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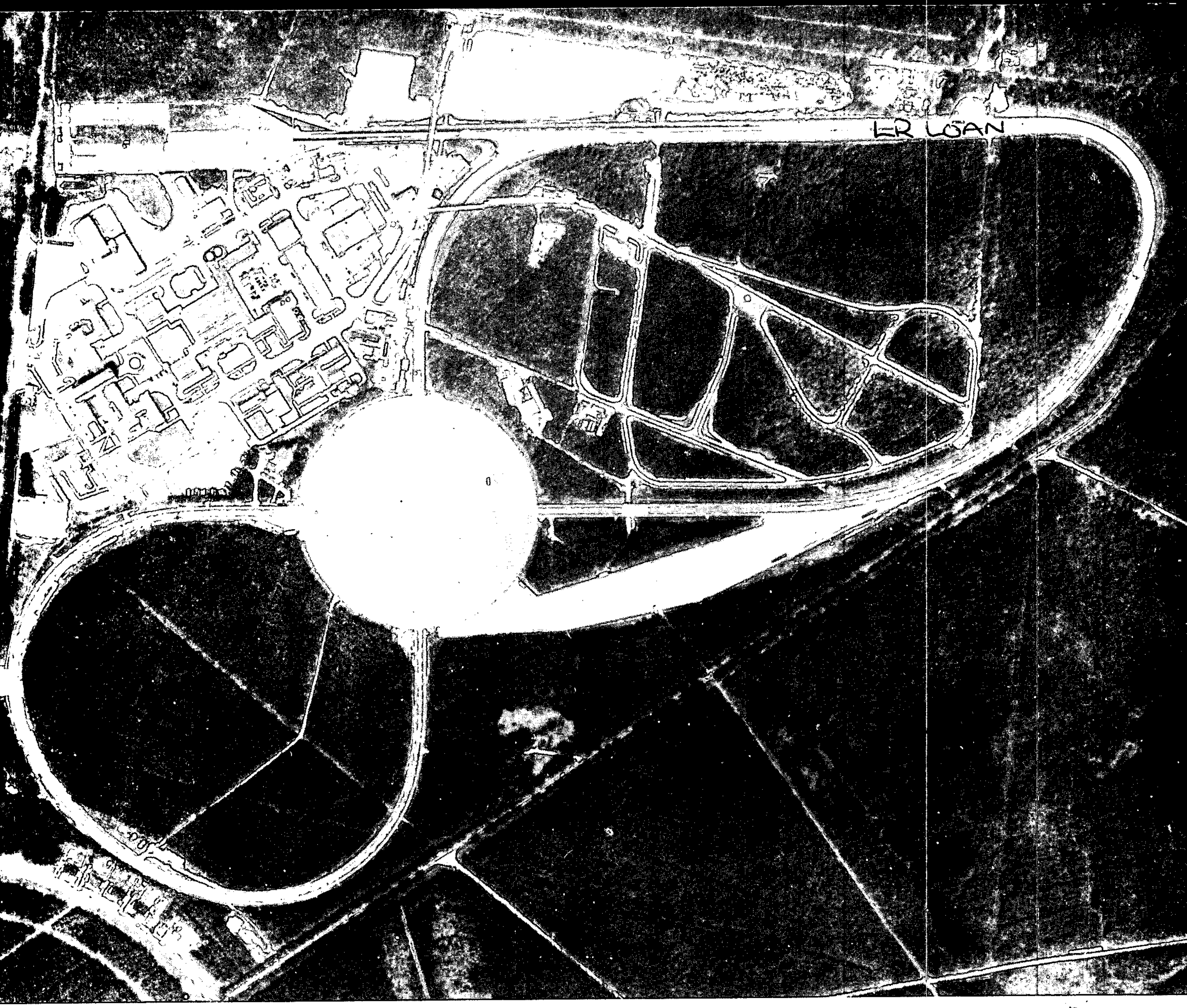

Pavement performance and deflection studies on Malaysian roads

by

J. N. Bulman and H. R. Smith

TRANSPORT and ROAD RESEARCH LABORATORY

Department of the Environment
Department of Transport

DIGEST OF REPORT

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PAVEMENT PERFORMANCE AND DEFLECTION STUDIES ON MALAYSIAN ROADS	
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This report describes a study of the performance of normally constructed road pavements in Peninsular Malaysia. Eight 1.6 km long lengths of road were selected for detailed study. The quality and thickness of the pavement layers were examined, the strengths of the subgrades were measured, and the volume and weight of the traffic transversing each site was monitored. The performance of the road pavements was assessed in terms of the amount of cracking and rutting that developed in the road surface. In addition the deflection characteristics of the road pavements were monitored.

Confirmation of pavement design recommendations A comparison of the pavement thicknesses of the eight road sites with TRRL and Shell pavement design recommendations[1,2,3] indicated that the pavements performed as would be predicted by the pavement design guides, thus confirming the applicability of these design recommendations in the Malysian environment. Two of the sites received bituminous overlays of structurally significant thickness (greater than 50 mm) during the course of the study, and the others received thin maintenance overlays towards the end of the study.

Only on one site was a sub-base provided and it is deduced that the lower part of the crushed stone bases could have been replaced by lower grade and cheaper materials without reducing the lives of the pavements. The quality of the bituminous surfacings was found to be generally low and it is concluded that higher quality but not necessarily thicker surfacings would have substantially increased the service lives of these pavements.

Subgrade conditions Subgrade strengths were generally in excess of CBR 10 and subgrade densities were equal to, or higher, than the maximum dry density in the British Standard 2.5 kg (5.5 lb) rammer compaction test[4].

One hundred and ninety measurements of the subgrade moisture content were made under the pavements at 73 different locations. More than half of these moisture contents were equal to or were drier than the optimum moisture content (OMC) of the subgrade soil given by the British Standard 2.5 kg (5.5 lb) rammer compaction test and three-quarters of them were drier than the OMC plus 2 per cent. The only places where subgrade moisture contents were wetter than this were where gross drainage deficiencies were apparent and free water was permitted to collect in the road bed.

Deflection characteristics Histories of the deflection characteristics of the pavements were traced over an eleven-year period. These were related to the traffic passing over each site expressed in terms of the cumulative number of equivalent standard (8200 kgf) axles. It was found that it was inadvisable to make deflection measurements when pavement temperatures were less than 32°C because of the difficulty of establishing temperature/deflection relationships below this temperature. Pavement temperatures in Penisular Malaysia rarely fall below 30°C in daylight hours, and usually lie within the range 35°C to 45°C.

Deflection criterion curve 'Deflection criterion curves'[5] which relate 'early life' deflections to the subsequent traffic carrying capability of a pavement were developed for bitumen-macadam surfacings on crushed-stone bases in the Malaysian environment. Slightly different curves were obtained for the verge side and offside wheel tracks, a somewhat smaller early life deflection in the verge side wheel track (as compared with the offside wheel track) being required to ensure the same pavement life. This is probably because moisture content changes in the subgrade and shoulder contribute to pavement deterioration more strongly at the edge of the road than near the road centre.

Overlays The reduction in deflection effected by the laying of bitumen macadam overlays at two sites was monitored. Very scattered results were obtained at one site, no reduction in deflection being recorded at many points. At the other site more consistent results were obtained, but only about half the reduction in deflection was obtained as compared with the effect of hot-rolled asphalt overlays in Britain. This is probably mainly due to the higher pavement temperatures that commonly prevail in Malaysia, but the quality and density of bituminous surfacing materials may also be factors.

Conclusions The following conclusions can be drawn from this investigation:-

1. Current pavement design recommendations for flexible pavements set out in Road Notes 29 and 31 can be applied with confidence in environments similar to that of Malaysia.

2. Subgrade densities in Malaysia are commonly in excess of the maximum dry density of the British Standard 2.5 kg (5.5 lb) rammer compaction test, and subgrade moisture contents are unlikely to be more than two per cent wetter than the optimum moisture content given by this compaction test, except in very adverse drainage conditions.

