	-	-	-	110-260	
Bitumen content (per cent by mass)	55-80	55-80	55-80	55-80	GPC method as desc. in specification*
Ductility mm (min)	1 000	1 000	1 000	1 000	IP 32
Homegeneity by microscopic exam. and as noted during ductility test	Homogeneous	Homogeneous	Homogeneous	Homogeneous	—
Stability Index (max)	0,8	0,8	0,8	0,8	As desc. in specification
Accelerated Weathering Test (Inc. in Evt °C)	15-27	12-25	10-20	5-20	As desc. in specification

*See Appendix A. 2.2 + See footnote on the previous page

Suitable spraying temperatures are suggested from viscosity-temperature plots, in the spraying viscosity region given by the grades. Plots for the 180/410 and 410/1000 grades are given in Figure 3 - 35. Plots for blends heavier than the 410/1000 grades are shown in Figure 3 - 36. The recommended temperatures are as follows:

25/75	125 - 145°C (estimated)
75/180	130 - 150°C
180/410	135 - 155°C
410/1 000	145 - 160°C

It should be noted that the spraying temperatures recommended are for bitumen-rich blends and that tar-rich blends would be expected to have different spraying temperatures.

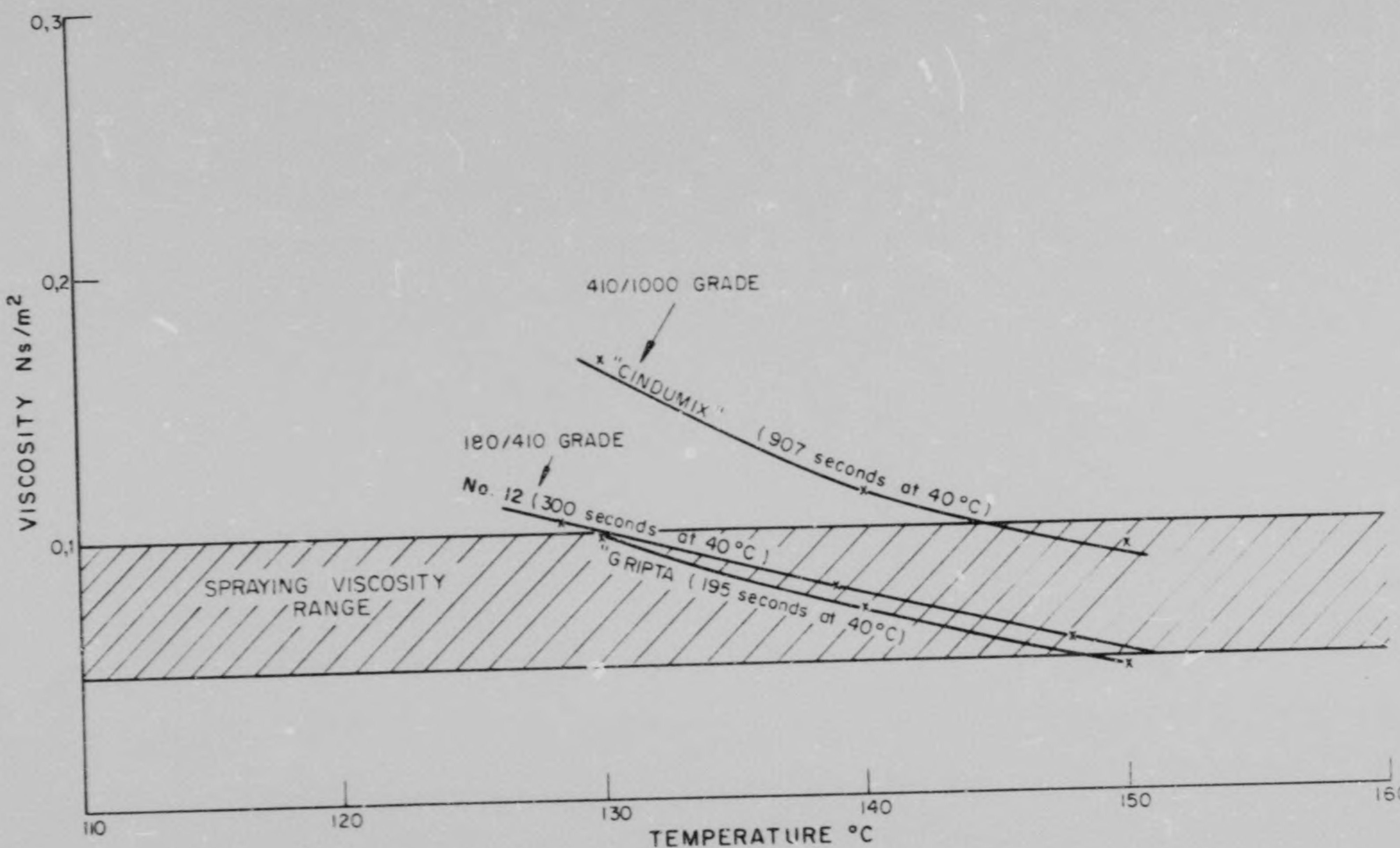

FIGURE 3-35

VISCOSITY-TEMPERATURE PLOTS IN THE SPRAYING VISCOSITY REGION OF TAR/BITUMEN OF PROPOSED GRADES 180/410 AND 410/1000

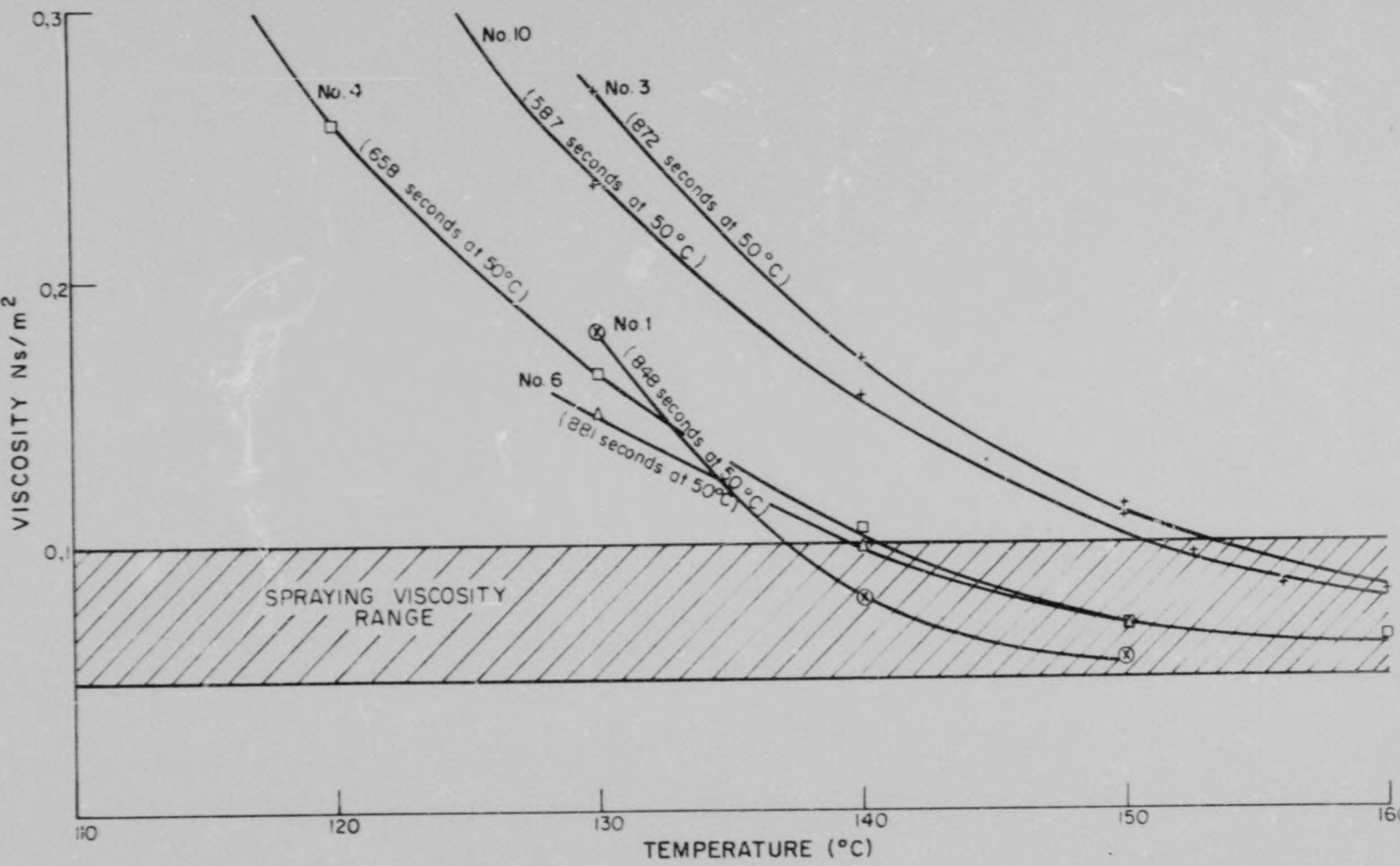

FIGURE 3 - 36

VISCOSITY - TEMPERATURE PLOTS, IN THE SPRAYING VISCOSITY REGION, OF TAR / BITUMEN BLENDS HAVING VISCOSITIES EXCEEDING 260 STV SECONDS AT 50 °C.

3.3 TARS IN THE LOWER LAYERS OF MULTIPLE SEALS

Resumé

The performance of experimental sections containing coke-oven tar in the lower layers is reviewed. These earlier road experiments included multiple-surface treatments and single-surface treatments on which was placed either a bitumen mastic (Cape-seal) or an emulsion slurry. The general performance was satisfactory and, in addition , Lurgi tar is performing well in experimental double-surface treatment sections constructed in 1974. Viscosity monitoring tests show that where the tar was used in both layers a minimum service life of five years may be expected. It is suggested that vertical-retort tars may be equally suitable for lower layers.

In all cases low-volatile tar compositions are stipulated.

A number of types of multiple-seal constructions are used in South Africa, particularly for the surfacing of newly constructed major trunk roads. These have been enumerated (National Institute for Road Research 1971). In such cases the binder used in the lower layers is not exposed to conditions where oxidation may take place nor is it feasible for rapid evaporation of light oil constituents to occur. Under these circumstances the weathering susceptibility of the various types of tar binder may be expected to be of less importance than in the upper layer.

3.3.1 Coke-oven tar

The National Institute for Transport and Road Research has constructed a number of multiple-seal sections in full-scale road experiments since 1952. In several cases coke-oven tar binders have been used and the author has studied performance assessments for three types of seal: multiple-surface treatments, single-surface treatments topped with either bituminous mastic (Cape-seal) or an emulsion slurry, and double-sand seals.

