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A FULL-SCALE EXPERIMENT TO EXAMINE IMPROVED BITUMINOUS SURFACINGS FOR HEAVILY TRAFFICKED MOTORWAYS - M1, 1973

by

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ABSTRACT

On certain heavily-trafficked motorways some deterioration of the surfacing, particularly in the nearside lane, has occurred as a result of the continual increase in the number of vehicles and of the average axle load. This Report describes the laying of five experimental surfacings on the M1 motorway near Watford Gap. The surfacings comprise a pervious macadam designed to reduce spray from vehicles when the road is wet and four rolled asphalts with an improved resistance to deformation. All the surfacings are designed to have a high resistance to skidding. Two control sections of rolled asphalt have been included for comparison. The effect of build-up of black deposits which sometimes occur after long dry spells of weather will be observed.

1. INTRODUCTION

The continual growth of traffic on certain motorways including the M1 has resulted in some deterioration of the surfacing, particularly in the nearside lane. The increase in average axle load of commercial vehicles has in some areas produced tracking or transverse deformation of the wearing course and the increase in total number has led to a reduction in the resistance to skidding. In hot dry weather black deposits are tending to form; these consist of a mixture of about 30 per cent rubber, 40 per cent mineral oil and 30 per cent of mineral matter, and render the skidding problem still more severe. Spray from vehicles on a wet road also presents a hazard to drivers.

This Report describes the laying of experimental rolled asphalts designed to have an improved resistance to deformation and an improved resistance to skidding, and of a pervious surfacing designed to reduce the spray from vehicles when the road is wet. The effect of these surfacings on the build-up of black deposits will be observed.

In addition cores were inserted in the wearing course to study the effect of macro-texture and type of binder on the deposition of black deposits; removable plates, surface-dressed with epoxy resin and a range of aggregates, were inserted to examine the effect of polished stone value of chippings and to enable the amount of black deposit to be determined. This investigation will be reported separately.

2. SITE OF THE EXPERIMENT

The site of the experimental sections is the southbound carriageway of the M1 motorway about 1 km south of the Watford Gap Service Area starting at Marker Post 119/8 and ending at Marker Post 118/2, ie the site is 1600 m long (Fig 1).

The traffic on the motorway (both directions) on an average August day in 1972 is given by the DOE General Traffic Census as 50,313 vehicles including 13,038 commercial vehicles.

In June 1974 a 16-hour visual count adjusted to 24 hours showed that the total number of vehicles was 46,800 of which 19,500 were commercial vehicles.

On the southbound carriageway there was a total of 24,000 vehicles of which 11,000 were commercial; 7,000 of these commercial vehicles trafficked all the experimental sections in the nearside lane, 3,900 the centre lane and 100 the offside lane.

3. SCOPE OF THE EXPERIMENT

One method of increasing the resistance to deformation of rolled-asphalt wearing-course is to increase the stone content. In order to obtain a sufficiently rough texture for a good resistance to skidding for high-speed traffic, coated chippings applied at a heavy rate to the surface must be able to penetrate the surface of the material. The maximum stone content that can be used in the body of the mix for this to occur is 45 per cent but observations of earlier work, including the full-scale experiment on A30 at Blackbushe[1], suggest that, at this stone content, the rate of spread of chippings should be slightly reduced and their size restricted to 14 mm. Because of the reduction in the number of chippings some of the coarse aggregate in the mix is exposed after several years of service. For motorways, therefore, where it is important to maintain a good resistance to skidding, it is necessary to choose a non-polishing stone for this coarse aggregate. In order to obtain a direct comparison between all the sections of rolled asphalt the same coarse aggregate (Bayston Hill Quarry, PSV 65) was used in this work.