3. Subgrade CBR values in Malaysia are commonly in excess of 10 per cent.

4. The use of sub-bases under Malaysian pavements would be advantageous.

5. An early life deflection 60 x 10^{-2} mm (25 x 10^{-3} in) on the 50 mm to 100 mm thick bitumen-macadam surfacings studied (overlying crushed-stone bases) indicates a life of 500 000 standard axles in the Malaysian environment.

6. Macadam-type bituminous overlays have markedly less effect in reducing pavement deflection in the Malaysian environment than denser mixes achieve in temperate climates.

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The work described in this Digest was carried out by the Overseas Unit of TRRL in co-operation with the Malaysian Public Works Department. It forms part of the programme undertaken for the Ministry of Overseas Development, but any views expressed are not necessarily those of the Ministry.

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CONTENTS

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ABSTRACT

Details are given of the performance over a period of eleven years of normally-constructed road pavements in Malaysia. Current pavement-design recommendations are compared with the thickness and quality of the pavements studied. Pavement deflection characteristics are related to performance under traffic, and deflection-criterion curves are given for roads with crusher-run bases and bitumen-macadam surfacings in the Malaysian environment. It was found that typical Malaysian bituminous overlays reduced deflections less than might be expected from experience gained elsewhere. In spite of the high rainfall in the country and the permeable pavement construction employed, it was found that subgrade moisture contents are rarely more than 2 per cent wetter than the optimum moisture content in the British Standard 2.5 kg rammer compaction test and they are usually significantly drier than this. It is concluded that the pavement design recommendations for flexible pavements set out in Road Notes 29 and 31 can be applied with confidence in environments similar to that of Malaysia, and that the use of sub-bases in Malaysia would be advantageous.

1. INTRODUCTION

The performance of normally-constructed road pavements in Malaysia has been studied over a period of eleven years and current pavement design recommendations have been compared with the thickness and quality of the pavements in relation to the traffic carried and subgrade strength.

The use of deflection beams[1] for monitoring the condition of road pavements has become increasingly popular in recent years, and in several countries deflection techniques have become an integral part of the highway maintenance process[2,3,4]. In others, deflection measurements are used for pavement design purposes[5,6]. The deflection characteristics of typical Malaysian road pavements have been studied to determine whether they are different from those of typical road pavements in temperate climates.

Most of the experience of the use of deflection techniques in highway engineering has been acquired in temperate climates and the purpose of the Malaysian study was to investigate whether any differences in approach are necessary in hot tropical climates. In particular, it was desired to find out whether the early-life transient deflection of a road pavement under a standard wheel load correlated with the subsequent 'life' of the pavement as has been demonstrated elsewhere[7,8]. In the United Kingdom long-term studies of the deflection characteristics of road pavements[9,10] have enabled 'deflection criterion curves' to be derived[11] which provide the highway engineer with a technique for predicting the future traffic-carrying capacity of existing pavements. This is particularly useful for designing road strengthening measures.

A co-operative research programme was commenced in Peninsular Malaysia in 1964 by the Malaysian Public Works Department (Jabatan Kerja Raya) and a team from the UK Transport and Road Research Laboratory. Full-time studies were undertaken in the period 1964—1967, and intermittent pavement performance and traffic surveys have been undertaken subsequently. Eight road sites were studied in detail, each site being used both to check current pavement design recommendations[12,13,14] and to study long-term deflection characteristics. In addition during the course of the study different methods of undertaking deflection surveys with deflection beams were investigated[15], and several other parallel studies were undertaken which have been reported separately[16,17,18,19,20,21].

2. DETAILS OF THE ROAD SITES STUDIED

2.1 Locations of the sites

Deflection and performance studies were carried out on eight 1.6 km (1 mile) long sections of normally-constructed road. The locations of the road sites are shown in Figure 1. Where possible the sites were located on recently-constructed roads on the more heavily trafficked routes in the country.

Seven of the eight lengths of road had pavements consisting of crushed stone bases with bitumen-macadam surfacings. This is the form of construction most commonly used for main roads in Malaysia. The eighth road site had a pavement consisting of a cement-stabilised sand base with a sand-bitumen surfacing. This form of construction is uncommon in Malaysia.

2.2 Subgrade soils and climatic conditions

Descriptions of the subgrade soils at each site are given in Table 1. Seven of the sites were located on highly-weathered granite or weathered sandstone-shale, these soils being typical of the greater part of the surface area of the Malay peninsula. One site was located on a sand ridge resulting from an ancient beach line.

All the sites experience heavy rainfall and high temperatures. Table 2 gives rainfall data[22] collected at stations adjacent to the road sites. Maximum daily temperatures are virtually constant throughout the year at all sites, remaining at about 32° or $33^{\circ}C$ (89° to $92^{\circ}F$).

3. THE MEASUREMENTS AND TESTS MADE

3.1 The standard of construction of the roads

During the course of the study a series of test pits and inspection holes was dug at each road site to establish the quality and thickness of the pavement layers.

At each site, four 50 cm by 50 cm (20 in by 20 in) test pits were dug through the pavement and measurements were made of the in-situ density of the subgrade using the sand replacement method[23]. The strength of the subgrade was also assessed at these points by means of in-situ CBR and cone penetrometer tests. The thickness of each pavement layer was noted and samples of the pavement materials and the subgrade were taken for testing in the Laboratory.

TABLE 1

Details of sites investigated

Site No	Location	Subgrade materials	Pavement type	Date opened to traffic
1	Route 1. Trolak, 60 ml (96.6 km) south of Ipoh	Sedimentary, varying lithological types, mostly silty shales	Two-course bitumen-macadam surfacing on crushed granite base	February 1965
2	Route 2. Sungei Way new village 7 ml (11.3 km) west of Kuala Lumpur	Granitic soil plus some sandy tin mine tailings	Two-course bitumen-macadam on crushed limestone base	1956
3	Route 2. Subang Airport approach road 13 ml (20.9 km) west of Kuala Lumpur	Weathered granite	Single-course bitumen-macadam on crushed limestone base	December 1964
4	Route 2. Batu Tiga 16 ml (25.8 km) west of Kuala Lumpur	Carboniferous shales, sandy shales and sandstone	Two-course bitumen-macadam on crushed limestone base	1961
5	Route 2. Klang 19 ml (30.6 km) west of Kuala Lumpur	Soil derived from deeply weathered rocks, mostly silty shales with hard ferruginous gravel bands	Two-course bitumen-macadam on crushed limestone base	June 1964
6	Route 1. Southern Approach 6 ml (9.7 km) south of Kuala Lumpur	Weathered granite	Single-course dense bitumen-macadam on crushed granite base	October 1964
7	Route 1. Sungei Dua 54 ml (86.9 km) south of Seremban	Sedimentary, varying lithological types, mostly silty shales	Single-course bitumen-macadam on crushed granite base	1962
8	Route 3. Kuala Rompin-Endau 94 ml (151.3 km) south of Kuantan	Quaternary dune sand	Bitumen-sand mix on cement-stabilised sand base	1963

TABLE 2

Rainfall data from meteorological stations adjacent to the road sites

Station	Annual average total rainfall		Average range monthly totals		No. of years of observations	Adjacent to* road sites Nos
	in.	mm.	in.	mm.		
Tanjong Malim	120.6	306.4	6.3–14.7	15.9–37.4	38	1
Kuala Lumpur	94.9	240.9	4.0–11.0	10.2–27.9	69	2, 3, 4, 6
Port Swettenham	90.6	230.2	4.3– 9.9	10.2–25.2	17	5, 4
Segamat	78.4	199.1	4.1–10.9	10.5–27.7	33	7
Tampin	80.4	204.2	4.2– 9.5	10.6–24.1	46	7
Mersing	111.1	282.2	5.4–20.3	13.8–51.6	32	8
Kajang	93.8	238.1	4.0–10.9	10.2–27.7	58	6

* see Table 1 for location of sites

In addition to the test pits, approximately ten smaller holes were dug at each road site adjacent to the deflection test points. The same measurements of the pavement structure were made in these smaller holes as in the pits, except that in-situ densities were not measured.