3.3.1.1 Multiple-surface treatments

Performance assessments from four experiments in which tar was used either as a tack coat or in both tack and seal layers are given in Table 3 - 28.

TABLE 3 - 28

THE PERFORMANCE OF COKE-OVEN TARS IN NITRR MULTIPLE SURFACE TREATMENT EXPERIMENTS

Experiment	Type of seal	Layer in which tar was used**	Tar source and type	Volatility-distillation characteristics				Service performance	Comments
				Method 1*		Method 2*			
				per cent oils blg. 300°C	per cent blg. 300°C - 75°C soft/pt. (r&b) pitch	per cent oils blg. 340°C	Soft pt. (r&b) (°C) of dist. residue		
Marikana (1954)	Double	Seal and tack	Supplier A (Normal)	–	–	17,1	62,0	+ $11\frac{1}{2}$ yrs.	Difference in volatility
			Supplier A (P3)***	–	–	13,8	48,5	+ $11\frac{1}{2}$ yrs.	characteristics did not affect performance
Malmesbury (1961)	Double	Tack	Supplier A (Normal)	8,3-10,5	12,8-14,6	–	–	+ 8 yrs	
Kroonstad (1964)	Double	Seal and tack	Supplier A (P3) ***	–	–	15,6	64,5	4 - 6 yrs.	P3 performed slightly worse than rubberised tar
			Supplier A (Normal + 8 per cent coal + 1 per cent rubber	–	–	–	–	4 - 6 yrs.	
Platrand (1960)	Double and Triple	Tack	Supplier A (Normal)	12,5	9,6	–	–	6 - 7 yrs	
		Tack + 1st seal	Supplier A (Normal)	12,5	9,6	–	–	+ 8 yrs.	

* The distillation test used to describe the composition of tar oils, has changed since the earlier experiments were carried out. According to the earlier procedure for low-volatile tars the amount of oils boiling below 300°C was specified and also the oils boiling between 300°C and the formation of a 75°C (ring and ball) softening point was specified. The limits in the proposed revision of the specification (Appendix L) for 55°C Evt tars are: total oils to 340°C - 12 per cent(maximum), softening point 56°C (ring and ball) (max.).

**Each type of tar was tried in both layers

***The P3 type was an earlier formulation for a supposed low-volatile tar. However, as the distillation test data show low-volatility was not necessarily achieved.

Where the tar was used in the lower layers only, the results have been entirely satisfactory. Where tar was used in seal and tack coat layers the outcome was variable; in the Marikana experiment excellent results were obtained but in the Kroonstad experiment the performance was unsatisfactory.

More details of the constructions used in the Kroonstad experiment are given in Table 3 - 29. In this experiment the effect of a final emulsion fog-coat was also investigated. Where bitumen was placed over tar, the performance was as good as where bitumen was used in both layers and where the emulsion fog-coat was placed over two layers of the tar, the performance was also equal to that of bitumen in both layers. These observations were made after six years in service.

It is clear that tar can be substituted for bitumen in the lower layers of multiple-surface treatments provided that a final seal "coat" of bitumen is applied. The application of different binders for different layers is convenient where surfacings are to be constructed near to supplies of tar. Where this is not the case it may be argued that there is sometimes a problem resulting from the need to store the two binders on site and use one distributor for spraying both binders. It is true that indiscriminate mixing of tar and bitumen leads to a precipitation of a sludge (as discussed in Part 3, Chapter 2) which can cause blocking of spray-bar nozzles. However, in the majority of cases tar is supplied to the site and sprayed by the suppliers' own machines, in which circumstance this difficulty will not occur.

The use of unmodified coke-oven tar for the lower layer of multiple surface treatments is recommended, particularly where large savings in initial construction costs will result.

3.3.1.2 <u>Single-surface treatments covered with mastic (Cape-seal) or emulsion slurry</u>

The application of a bitumen mastic to a freshly laid single-surface treatments was popular at one time but the bitumen mastic has now been replaced by the slurry seal. In the former case a 19 mm single-sized stone was used in the surface treatment, whereas with the slurry seal the surface treatment is constructed with a 13,2 mm stone. The performance of both types of construction, incorporating tar, in NITRR experiments is summarised in Table 3 - 30.

TABLE 3 - 29

PERFORMANCE OF DOUBLE SEALS IN THE KROONSTAD EXPERIMENT

AFTER SIX YEARS SERVICE

Binder used in:		Was fog-coat used?	Performance after 6 years
Lower layer "tack coat"	Upper layer "seal coat"		
	13,2 mm + 6,7 mm dolerite		
50-55°C Evt tar	150/200 Pen. bitumen	No	G_
	45-50°C Evt tar	No	Best section F_
	45-50°C Evt tar	Yes	G_
	Coal-rubber modified tar	No	Best section FG_
	Coal-rubber modified tar	Yes	FG_ to G_
150/200 Pen. bit.	150/200 Pen. bitumen	No	G_
	150/200 Pen. bitumen	Yes	G_
Emulsion bit.	Emulsion bitumen	No	FG_
	Emulsion bitumen	Yes	FG_ to G_
	13,2 mm dolerite + river sand		
50-55°C Evt tar	150/200 Pen. bitumen	No	FG_ to G_
	MMC5 bitumen	No	FG_ to G_
	45-50°C Evt tar	No	F_ to FG_
	Coal-rubber modified tar	No	F_ to G_
150/200 Pen. bit.	150/200 Pen. bitumen	No	G_

TABLE 3 - 30

THE PERFORMANCE OF COKE-OVEN TARS IN TACK COATS OF CAPE AND SLURRY SEALS; NITRR EXPERIMENTS

Experiment	Type of seal	Layer in which tar was used	Tar source and type	Volatility-distillation characteristics: Method 1*		Method 2*		Service performance	Comments
				Per cent oils blg. 300°C	Per cent blg. 300 75°C soft. pt. (r&b) pitch	Per cent oils-blg. 340°C	Soft. pt. (r&b) (°C) of dist. residue		
Baviaanspoort (1962)	Cape	Seal	Supplier A (Normal)	-	-	16,8-18,6	63,3-68,0	5-6 yrs.	Sudden drop in performance after 5 years
			Supplier A (P3)**	-	-	15,1	59,0	5-6 yrs.	Sudden drop in performance after 5 years
			Supplier A (Normal + 8 per cent coal)	-	-	-	-	2-4 yrs.	-
			Supplier A (Normal + 8 per cent coal + 1 per cent rubber	-	-	-	-	5-6 yrs.	Sudden drop in performance after 5 years
Kroonstad (1964)	Double Sand	Both	Supplier A (P3) **	-	-	15,6	64,5	4-6 yrs.	P3 performing slightly worse than rubberised tar at this stage
	Slurry	Tack	Supplier D	-	-	20,0	70,5	+ 6 yrs.	Very volatile tar
	Cape	Tack	Supplier D	-	-	20,0	70,5	+ 6 yrs.	Performing well at this stage
Platrand (1960)	Cape	Tack	Supplier A (Normal)	12,5	9,6	-	-	16 mths. to 8 yrs.	Performance dependent upon application and performance of bitumen in the seal layers
	Slurry	Tack	Supplier A (Normal)	12,5	9,6	-	-	0 years	

* The distillation test used to describe the composition of tar oils, has changed since the earlier experiments were carried out. According to the earlier procedures for low-volatile tars the amount of oils boiling below 300°C was specified and also the oils boiling between 300°C and the formation of 75°C (ring and ball).
The limits in the current specification are; Total oils to 340°C - 12 per cent (max). Softening point 56°C (ring and ball)

** The P3 type was an earlier formulation for a supposed low-volatile tar. However as the distillation test data shows that low-volatility was not necessarily achieved.

The tar-bound mastic used in the Baviaanspoort experiment failed between five and six years after construction. It is notable that the tar would not have complied with the distillation test requirements proposed for the revised specification (see Appendix L). However, where it was used in the tack layer (Kroonstad and Platrand experiments) i.e. as the surface-treatment binder, its performance was excellent, whether a bitumen mastic or emulsion slurry was used in the upper layer.

3.3.1.3 Double-sand-seals

The service performance of double sand-seals in the Kroonstad experiment is indicated in Table 3 - 31 from which the performance of tar and bitumen in this type of construction can be compared. Although the tar did not perform as well as bitumen when used in upper and lower layers, a service life of four to six years was obtained and this may be considered satisfactory for such an inexpensive form of surfacing.

As in the case of the multiple-surface treatments and single-seal and slurry constructions, the performance was better where tar was used in the lower layer only and was comparable to constructions where bitumen was used in both layers.

TABLE 3 - 31

THE PERFORMANCE OF DOUBLE-SAND-SEALS IN THE KROONSTAD EXPERIMENT (AFTER SIX YEARS' SERVICE)

Binder used in:		Performance
Lower layer	Upper layer	
50 - 55°C Evt tar	150/200 Pen. bit.	G_
50 - 55°C Evt tar	MMC5 cutback bit.	F_ to G_
50 - 55°C Evt tar	45 - 50°C Evt tar	FG_ to G_
50 - 55°C Evt tar	Rubber mod. tar	F_
150/200 Pen. bit.	150/200 Pen. bit.	G_

3.3.2 Performance of Lurgi tar in double-surface treatments

In view of the good results obtained when coke-oven tars were used in the lower layers of seals, it was decided to investigate the possibility of using Lurgi tar for a similar purpose. To achieve this objective experimental sections of double-surface treatments were placed on a newly constructed section of route P 3/4 (Klerksdorp-Wolmaransstad).

The specification for the surfacing in this case was a double-surface treatment using successive layers of binder with 13,2 mm and 6,7 mm stone sizes, followed by a final fog-spray of bitumen emulsion.

3.3.2.1 The Klerksdorp-Wolmaransstad experiment

The layout of the experimental section is shown in Figure 3 - 37.

The experiment mainly comprised sections in which tar was used in the lower layer with bitumen and emulsion fog-coat in the upper layer.

This opportunity was also used to compare the durability of Lurgi tar with that of coke-oven tar and bitumen when used in seals. Although laboratory data suggests (see Part 2, Chapter 3) that Lurgi tar may weather more rapidly than those other binders, there was a complete absence of any practical evidence of this. To enable this question to be studied, sections were included in which Lurgi tar as well as coke-oven tar and bitumen were used in both upper and lower layers and no final emulsion fog-coat was applied. It was proposed to assess the durability by regularly monitoring the viscosity of the binders in these sections. The experiment was constructed in March 1974 and although this is too recent to judge the eventual service performance it is possible to make an assessment of minimum service life by extrapolating the results of the viscosity monitoring tests.

In order to obtain information on the effect of volatility on their hardening and performance, two types of Lurgi tar were incorporated. These were a high-volatile and a low-volatile type. The standard test properties of the stone and binders used in the experiment are given in Appendix L, Tables XIX to XXII.