Pitch-bitumen is most commonly used as the binder for rolled-asphalt wearing-courses because of its suitable weathering characteristics which ensure a continuing high texture depth. However this type of binder has a higher temperature susceptibility of viscosity than most bitumens of the same penetration grade and it can therefore be softer at high road temperatures; to some extent this is offset by the marked, but variable, amount of hardening that can occur during mixing and laying. Some bitumens have been produced which have a relatively low temperature susceptibility of viscosity, ie, a high Penetration Index and it has been found that these binders can have weathering characteristics as good as or better than pitch-bitumen. Two sections of rolled asphalt have therefore been laid, one with 30 per cent of coarse aggregate and one with 45 per cent, and both incorporating a special bitumen; these are compared with two similar asphalts but containing pitch-bitumen binder.

Following a long, dry spell of weather in the summer of 1972, black deposits formed on the surfacings of M1 and M6 motorways where the amount of commercial traffic was particularly heavy. Analyses showed that the deposit consisted of a mixture of 40-46 per cent oil, 26-36 per cent tyre-rubber compound and 24-30 per cent of mineral matter (dust). The effect of the deposit on the resistance to skidding at 50 km/h as measured by SCRIM is at present under investigation on the existing traffic-polished surfacing, but, in order to provide more information on this phenomenon on surfacings less liable to polish than are provided by present specifications, the experimental sections of rolled asphalt incorporate chippings with a high resistance to polishing (14 mm Craig-yr-Hesg, PSV 67). For comparison two control sections were included, one with 14 mm Bardon Hill chippings (PSV 59) for direct comparison with the other experimental sections and the other with 20 mm Bardon Hill chippings which are more usually employed.

The surface texture of a surfacing may also affect the amount of material deposited and, in order to provide information on this, a pervious macadam has been included in the experimental materials. As this material is structurally weaker than rolled asphalt it has been superimposed on the existing rolled-asphalt wearing-course. At other sites[2,3] it has been found that pervious macadam substantially reduces splash from vehicles, thus making overtaking in wet conditions less hazardous. This material was laid, therefore, across all three lanes of the carriageway and in order to avoid changes in level it was also continued across the hard shoulder. The aggregate used in the mix was Craig-yr-Hesg to correspond with the chippings in the asphalts.

Seven sections of material were laid (Fig 2) including two of rolled-asphalt wearing-courses that were non-experimental; these were used as controls. For these two sections and for the four experimental rolled-asphalt wearing-courses the nearside lane of the southbound carriageway was cold-planed to a depth of 40 mm and the surfacing replaced by the materials under investigation. The seventh section, the pervious macadam, was superimposed on the existing carriageway across the three lanes and the hard shoulder. Ramps of rolled asphalt 20 m long were laid to adjust the changes in level. The layout of the sections is given in Fig 2.

To produce rolled asphalt mixtures with a high resistance to deformation the Marshall Test was used to select a sand giving a high stability value to the asphalt mortar. The results of the design procedure (subsequently published in BS594: 1973) are given in Table 1 where it can be seen that a stability value of 5900 N was obtained for the sand/filler/binder system with a flow value of 4.8 mm. The design binder contents for 30 and 45 per cent of coarse aggregate are only 0.1 per cent greater than the mid-Schedule 1 values (7.9 and 6.7 per cent respectively) given in BS594: 1961.

TABLE 1

Results of BS594: 1973 design procedure

Optimum binder content for sand/filler/binder mixtures - per cent				Design binder content for 30 per cent stone - per cent	Design binder content for 45 per cent stone - per cent
Maximum stability	Maximum mix density	Maximum aggregate density	Mean		
11.0	11.0	9.5	10.5	8.0	6.8

Maximum stability - Newtons	Maximum mix density - g/ml	Maximum aggregate density - g/ml	Flow value - mm	Void content - per cent	Per cent voids filled with binder
5900	2.130	1.909	4.8	9.4	70.2

The specifications for the rolled asphalts and the pervious macadam are given below.

3.1 *Rolled-asphalt control (Section 1 (NX))*

Rolled asphalt to Schedule 1, BS 594:1961.

30 per cent of coarse aggregate from Bayston Hill Quarry (nominal maximum size 14 mm).