The results of the pavement thickness investigations and the subgrade measurements are summarised in Table 3.

3.2 Tests on the pavement and subgrade materials

Samples of the bituminous surfacing materials were analysed to determine the bitumen contents and the aggregate gradings. The results are given in Table 4. In addition, checks were made of the penetrations of the binder recovered from single samples from each site and the results of these tests are also included in Table 4.

Samples of the crushed-stone bases were taken and their gradings were determined. A limited number of aggregate impact tests[24] were carried out on the recovered material. The grading results and the impact test results are given in Table 5.

Samples of the subgrade soils were taken for moisture content tests, and the standard classification tests[23] were carried out on most of the samples. Compaction tests[23] were carried out on the bulk samples obtained from the larger test pits. The results of the tests on the subgrade soils are summarised in Table 3.

3.3 Deflection tests

Deflection measurements were made in both vergeside and offside wheelpaths at approximately twenty chainages on each road site over a period of eleven years. The test points were referenced to permanent markers in the road verge so that the tests could be repeated at precisely the same points in successive years. The standard TRRL dynamic method of making deflection beam measurements was used. This employs a 6350 kg (14,000 lb) axle load. (See Appendix 1.)

TABLE 3

Pavement thickness and subgrade data*

Site No.	1	2	3	4	5	6	7	8
Thickness of bituminous surfacing mm	96 (20)	110 (13)	72 (17)	102 (17)	86 (17)	106 (14)	47 (16)	44 (20)
Thickness of base mm	166 (20)	166 (13)	329 (17)	(BLOCKS) 238 (17)	266 (17)	306 (14)	(BLOCKS) 273 (16)	213 (20)
Thickness of sand blanket mm	0 (20)	0 (13)	13 (17)	0 (17)	0 (17)	29 (14)	0 (16)	0 (20)
1965/67 Subgrade Surface Mean in-situ CBR Per cent Range Per cent Mean moisture content Per cent	 19 (8) 9 – 32 19.7	 40 (8) 12 – 90 14.2	 31 (16) 14 – 48 18.6	 26 (10) 11 – 42 14.3	 23 (7) 13 – 30 19.0	 11 (7) 10 – 12 17.0	 6 (8) 1 – 10 29.9	 54 (8) 28 – 87 19.8
1965/67 At Depth of 150 mm Mean in-situ CBR Per cent Range Per cent Mean moisture content Per cent	 14 (4) 12 – 16 18.2	 16 (3) 12 – 21 19.6	–	 30 (6) 18 – 45 14.2	 15 (3) 12 – 17 25.1	 17 (5) 12 – 23 19.5	 6 (7) 1 – 17 35.9	 45 (3) 30 – 55 19.8
1971 Top 100 mm of Subgrade Mean in-situ CBR Per cent Range Per cent Mean moisture content Per cent (CBR measured with MEXE penetrometer†)	 14 (8) 7 – 15+ 20.2	 14+ (5) 7 – 18+ 17.9	–	 13+ (7) 9 – 18+ 17.6	 17+ (9) 15 – 18+ 19.3	 15+ (6) 12 – 18+ 16.2	 9 (8) 5 – 18 23.3	–
In-situ Dry Density (1965/67) kg/m^3 @ Moisture content Per cent Density relative to British Standard Compaction Per cent	1890 (8) 18.3 (8) 104	1858 (8) 15.2 (8) 102	1746 (8) 18.3 (8) 105	1938 (8) 13.5 (8) 104	1730 (8) 20.2 (8) 106	1762 (8) 18.3 (8) 103	1490 (8) 32.6 (8) 96	1698 (8) 20.8 (8) 105
British Standard Compaction Optimum moisture content Per cent	17.4	15.3	19.7	14.5	23.0	18.3	25.9	19.3
Subgrade plasticity index Per cent	0 – 22	17 – 30	29 – 43	0 – 25	15 – 40	16 – 24	9 – 36	0 (8)

TABLE 3 (continued)

<table>
<tr><th colspan="2">Site No.</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td colspan="2">Grading of Subgrade Material</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Gravel</td><td>Per cent</td><td>18 (11)</td><td>11 (11)</td><td>0 (4)</td><td>3 (14)</td><td>23 (16)</td><td>5 (12)</td><td>24 (17)</td><td>0 (8)</td></tr>
<tr><td>Sand</td><td>Per cent</td><td>35 (11)</td><td>51 (11)</td><td>44 (4)</td><td>43 (14)</td><td>26 (16)</td><td>44 (12)</td><td>12 (17)</td><td>65 (8)</td></tr>
<tr><td>Silt</td><td>Per cent</td><td rowspan="2">47 (11)</td><td rowspan="2">58 (11)</td><td>12 (4)</td><td rowspan="2">54 (14)</td><td rowspan="2">51 (16)</td><td rowspan="2">51 (12)</td><td rowspan="2">64 (17)</td><td rowspan="2">35 (8)</td></tr>
<tr><td>Clay</td><td>Per cent</td><td>44 (4)</td></tr>
</table>

* Average values for each site are given in the table and the number of separate measurements that were made at each site are shown in brackets

† Maximum CBR measurable is 18 depending upon soil type

TABLE 4

Laboratory test results of samples of bituminous surfacing materials

Site		1		2		4			5		6		7
Course / BS Sieve Size in.	mm.	Binder/ Wearing	New Overlay	Binder	Wearing	Binder	Wearing	New Overlay	Binder	Wearing	Binder	Wearing	Binder/ Wearing*
		Percent passing											
1½	38.1	100		93–100		90–100			100				100
1	25.4	100		–		72–85	100		82–96		100		97–100
¾	19.1	95–100	100	54–82	100	51–68	95–100	100	72–85	100	74–89	100	86–100
½	12.7	77–92	95–97	43–63	91–97	34–50	71–89	98–99	51–70	85–97	48–68	96–98	66–81
⅜	9.5	61–81	–	–	–	–	–	–	–	–	–	–	–
¼	6.4	36–63	74–83	22–41	56–71	13–20	33–51	69–75	31–44	58–69	37–56	65–72	31–49
⅛	3.2	–	59	–	–	–	–	46–55	21–32	–	–	–	–
No. 7	2.4	18–41	–	13–28	33–44	9–16	14–27	41–50	16–25	36–42	28–46	41–46	14–26
No. 14	1.2	–	–	–	–	–	–	–	–	–	25–39	28–33	–
No. 25	0.6	10–23	32–36	8–18	20–28	6–11	6–14	24–32	9–14	21–26	21–23	21–31	6–12
No. 52	0.3	7–16	21–25	7–15	16–21	5–10	5–9	16–22	7–11	15–19	12–16	14–17	5–9
No. 100	0.15	–	–	–	12–15	–	–	11–16	–	–	5–8	10–13	4–6
No. 200	0.07	3–7	7–9	5–9	8–13	2–6	4–8	7–10	4–7	8–11	3–6	7–10	3–4
No. Samples		15	2	5	6	6	7	4	7	5	6	4	8
Bitumen Content percent		2.4–4.1	4.5–4.6	2.0–4.2	3.1–5.0	1.3–2.9	2.0–4.9	5.0–5.5	2.4–3.9	3.5–4.0	3.1–4.0	4.1–5.0	3.5–5.0
Bitumen Recovery PEN' at 25°C		21	52	–	35	–	5	48	–	7	–	35	13
No. of Samples combined		11	2	–	4	–	4	4	–	5	–	6	6
Age of Sampling Years		5	0	–	8	–	8	0	–	5	–	2	9

* 1 Layer

TABLE 5

Results of impact value tests and gradings of samples recovered from the crushed-stone bases