Full details of the construction are given in a confidential report (Jamieson et al. 1975). During the construction, as recommended for double-seal constructions (National Institute for Road Research, 1971), at least 24 hours was allowed for the binder in the lower layer to lose some volatile constituents before the upper layer was applied. This was adhered to in every case.

On the sections selected for the binder viscosity monitoring tests, samples of the lower layers were taken immediately prior to the application of the upper layer. The binder was extracted and the Evt determined according to the procedures described previously (Jamieson 1974a). The results are presented in Table 3 - 32.

	SECT No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
UPPER LAYER	FOG SPRAY	NO FOG SPRAY						FOG SPRAY ON WEST BOUND LANE ONLY			NO FOG SPRAY												FOG SPRAY								
	ROLLING	HEAVY PNEUMATIC — 4 PASSES																													
	STONE SIZE	6,7 mm																													
	BINDER	150/200 PEN BITUMEN												SASOL (HIGH - VOL.)			COKE-OVEN			SASOL (LOW - VOL.)			150/200 PEN BITUMEN								
	NOM. APP													O	O	O	O	O	O	O	O	O									
LOWER LAYER	ROLLING	HEAVY PNEUMATIC - 4 PASSES, FOLLOWED BY 1 FLAT																													
	STONE SIZE	13,2 mm																													
	BINDER	SASOL (HIGH - VOL.)			COKE-OVEN			BITUMEN			SASOL (LOW - VOL.)			SASOL (HIGH - VOL.)			COKE - OVEN			SASOL (LOW - VOL.)			SASOL (HIGH - VOL.)			COKE-OVEN			SASOL (LOW - VOL.)		
	NOM. APP	O	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+	O^-	O	O^+

O = DESIGN QUANTITY
O^- = DESIGN QUANTITY LESS 0,16 ℓ /m²
O^+ = DESIGN QUANTITY PLUS 0,24 ℓ /m²

FIGURE 3-37

LAYOUT OF KLERKSDORP-WOLMARANSSTAD FULL-SCALE EXPERIMENT (P3/4)

TABLE 3 - 32

THE CHANGE IN EVT DURING THE CURING PERIOD OF TARS USED IN THE KLERKSDORP - WOLMARANSSTAD EXPERIMENT

Tar type	Section No	Application $1/m^2$	Change in Evt during curing	Change in Evt Evt during AWT*
Lurgi (high-volatile)	2	0,98	12,0	38,1
	14	0,98	12,6	-
Lurgi (low-volatile)	11	1,14	4,0	21,0
	20	0,87	4,1	-
Coke-oven	5	1,03	9,2	24,8
	17	0,92	6,8	-

* Accelerated Weathering Test

The order of greatest change in Evt of the three types of binder is: Lurgi high-volatile > coke-oven > Lurgi low-volatile, which is also the order of greatest change in Evt in the Accelerated Weathering Test. The results indicate that all the tars hardened by an appreciable amount after only 24 hours' exposure in a single layer.

The author assembled a team of experienced engineers to inspect the condition of the sections and these performance assessments were carried out one month, one year and two years after construction. The assessments were made according to the Road Research Laboratory method (Road Research Laboratory, 1953) and average assessments and remarks on the performance are given in Table 3 - 33.

The most striking feature was the substantial loss of 6,7 mm stone from the "unfogged" sections within one month of the road being opened to traffic, whereas where the bitumen emulsion fog-spray was used no stone loss occurred, even after two years in service. This took place where bitumen, coke-oven tar and Lurgi tar were used in the upper layer; the loss was therefore probably not due to any deficiency in the binder properties. Despite this the surfacing remained effective as a seal and at the latest inspection the surface texture was such as to provide good skid-resistance without noticeably greater tyre-noise than the "fogged" sections.

At the one-year inspection it was noted that where high binder application had been used, the binder had flushed to the surface in localised spots or areas, mainly in the wheel paths of the traffic.

TABLE 3 - 33

PERFORMANCE RATING OF EXPERIMENTAL SECTIONS AT KLERKSDORP AFTER ONE MONTH, ONE YEAR AND TWO YEARS IN SERVICE

Sect. No.	Binder						Performance assessment			Remarks
	Tack coat			Seal coat			1 month	1 year	2 years	
	Type	Application $1/m^2$		Type	Application $1/m^2$					
		WB	EB		WB	EB	WB / EB**	WB / EB	WB / EB**	
1	Lurgi (high-vol) 45/50°C Evt	0,76	0,76	Bitumen 150/200 Pen.	1,31	1,36	VG	G_-	G_-	Estimated 30 per cent of 6,7 mm stone was lost after opening road to traffic. Seal still perfect, however. Some "fatty" (binder-rich) areas in wheel paths of sections 2 and 3
2		1,03	0,98				VG	G_-	G_{-v}	
3		1,20	1,36				VG	G_-	G_{-v}	
4	Coke-oven 45/50°C Evt	0,92	0,76	Bitumen 150/200 Pen.	1,41	1,36	VG	G_-	G_-	Loss of 6,7 mm stone as above, "fatty" areas became less noticeable later on
5		1,03	1,03				VG	G_-	G_-	
6		1,14	1,20				G_-	G_{-v}	G_-	
7*	Bitumen 150/200 Pen.	0,76	0,82	Bitumen 150/200 Pen.	1,14	1,41	VG / G_-	G_-/VG / G_-	VG / G_-	Stone loss as in section 1 - 6 none on the fogged westbound carriageway
8*		0,92	0,92				VG / G_-	G_-/VG / G_-	VG / G_-	
9*		1,09	1,09				VG / G_-	G_-/VG / G_-	VG / G_-	
10	Lurgi (low-vol) 45/50°C Evt	0,82	0,87	Bitumen 150/200 Pen.	1,36	1,41	G_-	G_-	G_-	All sections look satisfactory despite loss of 6,7 mm stone as above
11		1,09	1,14				G_-	G_-	G_-	
12		1,41	1,25				G_-	G_{-v}	G_{-v}	
13	Lurgi (high-vol) 45/50°C Evt	0,87	0,82	Lurgi (high-vol) 45/50°C Evt	1,41	1,41	G_-	G_-	G_-	Loss of 6,7 mm stone was less than on sections 1-3. Fatty patches on sections 14 and 15 improved after a further period in service
14		[illegible]	0,98				G_-	G_v / G_-	G_- cl	
15		[illegible]	1,25				G_v	G_{+v}	G_{-v}	
16	Coke-oven 45/50°C Evt	0,82	0,76	Coke-oven 45/50°C Evt	1,31	1,31	G_-	G_-	G_-	Stone loss as above fattiness on section 18 WB was bad after 1 year and "ponding" of binder occurred. This improved after 2 years
17		0,98	0,92				G_-	G_-	G_-	
18		1,09	1,14				G_-	G_{+v} / G_-	G_-	
19	Lurgi (low-vol) 45/50°C Evt.	0,76	0,82	Lurgi (low-vol) 45/50°C Evt.	1,36	1,41	VG	G_-	G_-	Stone loss as above otherwise satisfactory
20		0,98	0,87				VG	G_-	G_-	
21		1,25	1,03				VG	G_-	G_-	
22+	Lurgi (high-vol) 45/50°C Evt.	0,87	0,82	Bitumen 150/200 Pen.	1,14	1,14	VG	VG	VG	These sections achieved almost 100 per cent retention of 6,7 mm stone after 2 years
23+		0,92	0,98				VG	VG	VG	
24+		1,20	1,14				VG	VG	VG	
25+	Coke-oven 45/50°C Evt.	0,76	1,03	Bitumen 150/200 Pen.	1,09	1,20	VG	VG	VG	As in sections 22-24
26+		0,92	0,71				VG	VG	VG	
27+		1,25	1,03				VG	VG	VG	
28+	Lurgi (low-vol) 45/50°C Evt.	0,76	0,82	Bitumen 150/200 Pen.	1,14	1,14	VG	VG	VG	As sections 25-27. On section 30 a large fatty area occurred near to a culvert
29+		0,98	0,82				VG	VG	VG	
30+		[illegible]	0,98				VG	VG / G_+	VG / G_+	

* Westbound lane only was fogged. Application of 0,76 $1/m^2$ emulsion

\+ Both lanes fogged. Application 0,76 $1/m^2$ emulsion, (60 per cent cationic)

** WB = Westbound

EB = Eastbound

However, at the subsequent inspection these fatty areas had almost disappeared and it is presumed that the excess binder had been removed by the traffic.

These visual examinations showed that sections constructed with high-volatile and low-volatile Lurgi tar had performed well. This was true where the tars had been used in both the upper and lower layers as well as in the lower layer only.

These encouraging signs were supported by the initial results of the viscosity monitoring tests, which are shown in Figure 3 - 38. In these sections the total film thicknesses of the binder were similar* and these results may be taken as indicating the relative weathering rates of the binders. After two years the hardening of the low-volatile Lurgi tar and the coke-oven tar was similar whereas the high-volatile Lurgi tar had hardened by a greater amount.

The order of greatest hardening after one year and two years in service was the same as that given in the Accelerated Weathering Test. This is shown in Table 3 - 34.

TABLE 3 - 34.

THE HARDENING OF TARS IN THE KLERKSDORP-WOLMARANSSTAD EXPERIMENT

Sect. No.	Tar type	Change in Evt (°C)			
		In service 1 year	In service 2 years	AWT*	
14	Lurgi high-volatile	16,4	22,8	38,1+	34,2++
20	Lurgi low-volatile	7,0	14,1	21,0+	22,4++
17	Coke-oven	9,9	14,6	24,8+	24,9++

* Accelerated Weathering Test, + Lower layer, ++ Upper layer

Figure 3 - 38 has been used to assess the minimum service life of double-seals where the tar is used in the upper as well as the lower layer. This prediction is partly based on performance studies of single-seals in which it was noted that distress (stone-loss and cracking) seldom occurs where the viscosity is below 85°C Evt. Extrapolation of the curves in Figure 3 - 38 shows that even if the present rate of hardening continues, this viscosity level will not be reached for a further three to four years. Thus a minimum service life of five years for double-surface treatments constructed entirely from

* From Table 3 - 33 the total binder application (i.e. binder application in upper layer and binder application in the lower layer of the three sections) is: section 14 - 2,39 l/m^2, section 20 - 2,38 l/m^2, section 17 2,26 l/m^2.