Pitch-bitumen binder to Clause 907S of DOE Technical Memorandum H10/71.

14 mm coated chippings from Bardon Hill Quarry (PSV 59).

3.2 *Rolled asphalt with high PSV chippings (Section 2)*

As Section 1 but with 14 mm coated chippings from Craig-yr-Hesg (PSV 67).

3.3 *Rolled asphalt with high stone-content (Section 3)*

As Section 2 but with 45 per cent of coarse aggregate.

3.4 *Rolled asphalt with special bitumen binder (Section 4)*

As Section 2 but with a special bitumen of high Penetration Index used in place of pitch-bitumen.

3.5 *Rolled asphalt with special bitumen and high stone-content (Section 5)*

As Section 4 but with 45 per cent of coarse aggregate.

3.6 *Rolled asphalt control (Section 6 (NX))*

As Section 1 but with 20 mm Bardon Hill chippings instead of 14 mm Bardon Hill chippings.

3.7 *Pervious surfacing (Section 7)*

Aggregate from Craig-yr-Hesg Quarry, Pontypridd, with a Flakiness Index less than or equal to 20.

Aggregate grading on analysis of the mixed material to Table 2.

TABLE 2

Grading of aggregate on analysis

Passing BS sieve	Per cent by weight
28 mm	100
20 mm	90-100
14 mm	50-80
6.3 mm	25-35
75 μm	3-6

Binder content: 4.0 - 4.4 per cent of 100 pen Middle East petroleum bitumen.

Filler: The filler was required to contain 2 per cent by weight of total aggregate of hydrated lime, at least 75 per cent of which should pass a 75 μm BS sieve.

4. MIXING AND LAYING

Cold-planing of the existing wearing course started on 17 September 1973 at the northern end of the site (Section 1NX, Marker Post 119/8) on the southbound carriageway about 1 km south of the Watford Gap Service Area. The rate of working was about 1000m^2/h with a cut 2 m wide to a nominal depth of 40 mm. Asphalt adjacent to the hard shoulder was planed first, followed by a second cut to remove the remainder of the material from the nearside lane. In order to reduce traffic delays to a minimum, the amount of material removed was restricted to that which could be resurfaced on the following day.

Mixing of the material for the control and experimental sections was started on 18 September at a commercial asphalt plant 45 km from the site. Table 3 shows that the mixing temperatures of the asphalts ranged from 155 to 163°C averaging 159°C. The delivery and rolling temperatures were within the specified ranges and averaged 151°C and 116°C respectively. Because of difficulties in maintaining an accurate cut of 40 mm the rate of spread of asphalt was variable and ranged from 85 to 116 kg/m^2 with an average of 98 kg/m^2 representing a mean thickness of 43 mm.

The specified rate of spread of 14 mm Bardon Hill chippings used on Section 1NX and the 14 mm Craig-yr-Hesg chippings used on experimental Sections 2, 3, 4 and 5 was 8.5 $\pm$ 1 kg/m^2. A rate of 8.2 kg/m^2 was achieved for the first non-experimental section and the rates ranged from 7.7 to 9.5 kg/m^2 for the four experimental sections, averaging 8.4 kg/m^2. For the second control section (Section 6NX) 20 mm coated chippings from Bardon Hill Quarry were used as being typical of normal motorway practice and the specified rate was 11 $\pm$ 1 kg/m^2. Because it was necessary to switch the asphalt plant to the production of the pervious macadam for Section 7 it was possible to lay only part of this control section (Section 6ANX 260 m long) with a similar asphalt to that used for the first control section; the second part (Section 6BNX 150 m long) was surfaced with asphalt containing different aggregates from another mixing plant. The rate of spread of chippings achieved for Section 6ANX was 10.3 kg/m^2 and, for Section 6BNX, 10.9 kg/m^2.