Site No.		1	2	3	4	5	6	7	8
Base Material		Granite	←		Limestone		→	Granite	Sand-Cement
Specific Gravity				2.75			2.70–2.75		
Aggregate Impact Value		19.5–20.5	18.2–21.3	–	18.8–24.5	19.3–23.8	19.6–20.8	19.9–28.5	–
No. of Tests		4	3	–	4	4	3	2	–
BS Sieve Size		Percent passing							
in.	mm.								
2	50.8	100–95	100	100–89	100–95	100–95	100–85	100–67	–
$1\frac{1}{2}$	38.1	90–80	88–80	87–74	89–74	82–75	87–67	76–55	–
1	25.4	75–58	62–54	71–55	72–44	56–48	73–40	56–40	–
$\frac{1}{2}$	12.7	63–48	36–27	50–30	50–22	38–29	55–21	40–24	–
$\frac{3}{16}$	4.9	36–20	28–18	27–15	30–12	29–23	39–12	29–18	–
No. 7	2.4	28–14	24–17	20–11	23–9	24–18	29–9	23–15	–
No. 25	0.6	13–8	17–12	13–6	16–6	13–10	17–6	14–8	–
No. 52	0.3	11–4	12–6	9–5	12–4	10–7	12–4	10–4	–
No. 200	0.07	8–3	8–4	7–4	9–3	7–5	9–4	6–3	–
No. of samples		9	7	10	10	9	10	12	–

When deflection tests were being made the temperature of the pavement 40 mm (1.6 in) below the surface was measured with a mercury-in-glass thermometer inserted into an oil-filled hole driven into the road surfacing. The measured deflection was then corrected to its equivalent value at 35°C by use of temperature/deflection relationships established for the different sites as indicated in Figure 2. Each test was repeated and if the second reading differed by more than 4×10^{-2}mm (2.0×10^{-3} in) from the first, a third and sometimes a fourth test was made until two readings were obtained with not more than 4×10^{-2}mm (2.0×10^{-3}in) difference between them.

Summaries of the deflections measured at each of the eight sites over eleven years are given in Table 6.

3.4 Pavement condition measurements

At each of the deflection test points measurements were made of the transverse deformation in the wheelpaths and the amount of cracking of the road surface each time the deflection measurements were made. The deformation in the wheelpaths was recorded as the rut-depth measured beneath a 2 m (6 ft 6 in) long straight-edge laid transversely to the axis of the road.

The amount of cracking at the test points was recorded as the length of visible crack per unit area. A simple rating system for recording transverse deformation and cracking was devised (as is shown in Table 7). The deformation and cracking indices were assigned numerical values ranging from one to five. In this way an overall rating for each site can be obtained by adding together the values applicable to each deflection test point. These overall condition ratings are shown in Table 6.

The relation between pavement condition and deflection can be plotted against traffic as a 'deflection history' chart. Deflection history charts were prepared for all the sites and Figures 3 and 4 show typical charts for Sites 1 and 5. Site 1 was a site with very variable structural characteristics and Site 5 is typical of the more consistent sites. Figure 5 gives the key to the symbols used to record pavement condition in the deflection history charts.

3,5 Traffic counts

One-day (12-hour) counts of the numbers of commercial vehicles traversing the sites were made at intervals of one or two years during the course of the study. These were supplemented by one-day and seven-day sixteen-hour counts undertaken by Jabatan Kerja Raya (Public Works Department) as part of a regular national traffic census. Using Liddle's equivalency factors[25] and the results of axle load surveys undertaken in Malaysia[19], the numbers of commercial vehicles traversing the sites have been expressed in terms of the cumulative number of equivalent 8200 kgf (18000 lbf) standard axles that have passed over the sites (in one direction) since they were first opened to traffic. (Table 8.)

4. DISCUSSION

4.1 The performance of the pavements studied

Six of the eight pavements studied required maintenance overlays after periods ranging from six to ten years. Two of these sites (sites 1 and 4) were given bituminous overlays thick enough to add significantly to their structural value (ie greater than 50 mm), after six years' and ten years' service. Site 3 received its

TABLE 6

Summary of the pavement condition and the deflections recorded
(corrected for temperature) at the eight sites

Site No.	Date of Testing	November 1964	May 1965	October 1965	November 1966	February 1967	June 1967	November 1968	April 1971	July 1971	January 1973	May 1975
	No. of test points	20	20	20		20	20	20	20	20	20	20
	Surface condition rating 'D'	44	42	43		43	46	54	45	40	41	42
	Surface condition rating 'C'	40	40	40		57	58	90	123	40	123	85
1	No. of patched points	0	0	0		0	0	0	5	0	0	0
	Mean deflection x 10^{-2}mm	242	118	94		97	106	98	99	88	83	74
	Standard deviation x 10^{-2}mm	126	59	54		54	52	49	52	40	37	35
	Comments									Overlaid		½ Overlaid
	No. of test points	14	14		14		14	14	14		14	
	Surface condition rating 'D'	29	28		28		30	29	29		29	
	Surface condition rating 'C'	28	28		28		28	33	31		34	
2	No. of patched points	0	0		0		0	0	4*		10*	Re-aligned
	Mean deflection x 10^{-2}mm	50	41		40		45	45	51		43	
	Standard deviation x 10^{-2}mm	21	22		17		22	19	28		25	
	Comments								*Overlaid		*Overlaid	
	No. of test points	21		21		21	21	21	21		21	21
	Surface condition rating 'D'	42		45		42	47	43	42		43	42
	Surface condition rating 'C'	42		42		42	42	42	47		48	42
3	No. of patched points	0		0		0	0	0	0		0	0
	Mean deflection x 10^{-2}mm	46		31		20	28	32	36		31	30
	Standard deviation x 10^{-2}mm	17		10		9	9	7	7		9	10
	Comments											1st WRG' Course
	No. of test points	20	20		20		20	20	20	20	20	20
	Surface condition rating 'D'	53	57		54		70	68	39	40	40	41
	Surface condition rating 'C'	40	40		40		40	40	34	40	41	41
4	No. of patched points	0	0		0		0	2	13	0	0	0
	Mean deflection x 10^{-2}mm	55	50		49		48	64	65	55	50	34
	Standard deviation x 10^{-2}mm	23	17		19		17	16	16	14	11	11
	Comments								Patching	Overlaid		

TABLE 6 (continued)

Site No.	Date of Testing	November 1964	May 1965	October 1965	November 1966	February 1967	June 1967	November 1968	April 1971	July 1971	January 1973	May 1975
5	No. of test points	22	22		22		22	22	22		22	20†
	Surface condition rating 'D'	51	42		45		45	50	50		46	41
	Surface condition rating 'C'	46	36		44		52	48	56		86	111
	No. of patched points	0	8		*		2	*	0		0	0*
	Mean deflection x 10^{-2}mm	49	42		32		37	36	33		36	28
	Standard deviation x 10^{-2}mm	34	29		17		17	14	17		14	10
	Comments				Part *Overlaid			*Remainder Overlaid				*Resurfaced June
6	No. of test points	16	16			16	16	16	16		16	14†
	Surface condition rating 'D'	23	32			35	36	30	34		34	29
	Surface condition rating 'C'	32	32			31	48	41	36		48	45
	No. of patched points	0	0			1	1	9	0		0	0
	Mean deflection x 10^{-2}mm	75	69			64	63	68	67		57	51
	Standard deviation x 10^{-2}mm	27	22			24	20	21	14		20	22
	Comments								Overlaid			
7	No. of test points	20		20		20	20	20	20		20	Overlaid
	Surface condition rating 'D'	44		45		49	48	50	48		48	
	Surface condition rating 'C'	40		40		42	42	47	63		62	
	No. of patched points	0		0		0	0	0	0		*	
	Mean deflection x 10^{-2}mm	80		64		76	84	73	98		82	
	Standard deviation x 10^{-2}mm	35		35		56	56	41	70		43	
	Comments										*½ Overlaid	
8	No. of test points	28		28	28	28		28	28		28	Overlaid
	Surface condition rating 'D'	56		–	56	56		56	62		58	
	Surface condition rating 'C'	64		–	74	83		87	92		114	
	No. of patched points	0		0	0	0		0	0		0	
	Mean deflection x 10^{-2}mm	29		33	46	45		56	64		78	
	Standard deviation x 10^{-2}mm	9		14	16	18		29	30		29	
	Comments											