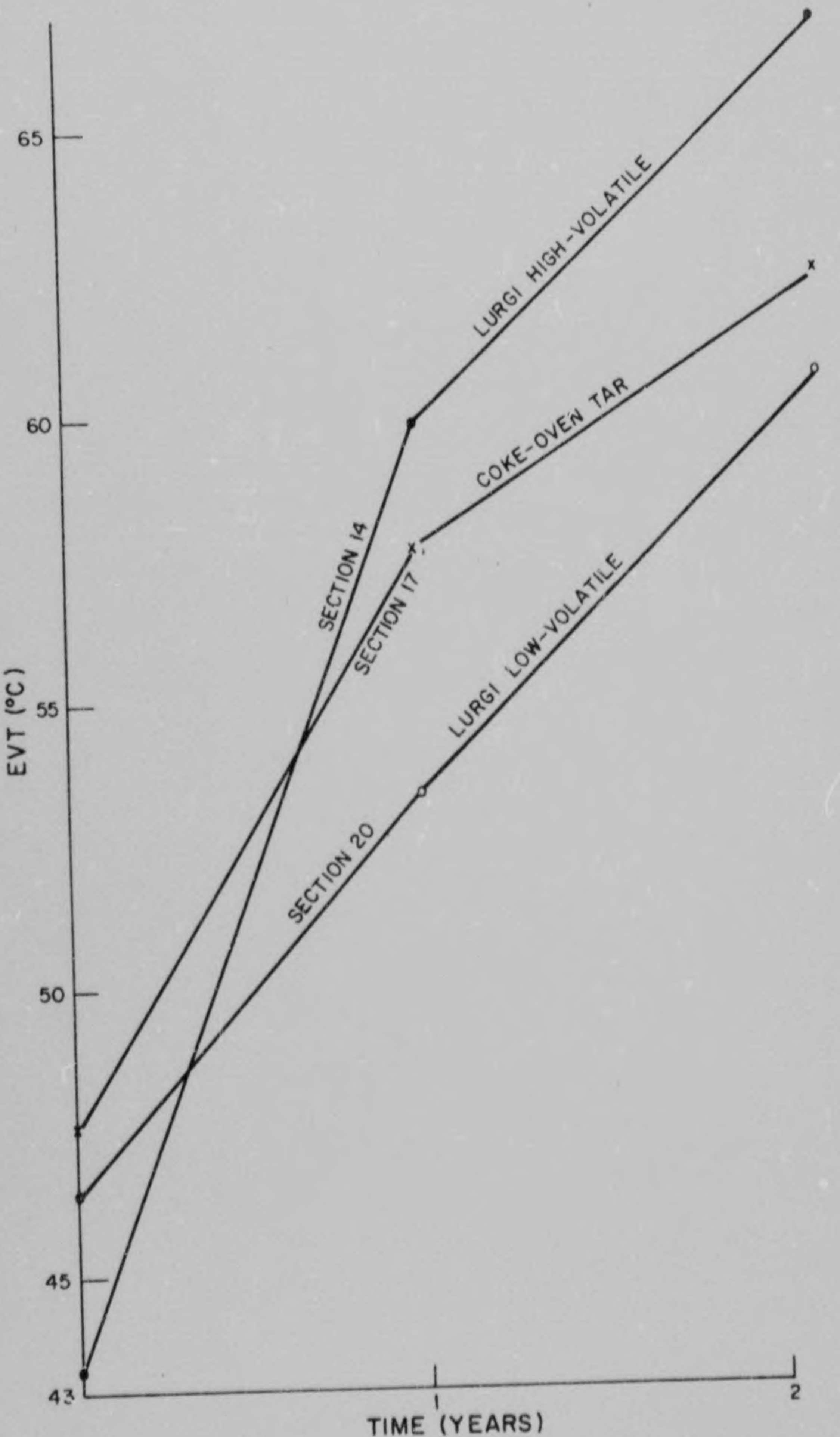

FIGURE 3-38

EFFECT OF SERVICE LIFE ON THE EVT OF TARS USED IN THE KLERKSDORP-WOLMARANSSTAD EXPERIMENT

Lurgi tar seems likely. It would be expected that double-surface treatments incorporating Lurgi tar in the lower layer and a more durable binder such as bitumen in the upper layer would have a useful service life considerably in excess of five years. These conclusions apply to double-seals constructed with 13,2 mm and 6,7 mm stone.

3.3.2.2 The Kempton Park trial

In addition to the above carefully controlled experiment the author observed the construction of a double-surface treatment in which the Lurgi tar used in upper and lower layers was covered with a bitumen emulsion fog-coat. The binder was of a high-volatile nature displaying an AWT result (Δ Evt = 37°C) similar to those of the high-volatile blends used in the Klerksdorp-Wolmaransstad experiment. In this case the hardening in a trial section in which no emulsion fog-coat was applied was greater than occurred in the experiment after a similar period. This is at least partly due to the thinner application of binder used in the Kempton Park trial (1,85 l/m^2 as compared to 2,39 l/m^2) in the experiment). It was impossible to correlate these results with the performance of the surfacing as the road was soon in a poor condition due to the collapse of the foundation. (The double-seal was laid directly on top of levelled and compacted in-situ material.).

3.3.3 Gas-works (vertical-retort) tar

In recent times by-product tar from South Africa's three gas-works has not been used to any great extent in conventional road making or maintenance processes though small quantities of crude tars are used from time to time as basecourse primes. However, in view of the constitution of these tars and the promising performance of Lurgi tars in the lower layers of multiple seals, it seems likely that low-volatile grades of vertical-retort tar would be equally satisfactory in these layers or in any construction where weathering of the tar can be prevented.

This could be the subject of future practical investigations.

3.3.4 Summary of practical recommendations.

The results of the work described in this Chapter have shown that unmodified tars are adequate for constructions in which they may be used in lower layers and so prevented from weathering.

Coke-oven tars have performed well in the following situations:

(i) The lower layers of multiple-surface treatments

(ii) Single-surface treatments overlaid by a bitumen mastic (Cape-seal) or a bitumen emulsion slurry.

(iii) Double sand-seals. Where tar was used in both layers a service life of four to six years was obtained.

Lurgi gasification tar is also recommended for the lower layers of multiple-seals, It may be used in upper and lower layers where a service life of five years is adequate.

It is suggested that refined vertical-retort tars from conventional gas-works processes should be employed in the under layers of multiple seals on a trial basis.

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PART 4

Tar binders in mixtures for basecourses and surface courses

INDEX TO PART 4

INTRODUCTION TO PART 4

The greatest proportion of binder used by the road industry goes into premixed bituminous bound mixtures for pavement layers. Though a number of different pavement layers may be distinguished, in this study they are considered to be either lower pavement layers, referred to as basecourses, or surface or wearing course layers.

It is commonly believed that in South Africa tar-bound mixes have not performed satisfactorily in surface layers and it is assumed that this is due to rapid weathering of the tar. As a result earlier research by the National Institute for Transport and Road Research (NITRR) was concentrated on the use of tar in basecourse layers. In 1965 tar basecourse sections were incorporated in an experiment at the Institute's test track (Marais, 1967) and in 1966 in co-operation with the Johannesburg City Council, experimental tar basecourses were constructed on Main Road, Newlands, Johannesburg, (Ellis, 1967).

In view of the more recent improvements in the durability of locally produced tars, whose development is described in Part 2, fresh interest has been expressed in evaluating these tars in mixes used in surface layers. Previously a guide to the use of tar-bound mixes has been prepared by Freeme (1974a).

The purpose of the investigations described in this section was to evaluate tar-bound mixes in surface and basecourse layers by laboratory and field experiments and in particular to determine whether the more durable tars described in Part 2 and 3 could be used to replace bitumen in surface courses.

4.1 PROPERTIES OF TAR-BOUND MIXTURES

Resumé

Mechanical tests show that tar-bound mixes are stiffer than bitumen-bound mixes and are suitable for basecourse layers. The indirect tensile strength of a semi-gap-graded mix was superior to that of a continuously graded mix. The latter type has performed will in an experimental section on a heavily trafficked road.

Elastic modulus measurements suggest that at high strain levels, such as may occur in surface layers, tar-bound mixes may have lower fatigue resistance than bitumen-bound mixes. However, in sections of experimental surfacings in which low strain levels occur, due to stiff base layers, the fatigue resistance may be adequate. In the latter surfacings the weathering of the binder and changes in mix stiffness have been monitored over a two-year period.

Mixes prepared with PVC/tar should be more durable than bitumen or unmodified tar-bound mixes in areas where heavy loads and spillage of petroleum products occur. However, apart from the increase in stability resulting from the increase in binder viscosity the PVC has no effect (with up to 5 per cent PVC in the tar) on the stability characteristics of mixes. In such cases the PVC/tar binder should be pre-prepared and deleterious effects may result if it is attempted to add the polymer via the fine aggregate fraction

It is well known that the optimum design of a mix depends upon the purpose for which it is required. In basecourses the object is to provide a stable layer for the distribution of traffic loads. For surfacings more stringent requirements are necessary to give flexibility, durability, stability, impermeability, skid resistance and smoothness of ride.

In Part 2, Chapter 4, it was mentioned that the behaviour of road binders may be expressed over the whole range of practical conditions by the ratio of stress/strain for a particular temperature and time of loading, as long as stress and strain are linearly related. This stiffness modulus is analogous to the modulus of elasticity.

$$S_{T,t} = \frac{\sigma}{\varepsilon t} \quad \text{(where } \sigma = \text{stress, } \varepsilon = \text{strain,}$$
$$T = \text{temperature and } t = \text{time of loading).}$$

The stiffness modulus can also be used to express the mechanical properties of binder-stone mixtures (Van der Poel, 1954) and the stiffness modulus of mixes may be related to the stiffness of the binder component (Heukelom, 1966). Other factors will affect the mix stiffness such as stone grading and voids content. Curves relating bitumen stiffness and mix stiffness are shown in Figure 4 - 1 and plots of tensile strength of bitumen versus stiffness of mixes of different types have a similar shape. It has been suggested (Heukelom, 1966) that the influence of the stone in a mix is constant for any particular mix type irrespective of temperature or loading time and could be expressed in terms of a mix factor. A relationship has been described by Marek and Dempsey (1972):

$$S_{mix} = \left[1 + \frac{2,5}{n} \quad \frac{C_v}{1-C_v}\right]^n S_{bit.}$$

where S_{mix} = mix stiff, kg/cm^2

S_{bit} = bitumen stiffness at the desired temperature and time of loading as determined from a nomograph, kg/cm^2

$$n = 0,83 \log \frac{400\ 000}{S_{bit}}$$

C_v = volume concentration of stone in the mix

$$= \frac{\text{stone volume}}{\text{volume (stone + bitumen)}}$$

Fracture of mixes will occur in the binder films, and fatigue measurements (the number of repeated load applications to induce cracking) show that the strain level in the binder is related to the fatigue life (Monismith, 1966). Bituminous (tar or bitumen) bound materials may fail structurally either through fatigue or deformation and both modes are traffic-load-associated. Fatigue failures are associated with rapid rates of loading while deformation failures are associated with slow rates of loading. It should also be mentioned that both failure modes may arise as a result of deformation in lower non-bituminous layers of the road structure.