The laying of the pervious macadam started on 26 September (before the completion of Section 6NX) and the material was laid on top of the old surface to avoid weakening the structure. The material was laid across the hard shoulder and all three lanes of the carriageway. The macadam was laid in five strips, each about 3 m wide, to reduce traffic delays to a minimum; this meant that some of the longitudinal joints were in the wheel-tracks. Although no joint heater was used, immediate rolling of the joints while the material was hot produced moderately good joints with only a small loss of stone under traffic. To ensure good permeability rolling of the rest of the material was delayed until the temperature had dropped to 80°C.

Laying of this 270 m length of macadam was completed on 3 October and the 20 m long ramps of rolled asphalt which were required to adjust the change in level at each end of the section were completed on 5 October.

TABLE 3

Results of tests on materials and surfacing

Section No	Temperature °C			Rate of spread of surfacing kg/m^2	Rate of spread of chippings* (14 mm except where stated) kg/m^2	Texture depth - mm
	Mixing	Delivery	Rolling			
1 NX	155	144	124	97	8.2	1.98
2	158	155	115	85	9.5	2.44
3	162	153	111	88	8.4	1.87
4	161	157	121	93	7.8	1.63
5	163	144	122	116	7.7	1.71
6A NX	155	139	120	100	10.3) 20	2.02
6B NX	-	166	100	109	10.9) mm	2.03
7	133	122	80	80	-	2.88 (nearside lane)

*The specified rate of spread was 8.5 ± 1 kg/m^2 for 14 mm chippings and 11 ± 1 kg/m^2 for 20 mm chippings (Sections 6A & B only). No chippings were applied to the pervious macadam (Section 7).

5. ANALYSIS AND COMPOSITION

Samples of the asphalts and pervious macadam were taken from the screws of the laying machine. The results of the analyses of the asphalts are given in Table 4.

TABLE 4

Composition of rolled asphalts

Section No	Material	Composition - per cent by mass (Specification in brackets)			
		Stone	Sand	Filler	Binder
1(NX)	Rolled asphalt, 30% stone Pitch/bitumen binder* 14mm Bardon Hill chippings	29.2 (30±5)	52.5 (51.7-54.7)	10.1 (7.9-9.9)	8.2 (7.4-8.4)
2	Rolled asphalt, 30% stone Pitch/bitumen binder* 14 mm Craig-yr-Hesg chippings	30.0 (30±5)	51.8 (51.7-54.7)	9.9 (7.9-9.9)	8.3 (7.4-8.4)
3	Rolled asphalt, 45% stone Pitch/bitumen binder* 14mm Craig-yr-Hesg chippings	44.5 (45±5)	41.8 (40.0-43.0)	7.5 (5.8-7.8)	6.2 (6.2-7.2)
4	Rolled asphalt, 30% stone High P.I bitumen** 14mm Craig-yr-Hesg chippings	30.6 (30±5)	52.4 (51.7-54.7)	9.2 (7.9-9.9)	7.8 (7.4-8.4)
5	Rolled asphalt, 45% stone High P.I bitumen** 14mm Craig-yr-Hesg chippings	44.3 (45±5)	41.5 (40.0-43.0)	7.4 (5.8-7.8)	6.8 (6.2-7.2)
6A(NX)	Rolled asphalt, 30% stone Pitch/bitumen binder* 20mm Bardon Hill chippings	29.9 (30±5)	53.5 (51.7-54.7)	9.0 (7.9-9.9)	7.6 (7.4-8.4)
6B(NX)	"	30.4 (30±5)	56.8 (51.7-54.7)	5.3 (7.9-9.9)	7.5 (7.4-8.4)

* Pitch/bitumen: Penetration 48, R & B softening point 51°C. PI = -1.2
Pen of recovered binder 29.

** High P.I. bitumen: Penetration 52, R & B softening point 58°C. PI = +0.8

The values given are in most cases the mean of three samples and in all cases the average stone content is within 1 per cent of the specified value. The binder and filler contents of the rolled asphalt with pitch-bitumen binder and 30 per cent of coarse aggregate, used for Section 1(NX) and 2 are near the upper limits specified whereas the binder content for Section 3 with 45 per cent of stone is at the lower limit. For the remaining three sections of asphalt, all the values are close to the mid-specification value except for the first load used for Section 6B(NX) which had only 1.6 per cent of filler. This reduced the mean value of the results below the specified limit and gave a corresponding increase for the amount of sand in the mix.