† 2 points lost due to reconstruction work

Note. A surface condition rating of greater than 4 x (No. of test points per site) for either cracking or deformation indicates that the pavement is in a critical condition

TABLE 7

Classification of road surface condition

Transverse deformation under a 2m (6.5ft) long straight-edge		Degree of cracking (visible cracks)	
Classification Index	Deformation	Classification Index	Crack length/unit area
D_1	Less than 10mm (3/8in)	C_1	Nil
D_2	10mm (3/8in) to 15mm (9/16in)	C_2	Not greater than $1m/m^2$
D_3	15mm (9/16in) to 20mm (13/16in)	C_3	Greater than $1m/m^2$ but not greater than $2m/m^2$
D_4 (regarded as 'failed' in UK)	20mm (13/16in) to 25mm (1in)	C_4	Greater than $2m/m^2$ but not greater than $5m/m^2$
D_5 (suggested failure criteria for main roads in Malaysia)	Greater than 25mm (1 in)	C_5	Greater than $5m/m^2$ (ravelling & potholing imminent, immediate maintenance required)

TABLE 8

Estimated cumulative number of standard axles
that have traversed the sites (in one direction)

Site	Date of Opening of Road	Date of Deflection Test	Est. of Cum. No. of CV's since opening of road (x 10^6)	Est. of Cum. No. of Std. Axles since opening of road (x 10^6)
1	October 1964	Nov 64	0.01	<0.01
		Apr 65	0.05	0.02
		Nov 65	0.09	0.04
		Feb 67	0.24	0.10
		May 67	0.27	0.11
		Nov 68	0.46	0.19
		Mar 71	0.81	0.33
		Jan 73	1.20	0.49
2	1956	Dec 64	2.82	1.16
		June 65	3.07	1.26
		Nov 66	3.89	1.59
		June 67	4.18	1.71
		Oct 68	5.05	2.07
		Apr 71	6.87	2.82
		Jan 73	8.50	3.49
3	December 1964	Dec 64	0.00	0.00
		Aug 65	0.03	0.01
		Feb 67	0.11	0.05
		June 67	0.18	0.07
		Oct 68	0.22	0.09
		Apr 71	0.43	0.18
		Jan 73	0.67	0.27
4	1961	Dec 64	1.42	0.58
		June 65	1.67	0.68
		Nov 66	2.46	1.01
		July 67	2.75	1.13
		Oct 68	3.54	1.45
		Apr 71	5.39	2.21
		Jan 73	6.97	2.86
5	June 1964	Dec 64	0.23	0.09
		June 65	0.47	0.19
		Nov 66	1.18	0.48
		July 67	1.57	0.64
		Nov 68	2.33	0.96
		Apr 71	4.60	1.89
		Jan 73	6.18	2.53

TABLE 8 (continued)

Site	Date of Opening of Road	Date of Deflection Test	Est. of Cum. No. of CV's since opening of road (x 10^6)	Est. of Cum. No. of Std. Axles since opening of road (x 10^6)
6	October 1964	Nov 64	0.03	0.01
		May 65	0.11	0.05
		Jan 67	0.27	0.11
		July 67	0.50	0.21
		Nov 68	0.87	0.36
		Apr 71	1.81	0.74
		Jan 74	2.67	1.09
7	1962	Jan 65	0.13	0.05
		July 65	0.17	0.06
		Jan 67	0.28	0.11
		May 67	0.29	0.12
		Nov 68	0.43	0.18
		Apr 71	0.68	0.28
		Jan 73	0.91	0.37
8	1963	Jan 65	$<$ 0.01	$<$0.01
		Jul 65	0.01	$<$0.01
		Oct 66	0.09	0.04
		Mar 67	0.10	0.04
		Nov 68	0.18	0.07
		Apr 71	0.27	0.11
		Jan 73	0.37	0.15

first wearing course after approximately eight years' service, but it is lightly trafficked. Site 8 was overlaid after approximately thirteen years. This is typical of the performance of most of the new main road construction undertaken in western Malaysia in the nineteen sixties and compares favourably with the service lives achieved with flexible road surfacings in other tropical countries.

All the pavements can be said to have performed satisfactorily in that they have carried the traffic loads imposed on them for more than ten years without suffering significant structural failure and the two pavements that received substantial overlays had thinner pavements in relation to traffic and subgrade strength than is recommended in any widely-used pavement design guide. However, when the amount of traffic traversing the sites is taken into consideration, big differences can be distinguished between the relative performance of the different pavements and the durability of the surfacings proves to be considerably less than would be expected of hot-mix bituminous surfacings in Britain. It is useful to examine the reasons for these differences in performance.

The total pavement thickness of the eight road sites are broadly similar to the recommendations given by the Transport and Road Research Laboratory[12,13], and the Shell Design Charts[14] for a fifteen year design life at the traffic levels experienced. Table 9 compares the pavement thickness measured at the sites with these recommendations. Precise comparisons may be misleading because of the differing criteria for pavement failure that are implicit both in the different pavement design methods and in normal highway engineering practice in Malaysia. For example, in Malaysia cracking of bituminous surfacings is the commonest form of failure (see Table 6) and high degrees of cracking are tolerated before overlaying, whilst in Britain deformation is much more significant as a mode of failure of bituminous surfaced roads. Nevertheless, whilst precise comparisons between the performance of the Malaysian pavements and the pavement design recommendations should not be made, general comparisons are useful. Generally speaking the thickness of bituminous surfacing and base found at the study sites was equal to, or greater than that which is recommended, but when the absence of the sub-base is taken into account the total thickness of pavement provided is of much the same order as is recommended, except perhaps for sites 1 and 4 which are significantly thinner. The effect of the practice of omitting sub-bases in Malaysia is thus to use high quality crushed stone material lower down in the pavement structure than is normally felt necessary elsewhere. The fact that subgrade strengths are relatively high would favour the use of sub-bases since material at sub-base level is relatively lightly-stressed on strong subgrades. It would, therefore, appear that economies could be made if cheaper lower-grade materials were used for sub-bases in place of the lower part of the crushed stone base. Possible materials for sub-bases could be decomposed rock and quarry overburden, the sand produced as a waste product in the tin mining industry, lateritic gravels, and possibiy lime stabilised soil.

Since the differences in pavement performance between the sites cannot be attributed primarily to differences in pavement thickness in relation to the traffic and subgrade strength, it is likely that differences in the quality of the pavement materials are responsible. Examination of the bituminous surfacing analyses (Table 4) and the grading results of the crushed stone bases (Table 5) indicates that there are large differences between sites in the qualities of the surfacing materials, but that the base materials, although poorly graded, are much the same on all sites. This is supported by visual observations of the quality of the surfacings which range from fine close-textured bitumen macadam on some sites (sites 2, 6 and part of 5) to very coarse open-textured macadams on others (1, 4, 7 and part of 5). It is notable that the sites with the denser surfacings have performed better (at much heavier traffic levels) than those with the coarse open-textured surfacings. It was also observed that densification of the surfacings in the wheel tracks was common, even with the close-textured mixes. Whilst this is to be expected to some extent with mixes of

TABLE 9

Comparison of the pavement thickness measured at the sites with those recommended in three pavement design guides