4.1.1 Tar mixes as basecourses

After the second world war tar-bound macadams were used in basecourses in Britain (Addis, 1969) as an alternative to hand-pitching crushed rock and gravel. Low-viscosity tars (34 - 38 ^{o}C EVT)

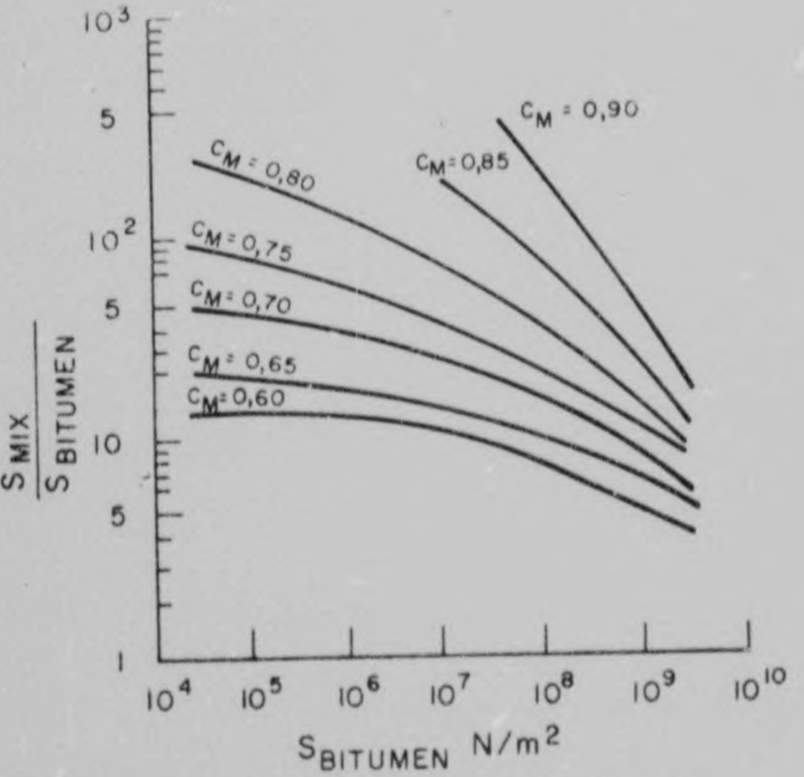

FIGURE 4-1

RELATIONSHIP BETWEEN THE STIFFNESS MODULUS OF MIXES AND STIFFNESS MODULUS OF THE COMPONENT BITUMEN (HEUKELOM 1966)

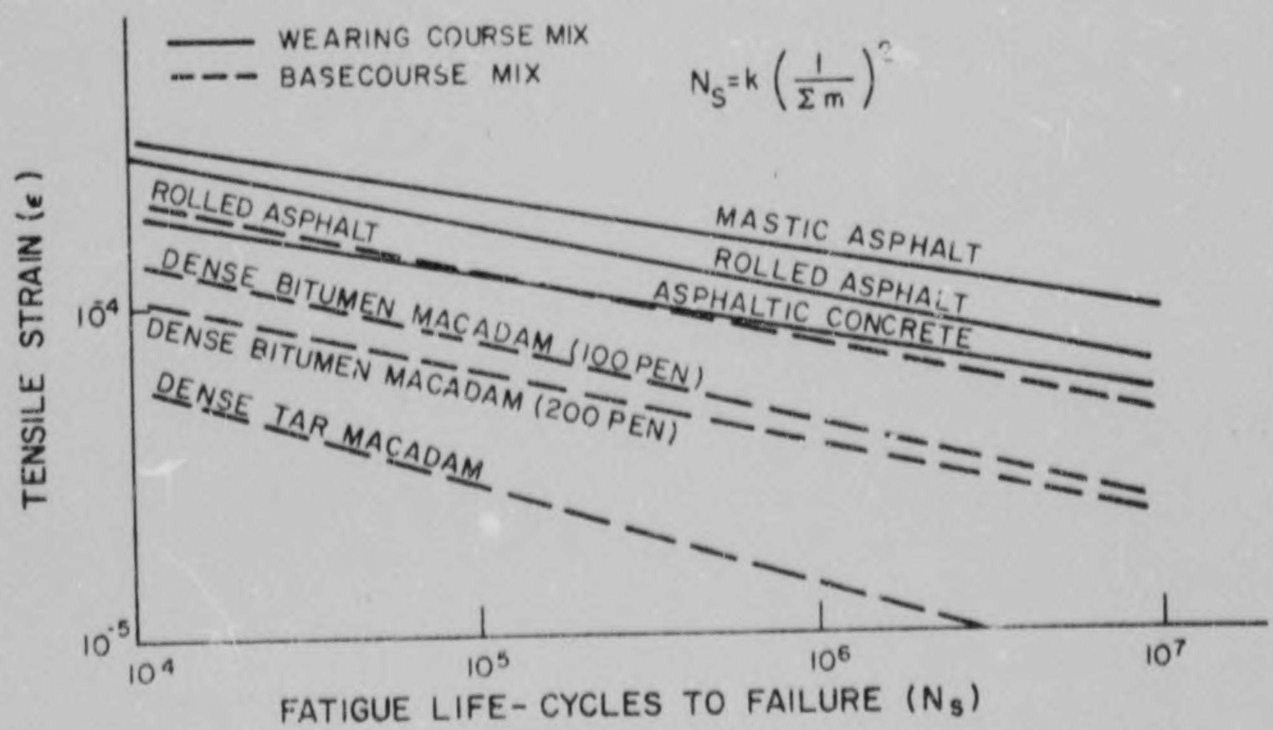

FIGURE 4 - 2

TYPICAL FATIGUE VS TENSILE STRAIN LINES FOR VARIOUS WEARING AND BASECOURSE MIXES (FROM PELL AND BROWN 1972) with large-sized aggregates performed well but the open texture of the mixes permitted ingress of moisture which led to stripping and loss of stability. As a result dense mixes have been developed and these have been credited with superior load-spreading properties, (Addis, 1969).

Freeme (1974a) has pointed out that although strength and stiffness are the main requirements of a basecourse, fatigue resistance may also be critical depending upon the properties of the underlying layers. At present there is a shortage of published information on the effects of repeated load applications on tar-bound mixtures although Pell and Brown, (1972) and Brown and Pell (1974) reported that at equivalent strain levels the number of load applications to failure for a particular "dense tar macadam" was considerably less than that determined on a number of bitumen-bound mixes, as shown in Figure 4 - 2.

Local experience (Blight, 1973) has been that load-associated permanent deformation is not a general problem on South Africa's main roads but it has been found overseas that tar-bound basecourses are susceptible to deformation if low-viscosity tars are used. In an RRL experiment in England (Addis, 1969) gravel tar macadam sections employing a 50°C Evt tar underwent considerable permanent deformation while little deformation occurred in comparable asphalt and lean concrete sections. The rutting was largely independent of the depth of the base and was attributed to shear in the upper part of the base layer, which probably occurred during a period of very hot weather that followed the construction. In a series of follow-up laboratory wheel tracking tests it was confirmed that the tar macadam mixes had a low resistance to plastic deformation*. Although tar macadams made with mixed gritstone gravel gave much more stable mixtures than those made with quartzite gravel it was found that the binder viscosity made a major contribution to the stability of the coated macadams.

In view of the load bearing requirements of basecourses it may be considered that creep and deformation can be minimised through the use of continuously graded mixes rather than the gap-graded type. Continuously graded mixes derive much of their density and stability from the high interparticle friction and the binder viscosity plays a lesser role than is the case in gap-graded mixes. However, in a

*For mixes to be used in surface layers on heavily trafficked roads in Britain a rate of "tracking" in the wheel tracking test of less than 4,5 mm per hour at 45°C is considered necessary (Please and Meyer,1968). For bases a maximum tracking rate of 37,5 mm/hour is considered adequate.

local investiaqion described by Marais (1967) a continuously graded mix bound with a 50 - 55°C Evt coke-oven tar deformed badly after a short period of trafficking. The stone grading used was of the continuously graded type specified in clause 810 of the Ministry of (British) Transport Specifications for Road and Bridge Works) (Ministry of Transport , 1969) In 1966 the National Institute for Road Research, in conjunction with the Johannesburg City Council, constructed an experimental pavement on Main Road, Newlands, Johannesburg, in which the object was to compare the performance of tar-bound, cement treated and unbound crusher-run basecourse sections. (A schematic representation of the sections is shown in Appendix K and full construction details are given in a report by Ellis, 1967)

In this work a high-viscosity (60 - 65°C Evt) coke-oven tar was used and the deformation of the sections has been estimated from levels measurements. The deformation after 10 years in service is shown in Figure 4 - 3. On all sections the deformation is low; the maximum (4,5 mm) being recorded on the cement-treated basecourse section. The deformation recorded on the tar-bound basecourse section was much less than that recorded in the TRRL experiments (Hinkley,1970). A comparison of the gradings used in five TRRL experiments with the grading (continuously graded MOT type) used in the Newlands experiment is given in Figure 4 - 4.

Deflection measurements (Benkelman beam) have been taken at regular intervals in the period following construction. These results are shown in Figure 4 - 5., and indicate the sound condition of all three types of basecourse after 8 years. In the case of the tar-bound basecourse section there has been an overall trend for the deflection to decrease with time.

4.1.2 <u>Tar mixes as surface courses</u>

It has previously been mentioned that the durability of the binder is of overriding importance as regards the service performance of surface mixes (Jamieson and Hattingh, 1970). However, it has also been shown that the durability of asphalt mixes can be improved and the hardening of the binder reduced by reducing the voids content in the mix, (Sisko and Brunstrun, 1969). It follows that the air permeability of tar-bound surface mixes will be of particular importance in view of the susceptibility of tar to weathering.