Table 5 gives the analysis results for the chippings used for the asphalts. The 14 mm and 20 mm chippings from Bardon Hill complied with all the specification requirements whereas the 14 mm chippings from Craig-yr-Hesg were marginally on the small side with 32 per cent passing the 10 mm BS sieve instead of the specified maximum of 30 per cent.

TABLE 5

Analysis of properties of chippings

BS sieve size	Per cent by mass passing				
	Bardon Hill 14 mm	Craig-yr-Hesg 14 mm	Specified for 14 mm	Bardon Hill 20 mm	Specified for 20 mm
28 mm				100	100
20 mm	100	100	100	98	90-100
14 mm	91	100	90-100	14	0-25
10 mm	20	32	0-30	1	0-4
6.3 mm	2	2	0-4		
75 μm	0.5	1.4	0-2	0.5	0-2
Binder content %	1.6	1.3	1.0-1.6	1.3	1.0-1.6
Flakiness Index	17	23	<25	22	<25

Analysis results of 10 samples of pervious macadam from Section 7 are given in Table 6 where it can be seen that the grading of the Craig-yr-Hesg aggregate was, on average, coarser than that specified; this resulted from deficiencies in material passing 6.3 mm sieve. Although this would tend to produce a material that drained more freely it might increase the risk of fretting. Some fretting could also result from the low average binder content but with the exceptionally heavy traffic on this site the risk would be substantially reduced.

TABLE 6

Composition of pervious macadam

BS sieve	Per cent by mass passing		
	Found		Specified
	Mean	Range	
28 mm	100		100
20 mm	98.9	96.4 - 100	90 - 100
14 mm	62.3	56.7 - 70.1	50 - 80
6.3 mm	22.5	13.6 - 34.4	25 - 35
3.35 mm	9.6	8.4 - 10.3	5 - 15
75 μm	3.9	3.3 - 4.6	3 - 6
Binder content* - per cent	3.8	3.5 - 4.0	4.0 - 4.4

* Binder penetration = 94.

6. TEXTURE-DEPTH MEASUREMENTS

The resistance to skidding of a bituminous road surfacing is determined by the polishing characteristics of the aggregate on the surface and the number of commercial vehicles using the site[4]. Skidding resistance also changes with the speed of the vehicle and the rate of change depends on the texture depth of the surfacing[5]. For high-speed roads (ie where some vehicles commonly travel at speeds above 95 km/h) it has been suggested that the drop in skid-resistance from 50 to 130 km/h should not be more than 20 per cent. This requires a minimum texture depth of 1 mm. On all seven sections initial texture depths in excess of 1.6 mm were achieved (Table 2) so that the minimum drop in skid resistance from 50 to 130 km/h should be less than 10 per cent.

7. FUTURE MEASUREMENTS

Measurements will be made at regular intervals of texture depth, transverse profile and resistance to skidding, together with visual observations of the amount of black deposit on the experimental surfacings. Continuous records of road surface temperature, atmospheric temperature and times for which the road is wet will also be made. Spray from vehicles on the wet road will be observed on the pervious macadam and compared with adjoining surfaces of the motorway.

8. ACKNOWLEDGEMENTS

The work described in this report was carried out in the Materials Division (G F Salt, Division Leader) of the Highways Department of the TRRL with the assistance of Mr J R Brown then of the Structural Properties Division of the Structures Department.