Site	Pavement layer	Mean thickness mm	Range of thicknesses mm	Recommended thickness for estimated total traffic loading at current flows and growth rates assuming 15 year design life			Subgrade design CBR per cent
				Road Note 31[13] mm	Road Note 29[12] mm	Shell Design Charts[14] mm**	
1	Surfacing	96	64–130	50	66	100	10
	Base	166	76–251	150	148	235*	
	Sub-base	–	–	100	150	–	
2	Surfacing	110	89–121	†	82	110	10
	Base	166	122–198		177	255*	
	Sub-base	–	–		150	–	
3	Surfacing	72	57–87	50	60	77	17
	Base	329	266–381	150	140	152*	
	Sub-base	–***	–	–	150	–	
4	Surfacing	102	86–124	†	90	120	10
	Base	238	171–289		186	255*	
	Sub-base	–	–		150	–	
5	Surfacing	86	64–121	†	92	115	17
	Base	266	227–298		190	185*	
	Sub-base	–	–		150	–	
6	Surfacing	106	89–124	†	86	110	10
	Base	306	225–368		180	250*	
	Sub-base	29	0–102		150	–	
7	Surfacing	47	16–102	50	62	90	7
	Base	273	95–387	150	142	300*	
	Sub-base	–	–	100	150	–	
8	Surfacing	44	22–51	–	52	65	17
	Base	213	197–229	150	128	140*	
	Sub-base	–	–	–	–	–	

* base and sub-base thicknesses combined, assuming materials with minimum CBR's of 80 and 40 respectively
** axles per day taken as those in the ninth year
*** some sub-base occurs on parts of this site, but it is ignored in this table
† traffic loading is above the range covered in this design guide

this type, it is also likely that the degree of initial compaction is sometimes deficient, probably as a result of the laying temperature being too low. When digging the test pits it was found that adhesion between the bituminous layers and between the surfacing and the base was very low or non-existent, and water was frequently found between layers. This indicates the high degree of permeability of the surfacings, one consequence of which is the rate at which the binder hardens. Table 4 shows that the binder in the older open-textured surfacings was found to be very hard, whilst the binder of the denser mixes on sites 2 and 6 had hardened much less.

Thus the evidence is that the overall performance of sites 1 to 7 would have been much improved if they had been sealed by surface dressings or surfaced with higher quality dense bituminous surfacings. Such mixes require the availability of plentiful supplies of non-plastic sand-sized material. This could be readily obtained in many parts of Malaysia by washing and screening the tin-mining waste that occurs widely.

The performance of site 8, which has a cement-stabilised base and a bitumen-sand surfacing, must be considered separately from the other seven sites since its mode of deterioration, block-cracking, is different from the cracking (accompanied by deformation) that occurs in the crushed stone bases. Transverse cracks at regular spacings appeared in the surfacing of this road soon after it was constructed. This is a very common feature in roads of this type and it need not necessarily give any cause for concern if the pavement is built on a freely draining sand subgrade such as exists at site 8. It has been shown that given reasonably adequate curing, the spacing, and hence to a large extent the size, of these characteristic transverse cracks is governed mainly by the tensile strength of the stabilised soil at the time when the pavement is first trafficked[26]. At site 8 after the transverse cracks had first appeared, there was very little further increase in cracking and virtually no transverse deformation for several years (see Table 6). After about four years' service however, the amount of cracking began to grow slowly under the traffic and after nine years it reached the stage where strengthening of the pavement was required. Figure 6 shows the extent of cracking adjacent to six of the deflection test points after four years of trafficking, and Figure 7 shows the crack arrangement six years later.

In relation to its thickness, the subgrade strength, and the amount of traffic carried, this pavement performed less well than pavement design recommendations would indicate. This may have been partly due to the brittle sand-bitumen surfacing that readily reflected cracks in the base and which wore away in the wheel tracks until the base was exposed. Nevertheless the growth in cracking that occurred at relatively low values of traffic was unexpected and may have been due to unrecorded heavy traffic using the road for certain periods when timber was being extracted from new areas served by the road.

An examination of the results of the tests made on the subgrade soils underlying all the road sites (see Table 3) shows that for seven of the eight sites the subgrade densities were equal to or higher than the British Standard maximum dry density in the 2.5 kg (5.5 lb) rammer compaction test[23]. Since all but one of the sites were relatively recently constructed at the time when the in-situ subgrade density measurements were made, it is unlikely that traffic compaction would have contributed very much to the density of the subgrades. Hence it can be concluded that it is reasonable to base pavement designs in Malaysia on the strength of the subgrade soil assessed at the British Standard 2.5 kg rammer test maximum dry density.

One hundred and ninety measurements of the subgrade moisture content were made under the pavements at 73 different chainages (the results are summarised in Table 3). More than half of these moisture contents were equal to or drier than the optimum moisture content (OMC) of the subgrade soil in the British Standard 2.5 kg (5.5 lb) rammer compaction test, and three-quarters of them were drier than the OMC plus 2 per cent. The only places where subgrade moisture contents were wetter than this were where gross drainage deficiencies were apparent and free water was allowed to collect in the road bed. The subgrade drainage characteristics of the eight sites were representative of the great majority of roads in Penninsular Malaysia; hence it can be concluded that if reasonable provision is made to drain off any water that may collect at subgrade level, pavement designs for most road situations in Malaysia can be based on a subgrade strength assessed at the optimum moisture content in the British Standard compaction test plus 2 per cent. Only when high water tables occur need higher subgrade moisture contents be assumed.

It should be noted from Table 3 that virtually all the in-situ subgrade CBR's that were measured were greater than CBR 10, and most were greater than CBR 15. Only on site 7, which had two very poorly drained areas, were significantly lower subgrade CBR's encountered.

4.2 The pavement deflection characteristics

From the beginning of the study it was the intention to trace the deflection characteristics of the pavements, so as to build up deflection histories which could be related to the pavement performance. Desirably, deflection measurements and performance ratings would have been made on all the sites from the time when they were first constructed, so that the effect of the magnitude of the 'standard early life deflections'[11] on the subsequent performance history of the pavement could be traced. The 'standard early life deflection' of a point on the road is defined by Lister in his studies in the United Kingdom as being the mean of up to five springtime deflection measurements made early in the life of a road, each measurement being corrected to a standard temperature of 20°C. (In the United Kingdom roads are weakest in the spring.) Deflections measured during the compaction phase of the road pavement, which normally occurs over the first 12 to 18 months of trafficking, are not included in this average. In Malaysia it was not possible to adopt precisely the same standard early life deflection because:

i) the standard temperature adopted was 35°C

ii) the time scale of the study was shorter and it was necessary to establish a reference deflection over a period of not much longer than a year. Typically three or four deflection measurements taken at approximately four month intervals were averaged to give the required reference deflection.

Furthermore it was considered appropriate in Malaysia to include deflections measured during the compaction phase since on some sites these were much higher than would normally be found in the United Kingdom, and they persisted at a high level long enough to affect the subsequent life of the bituminous surfacing. Because of the differences between the early life deflections as determined in the United Kingdom studies and those adopted in Malaysia the term 'standard reference deflection' has been used in the Malaysian studies.

When the study was started in Malaysia, it was not possible to find many completely new pavements and some of the sites were selected on lengths of road that were two or three years old, and in one case on a road eight years old. By combining the results from sites with the same type of construction, it has been possible to derive a deflection criterion curve of the type produced by Lister[11] for bitumen macadam surfacings on crushed stone bases in the Malaysian environment. It was not possible, however, to use the two oldest sites for this purpose (sites 2 and 4) because their previous performance history was too uncertain. Slightly different curves were obtained for the vergeside and offside wheel tracks, a somewhat lower standard reference deflection being required in the vergeside wheel track than in the offside wheel track to ensure the same pavement life (see Figures 8 and 9). The reason for this is probably that moisture content changes in the subgrade and shoulder, contribute to pavement deterioration more strongly at the edges of the road than near the centre.

It will be seen from Figures 8 and 9 that the criterion curves are plotted only to a traffic level of 400 000 equivalent standard axles (in one direction). It would have been desirable to have continued the performance studies to higher levels of cumulative traffic but 400 000 standard axles represent eight years of trafficking at the sites concerned, which was the longest period available before maintenance programmes required the sites to be overlaid.

Pavement temperatures prevailing in Malaysia necessitated the adoption of a higher standard temperature for deflection measurements than is used in Britain.