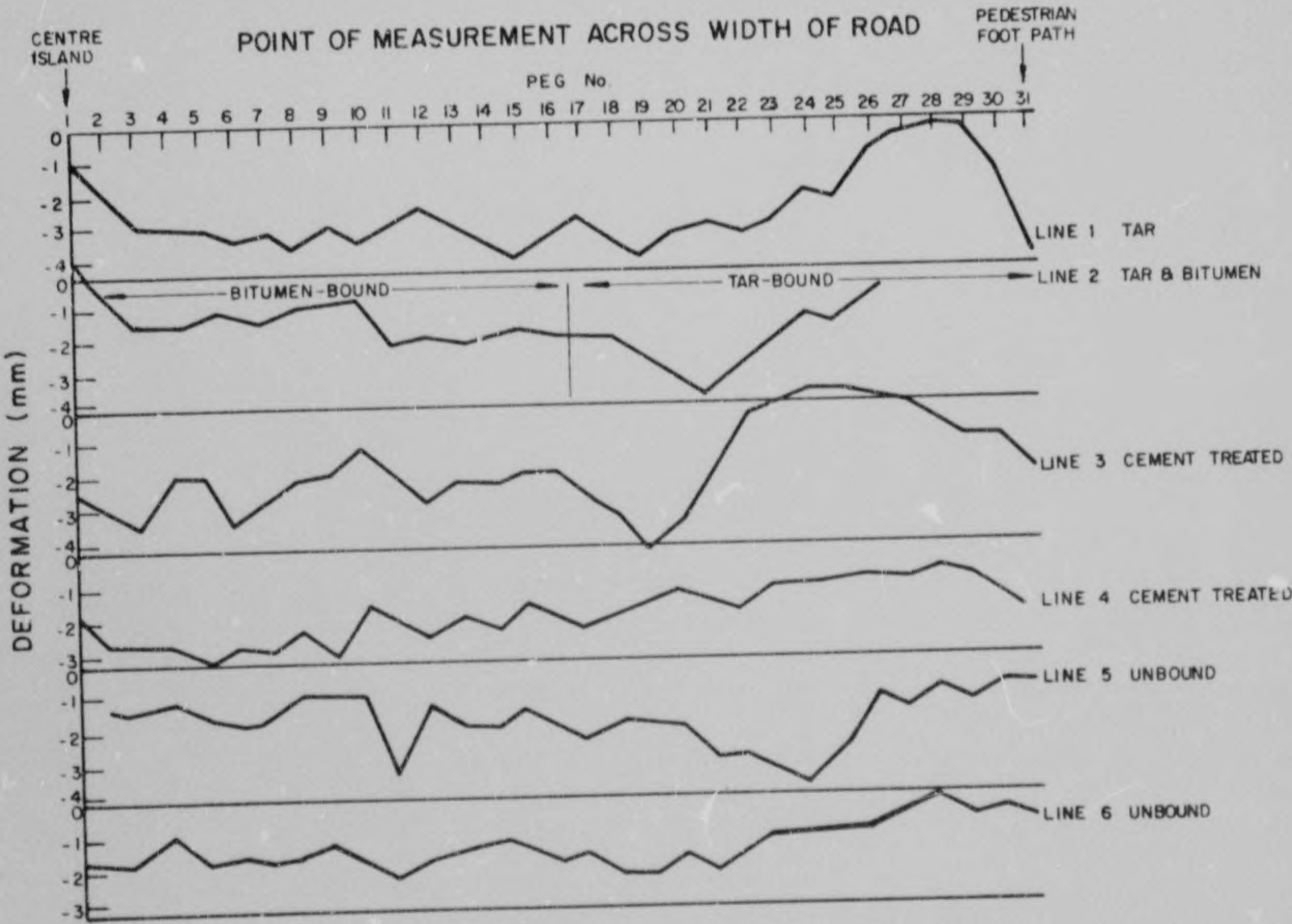

FIGURE 4-3

DEFORMATION OF BASECOURSES IN THE NEWLANDS EXPERIMENT ASSESSED BY LEVELS MEASUREMENTS (TAKEN IN 1973)

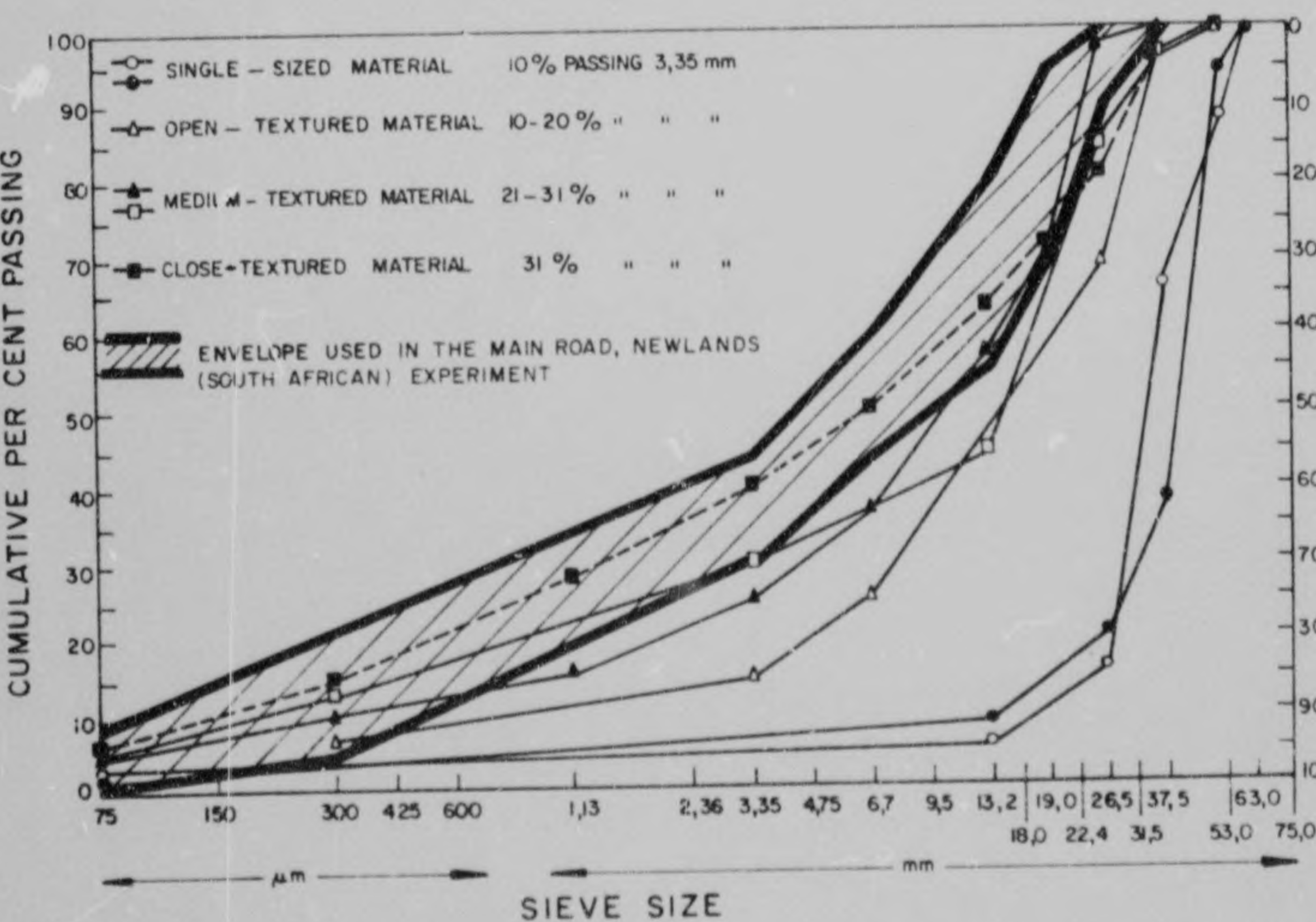

FIGURE 4-4

VARIOUS GRADINGS OF TARMACADAM ROAD BASE MATERIALS USED IN TRRL EXPERIMENTS (FROM HINKLEY'S DATA, 1970) AND THE ENVELOPE USED IN THE SOUTH AFRICAN EXPERIMENT.

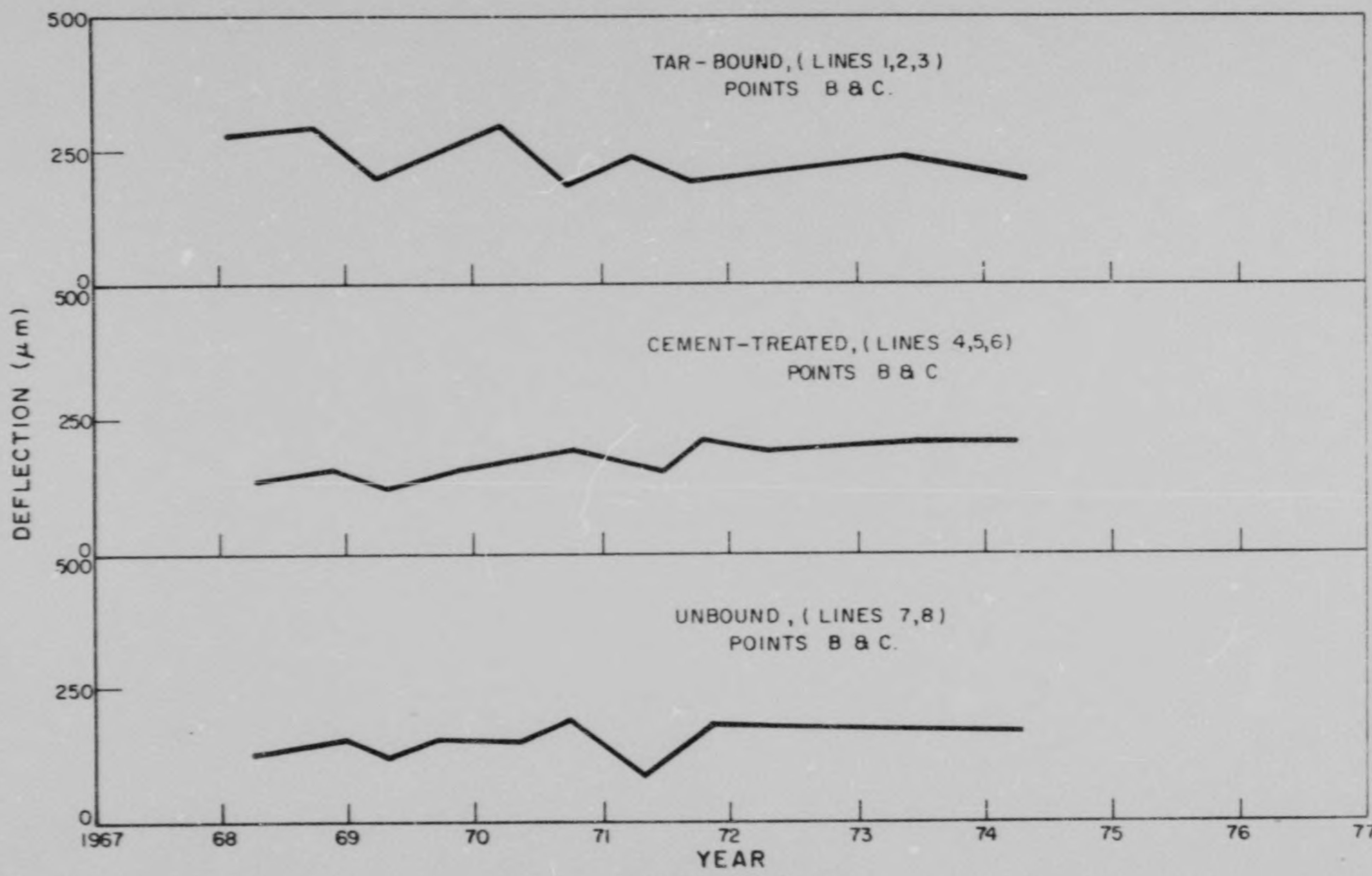

FIGURE 4-5

ANNUAL AVERAGE DEFLECTIONS AT POINTS B & C ON THE VARIOUS BASECOURSE SECTIONS OF THE NEWLANDS EXPERIMENT.