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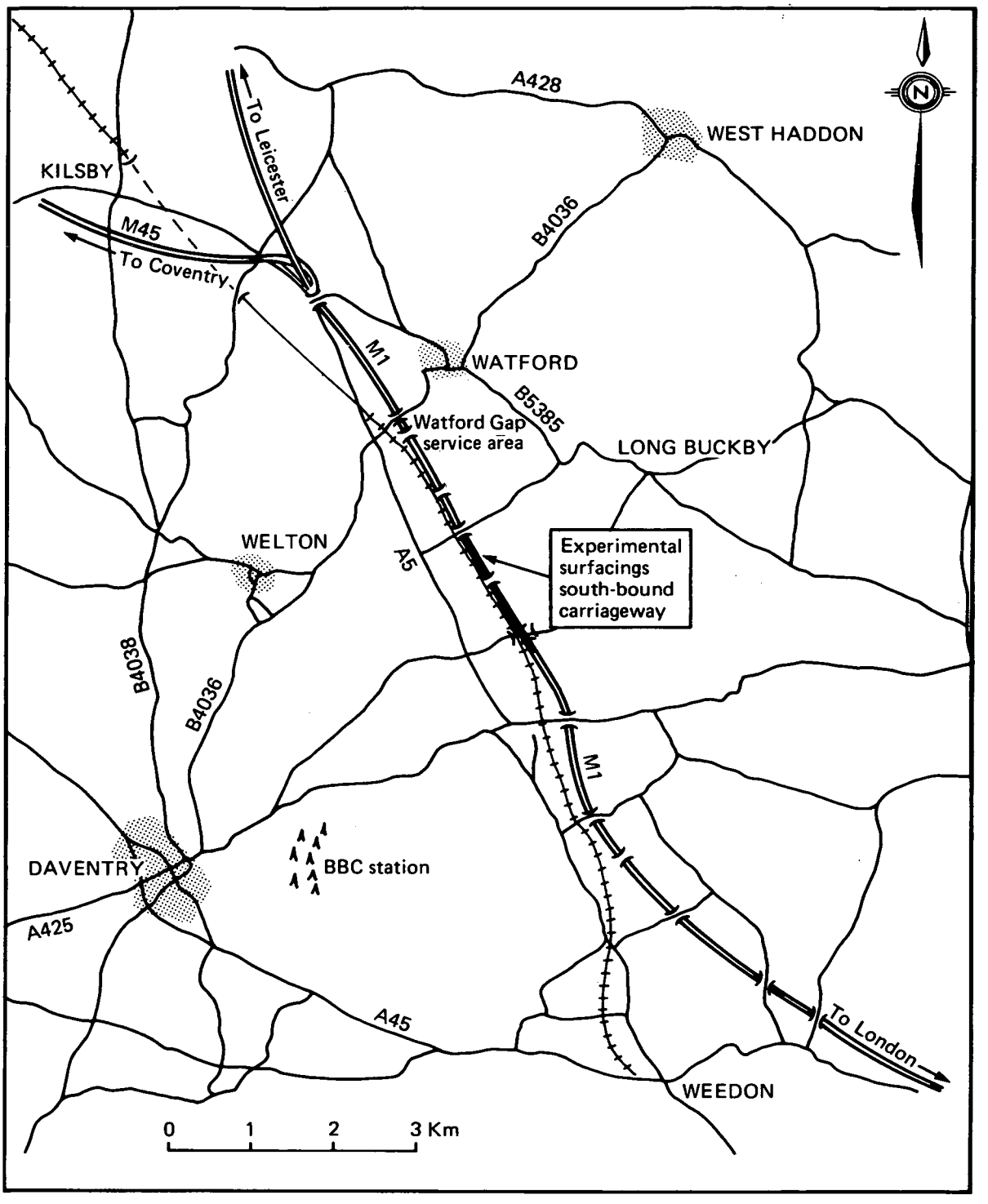
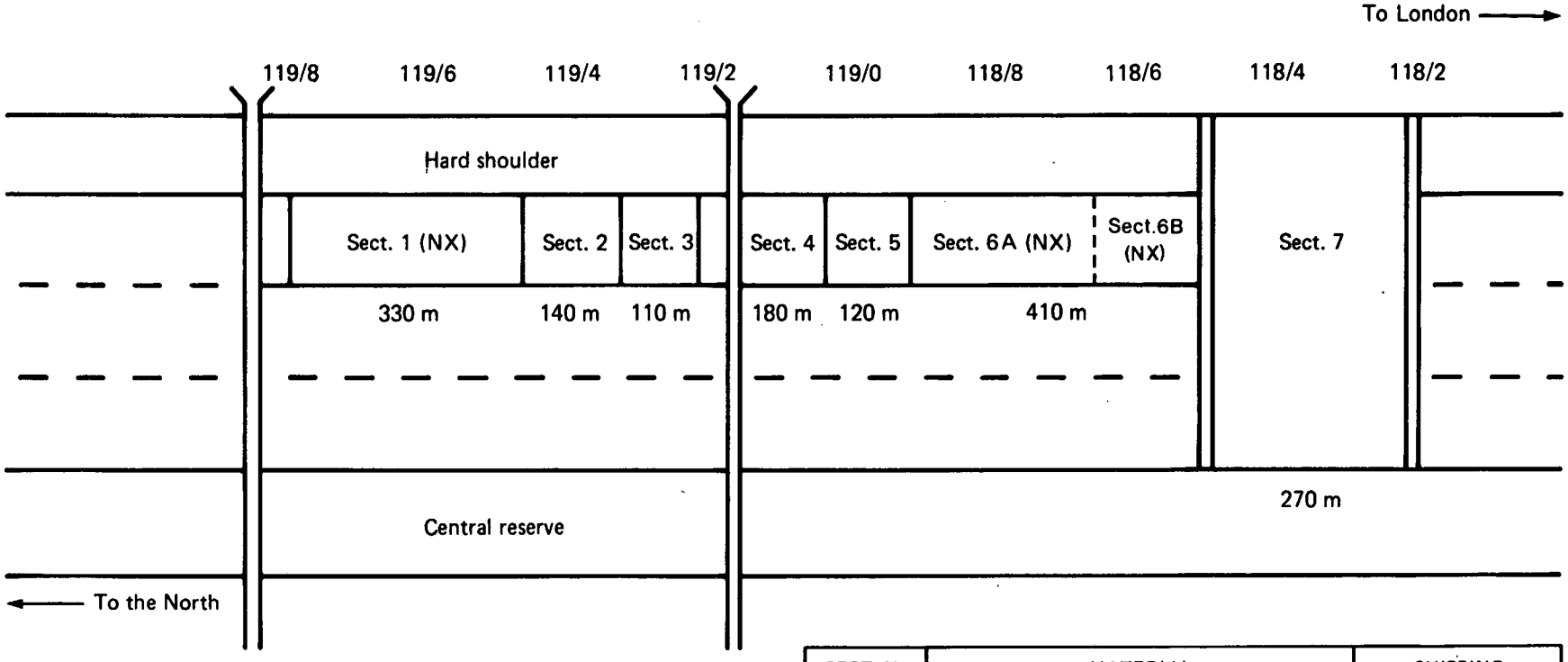


Fig. 1 SITE OF THE EXPERIMENT



SECT. No	MATERIAL	CHIPPING
1 (NX)	Rolled asphalt. Pitch-bitumen binder 30% stone	14mm Bardon Hill
2	Rolled asphalt. Pitch-bitumen binder 30% stone	14mm Craig-yr-Hesg
3	Rolled asphalt. Pitch-bitumen binder 45% stone	14mm Craig-yr-Hesg
4	Rolled asphalt. Special bitumen 30% stone	14mm Craig-yr-Hesg
5	Rolled asphalt. Special bitumen 45% stone	14mm Craig-yr-Hesg
6A & B	Rolled asphalt. Pitch-bitumen binder 30% stone	20mm Bardon Hill
7	Open-textured pervious macadam	None

Fig. 2 MOTORWAY M1 (SOUTHBOUND CARRIAGEWAY): LAYOUT OF THE EXPERIMENTAL SECTIONS

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