Although the Malaysian pavement temperatures rarely exceed 50°C, they are also rarely less than 30°C in daylight hours. It was found convenient to adopt a standard temperature of 35°C to which deflections measured at other temperatures were corrected using temperature/deflection relationships of the type shown in Figure 2. It was found that below 32°C, the stiffness of the pavement increased significantly more per degree drop in temperature than above 32°C, but because of the difficulty in establishing a clear relationship at these low temperatures (for Malaysia), it is recommended that deflection surveys are only carried out when the pavement temperature is greater than 32°C.

In many countries with a marked seasonal variation in climate, it is necessary when studying the deflection history of a road, to take account of the change in strength of the pavement that occurs as a result of seasonal moisture changes in the subgrade. On none of the sites studied in Malaysia however, was any seasonal variation in deflection characteristics detected. Thus because of the relatively uniform distribution of rainfall throughout the year that is experienced on the west coast sites, and on the east coast site (site 8) where distinct wet and dry seasons are experienced, the strength of the sand subgrade was insensitive to moisture content changes.

It was not possible to develop a deflection criterion curve for the sand-cement pavement (site 8) because the early deflection history of this site was unknown, and its deflection characteristics were probably more influenced in the beginning by the regularly spaced shrinkage cracking, rather than by traffic-induced cracking.

In Figure 10, the deflection curves derived from the Malaysian sites are shown together with some derived in the United Kingdom for roughly similar types of construction. Direct comparisons cannot be made because of the different pavement assessment procedures, the different modes of failure, the different climates and the different standard temperatures to which deflections are referenced. Nevertheless the much lower curve for the Malaysian bitumen macadam surfacings must partly reflect the low fatigue life of these materials in the Malaysian climate, susceptible as they are to weathering of the binder. It is probable that much longer surfacing life, and hence pavement life, could be achieved in Malaysia if denser yet more flexible mixes of the gap-graded type were used. Modified hot rolled asphalt[27], such as has been used successfully in South Africa[28,29], would be a very suitable mix to use for road surfacings in Malaysia.

Sites 1 and 4 were overlaid with substantial thicknesses of bituminous premix (varying between 40 mm and 125 mm thick) during the later stages of the study. Deflection surveys were undertaken immediately before overlaying and three months afterwards, to determine the effect of the overlays in reducing the deflections of the pavements. Figures 11 and 12 show the results obtained. On site 1, very scattered results were obtained, no reduction in deflection being measured at many points. This may have been due to inadequate compaction of the relatively thick overlay laid at this site and to non-elastic deformation of the overlay during subsequent deflection measurements. Deflection measurements made over a longer period of time after the overlay was laid, would probably exhibit less scatter due to the compactive effect of the traffic and the hardening of the bitumen in the overlay. The overlay on Site 4 produced less scattered deflection results, but in both cases, it is apparent that the overlays had much less effect in reducing deflections than hot rolled asphalt overlays do in Britain[30]. This is clearly due to the higher temperatures that prevail in Malaysia and the type of overlay materials that were used.

5. CONCLUSIONS

The following conclusions can be drawn from this investigation:

1. Current pavement design recommendations for flexible pavements set out in Road Notes 29 and 31 can be applied with confidence in environments similar to that of Malaysia, and it is probable that the application of the Road Note 29 recommendations would result in some degree of over-design, given the difference that exists between the definitions of 'pavement failure' in UK and Malaysia.

2. Subgrade densities in Malaysia are commonly in excess of the maximum dry density of the British Standard 2.5 kg (5.5 lb) rammer compaction test, and subgrade moisture contents are unlikely to be more than two per cent wetter than the optimum moisture content given by this compaction test, except in very adverse drainage conditions.

3. Subgrade CBR values in Malaysia are commonly in excess of 10 per cent.

4. The use of sub-bases under Malaysian pavements would be advantageous.

5. An early life deflection 60×10^{-2}mm (25×10^{-3}in) on the 50 mm to 100 mm thick bitumen-macadam surfacings studied (overlying crushed-stone bases) indicates a life of 500 000 standard axles in the Malaysian environment.

6. Macadam-type bituminous overlays have markedly less effect in reducing pavement deflection in the Malaysian environment than denser mixes achieve in temperate climates.

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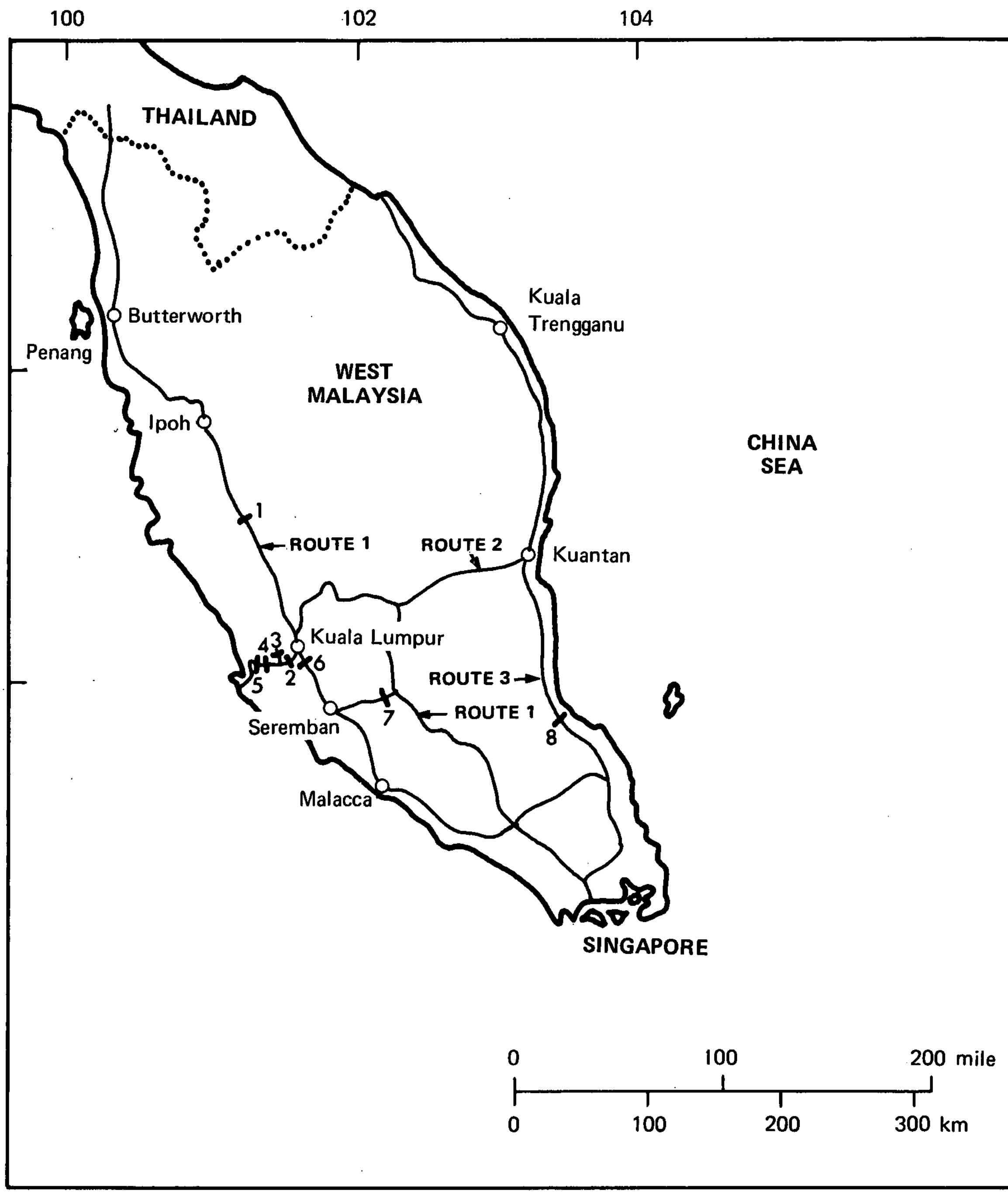