Because of the need to obtain high density on construction the use of gap-graded aggregates will be advantageous, as these have good compaction characteristics (Department of Scientific and Industrial Research, 1962a). With this type of grading there is some danger of instability with the low-viscosity tars that are desirable for surface layers and for this reason Freeme (1974a) suggested a compromise in a high-density semi-gap-graded tar-bound mix which had been used previously by the roads department of the Natal Provincial Administration. A typical grading envelope is given in Figure 4 - 6.

A dense tar surfacing mix (Department of Scientific and Industrial Research, 1962b) was developed in the United Kingdom in world war two at a time when bitumen was in short supply. This type of surfacing is still in use in that country and has found a new outlet more recently for car-parks, container terminals and aircraft standing-bays. The mix is similar in principle to the semi-gap-graded mix in that the aggregate is composed of stone, sand and filler fractions; in the development of the mix a study was made of the separate properties of the filler/tar, sand/filler/tar and stone/sand/filler/tar mixtures (Lee and Rigden, 1945). It was shown that the nature of the filler was critical, its purpose in the mix being to increase the effective viscosity of the tar. The filler content also affects the calculated average film thickness parameter and while Duthie (1975) has suggested that filler/binder ratios of 2/1* may be beneficial in reducing voids and optimum binder content and increasing density and stability, in the case of tar mixes the critical upper limit for filler/tar ratios may be much lower (even allowing for the difference in density between tar and bitumen) and minimum film thicknesses may have to be higher. This may be necessary in view of the greater stiffness and susceptibility to increase in stiffness on weathering (Daines, 1972) of tar as compared to bitumen.

4.1.3 Optimisation of mix variables in tar surfacing mixes

In designing tar-bound mixes, as with all bituminous mixes, an optimum balance of mix constituents is sought to get the best fit of all the mix criteria. As previously explained the cost factor is of particular importance. In a particular example a tar-bound mix overlay was

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* Latest recommendations (National Institute for Transport and Road Research, 1976) state that the filler/bitumen ratio should be between 1,0 and 1,5

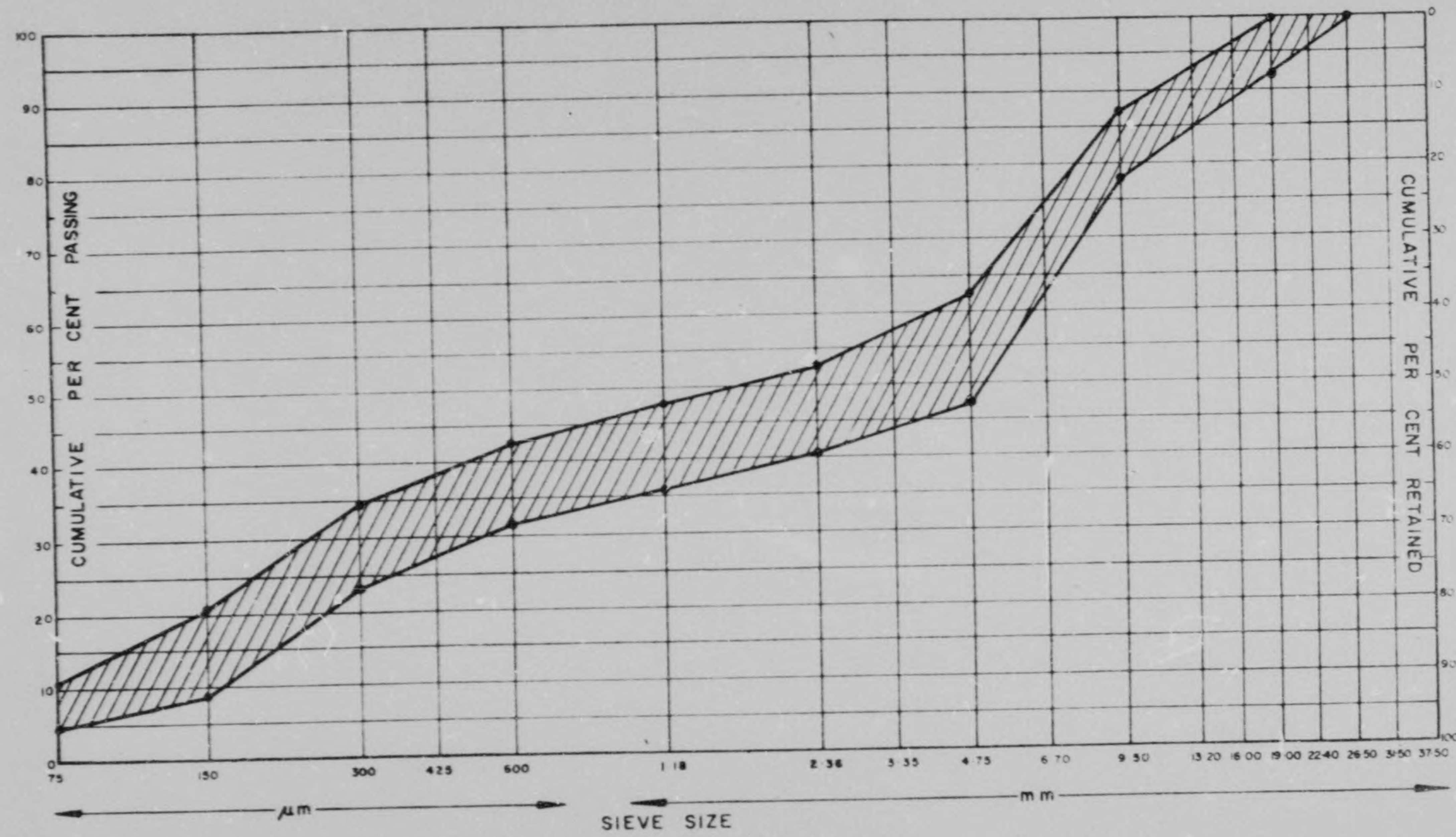

FIGURE 4-6

AGGREGATE COMPOSITION OF THE SEMI-GAP-GRADED MIX.

designed for a particular case where it was necessary to make an appreciable saving in construction costs compared to the alternative asphalt mix. For this reason it was decided that the tar content must not exceed 7 per cent by mass of the mix.

A semi-gap-graded mix was considered appropriate and to minimise the air permeability it was hoped to obtain voids (Marshall test specimens) in the 2 - 6 per cent range and also satisfy the other mix criteria which are based on the Marshall method. Criteria for gap-graded and semi-gap-graded asphalt mixes are given in " Technical Recommendations for Highways(TRH) No.8 " (National Institute for Transport and Road Research, 1976) as shown in Table 4 - 1.

TABLE 4 - 1

MARSHALL DESIGN CRITERIA FOR GAP-GRADED AND SEMI-GAP-GRADED ASPHALT (FROM TRH 8 NATIONAL INSTITUTE FOR TRANSPORT AND ROAD RESEARCH,1976)

No. of compaction blows each end of specimen	75	
	Min	Max
Stability (at 60°C) (kN)	3,0	12,5
Flow (mm)	2,0	6,0
Stability/flow (kN/mm)	1,5	-
Voids (per cent)	2,0	12,0
Air permeability (cm^2)	-	1×10^{-8}
Film thickness (μm)	5,0	-
Immersion index (%)	75	-
Filler/bitumen ratio	1,0	1,5

In order to satisfy the minimum filler content requirements the sand fraction consisted of a local river sand blended with crusher fines in proportions of 40 to 60.

A full Marshall design procedure was carried out on this mix and values at 6 and 7 per cent tar content together with criteria recommended for tar mixes are given in Table 4 - 2.

TABLE 4 - 2

MARSHALL PROPERTIES OF A SEMI-GAP-GRADED TAR MIX AT THE 6 PER CENT AND 7 PER CENT TAR-CONTENT LEVEL

Mix property	6 per cent	7 per cent	Suggested limits min.	max.
Stability at 60 °C (kN)	4,5	6,0	3,5	8,0
Flow at 60 °C (mm)	1,6	1,4	2,0	5,0
Stability/flow	2,8	4,2	1,5	-
Air voids (per cent)	8,3	6,2	2,0	6,0
Film thickness (μm)	5,0	6,0	5,0	-

The mix containing six per cent tar fails the requirements of low air voids and the film thickness is on the minimum limit. Although the seven per cent tar content mix complies better with the design criteria, the voids are still high and as in this case the tender document allowed in-situ densities to be as low as 92 per cent of the theoretical maximum this could mean that the initial pavement voids of this mix could be as high as 9,1 per cent. (The stability, density and voids measurements are given in full in Appendix M). As a result it was considered necessary to change the mix slightly to reduce the Marshall voids to below 5 per cent.

Two methods of reducing the voids were investigated:

(1) Adding more filler to the 60/40 crusher fines/natural sand blend,

(2) Increasing the proportion of crusher sand in the fine aggregate fraction.

Method 1 Sufficient cement filler was added to give a total filler/tar mass ratio of 1,64/1. (This is the approximate volumetric equivalent of the 2/1 filler/bitumen ratio recommended by Duthie, 1975).

Method 2 The fine aggregate proportions were changed from 60/40 to 75/25 (crusher fines/natural sand) without changing the proportion of coarse to fine aggregate.

Marshall tests were carried out on these mixes and results of tests on specimens ranging in tar content from five to eight per cent are given in Figure 4 - 7.

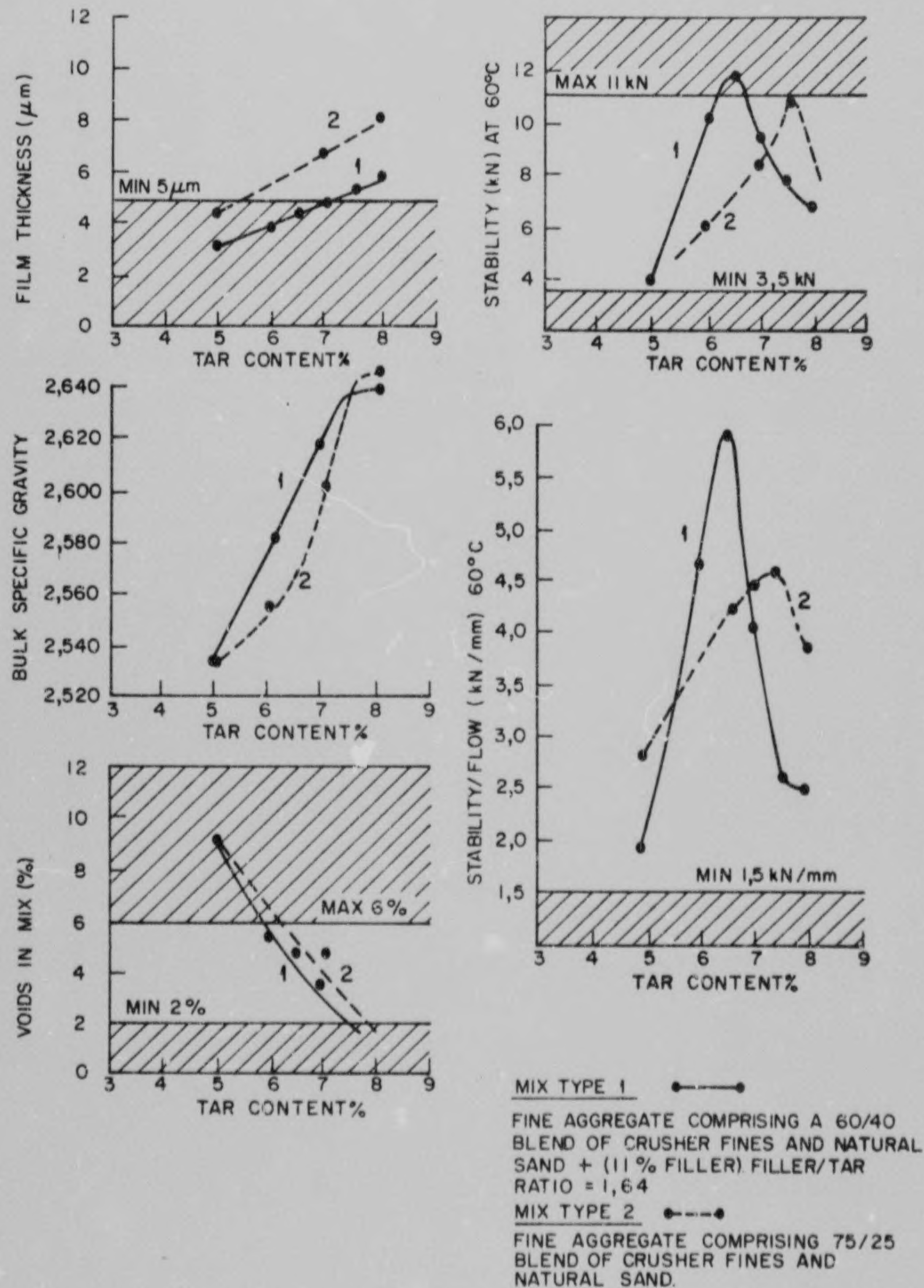

FIGURE 4 -7

MARSHALL TEST VALUES FOR TWO TYPES OF SEMI-GAP - GRADED TAR MIXES

At the 7 per cent tar content level both methods have achieved the object of reducing the voids to well within the optimum range. However, the second method is preferable to the first in view of the greater film thickness and the fact that at the seven per cent binder content level the stability versus binder content and stability / flow curves are still rising whereas with method 1 the curves have passed the maximum .

Air permeability measurements were carried out on these Marshall specimens using an apparatus (Asphalt Paving Meter Model A P-400A) first developed by Kari and Santucci, (1963). These results are given in Figure 4 - 8 and show that at the seven per cent tar content level both mixes are very impermeable.

4.1.4 Tensile strength of tar mixes

The tensile strength of a pavement layer has a significant effect upon its performance. Moore and Kennedy (1972) developed a repeated load test (1 cycle per second) using the principle of the indirect tensile test by means of which they studied correlations between fatigue life and other properties such as the stress-strength ratio* and the elastic modulus**. According to their data the fatigue life of a mix under conditions of repeated applications of a constant stress increases with increasing tensile strength, as determined by the static method.

The indirect tensile test or Brazilian test (Hudson and Kennedy, 1968) involves loading a cylindrical specimen with compressive loads which act along two opposing generators. This loading configuration results in a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane. When this tensile stress exceeds the tensile strength of the material, failure occurs, usually by splitting along the loaded plane, and the tensile strength is related to the maximum applied load. The test specimens used are compacted Marshall briquettes and the test is carried out in the Marshall test head. Aluminium blocks 25,4 mm wide with a radius of curvature of 50,8 mm are used for the application of the load and rate of loading is 50,8 mm per minute.

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* According to Moore and Kennedy $\log N_F = 9{,}793 - 4{,}68 \log \frac{\sigma_T}{S_T}$ $(R^2 = 0{,}76)$

where N_F = number of load applications to failure σ_T = indirect tensile stress (p.s.i.) and S_T = indirect tensile strength obtained from the static test.

** $\log N_F = 1{,}185 + 0{,}611E$)at 32 PSI stress level where E = elastic modulus.

+ At 25°C a 60/70 Pen. Bitumen has a similar viscosity to a 60-65°C Evt tar.

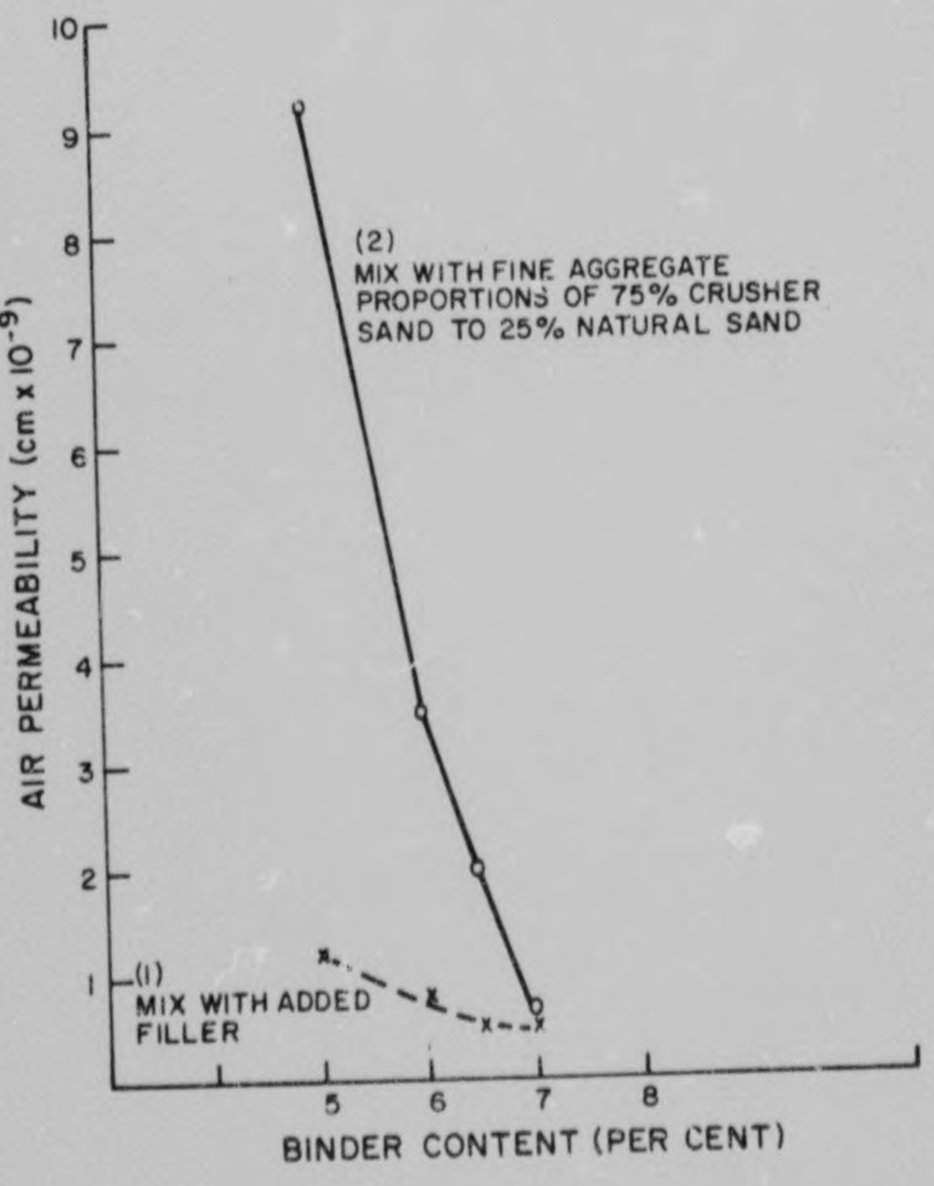

FIGURE 4-8

AIR PERMEABILITY OF TWO TYPES OF SEMI-GAP-GRADED TAR MIXES.

Static indirect tensile tests have been carried out on continuously graded mixes (as recommended for basecourses) and on semi-gap-graded mixes (as suggested for surface mixes). Four types of binder were used with each aggregate grading. These were:

(i) 60-65°C Evt PVC unmodified coke-oven tar

(ii) 60-65°C Evt unmodified coke-oven tar

(iii) 45-50°C Evt unmodified coke-oven tar

(iv) 60/70 Pen. bitumen (Viscosity at 25°C equal to 60-65°C Evt tar)

Indirect tensile strengths were determined at 20, 30 and 40°C and each value obtained was the mean of three determinations. The results given by mixes with about optimum binder content which corresponds to an equivalent volume of each type of binder, (i.e. 6 per cent by mass tar mixes and 5 per cent by mass bitumen mixes) are given in Figure 4 - 9. (Full results are given in Appendix M, Tables 1 to 111.)

With each type of binder used the semi-gap-grading of the aggregate gave higher indirect tensile strengths than the continuous aggregate grading. Thus, because of the Moore-Kennedy correlation between fatigue life and indirect tensile strength the fatigue life of the semi-gap-graded mixes would be expected to be superior to that of the continuously graded mixes under constant stress conditions. It is well recognised that in basecourses supporting a significant proportion of the applied load, or pavement thickness greater than 150 mm, the load application corresponds approximately to repeated applications of a constant stress (Monismith, 1966).

The results of this study also suggest that if fatigue life is the most important parameter for basecourses then tar may be a more suitable binder than bitumen for basecourse mixes. Plots of indirect tensile strength vs. temperature for the continuously graded mixes are shown in Figure 4 - 10 and a similar plot for semi-gap-graded mixes is shown in Figure 4 - 11. The tar mixes exhibit a greater change in indirect tensile strength with change in temperature than bitumen-bound mixes and this may be related to the greater temperature susceptibility of the tars. The tar mixes have greatest strength at low temperatures and this is further increased by the use of high-viscosity tar. The results of the indirect tensile tests imply that tar-bound mixes will be stiffer than bitumen-bound mixes (where the bitumen is of similar viscosity at 25°C) which will lead to lower levels of strain and hence longer fatigue lives under the constant stress conditions occurring in basecourse layers.