Fig. 1 TRUNK ROADS AND TEST SITE LOCATIONS IN WEST MALAYSIA

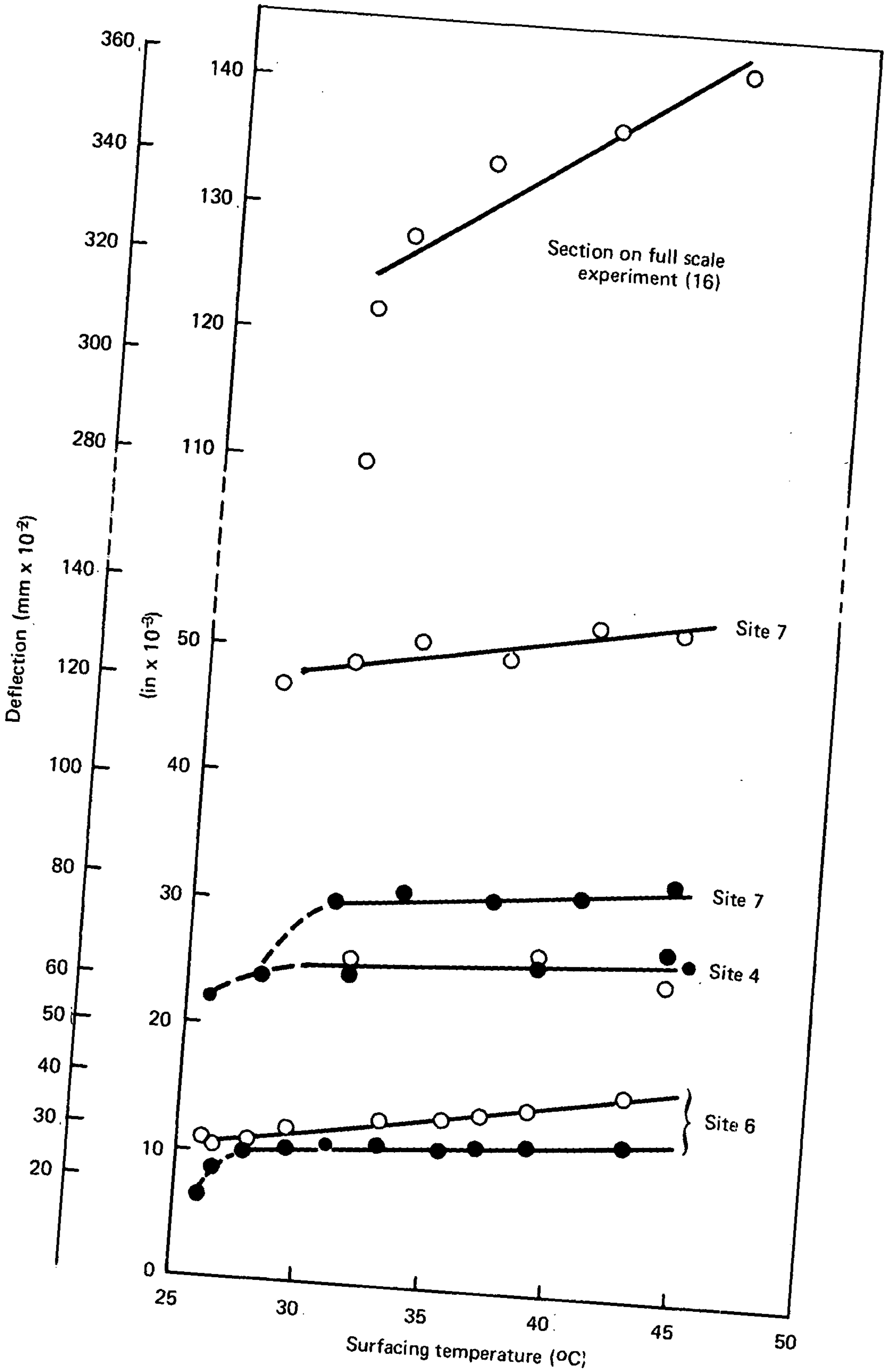

Fig. 2 TEMPERATURE/DEFLECTION RELATIONSHIPS

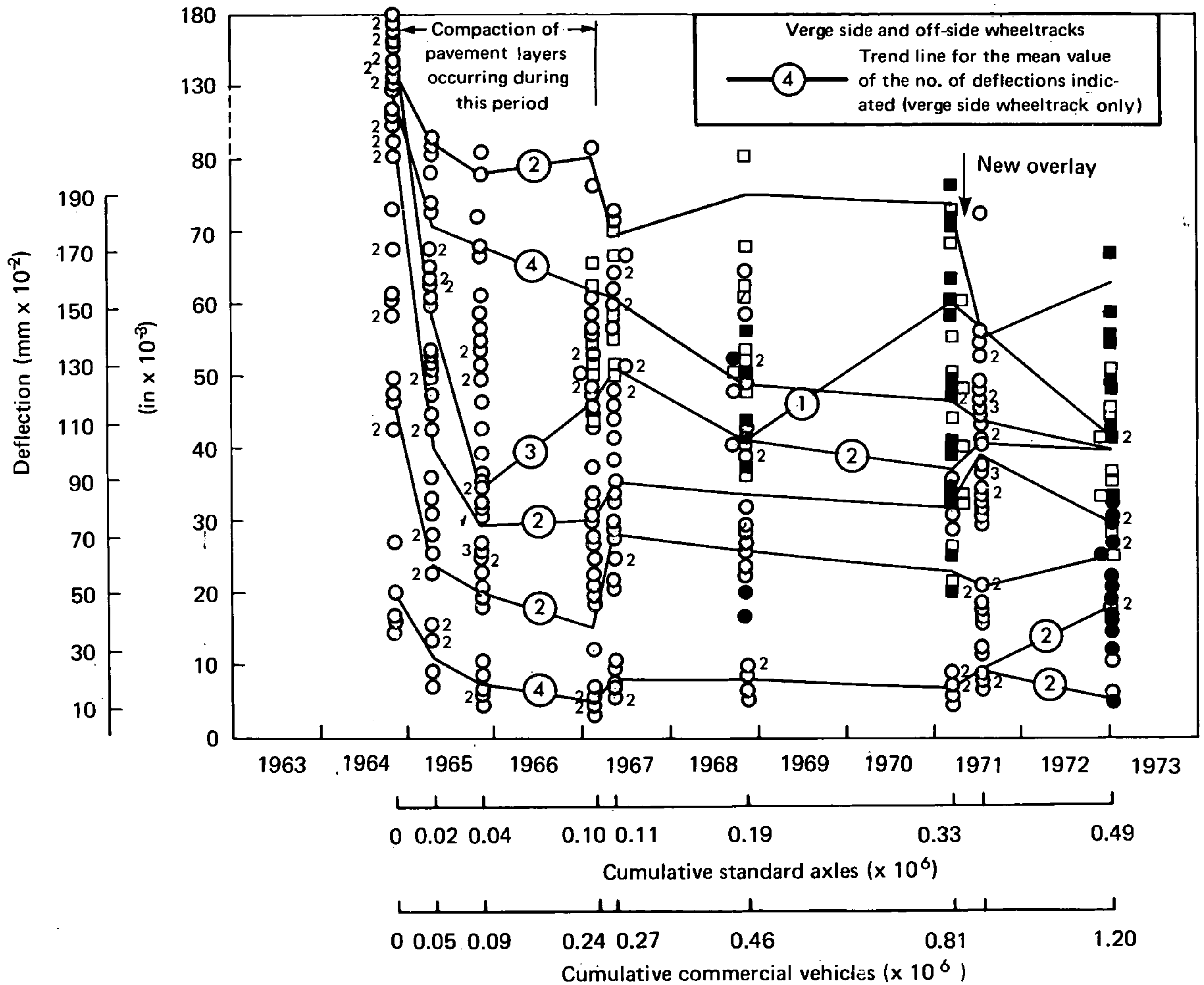

Fig. 3 DEFLECTION HISTORY CHART FOR SITE 1

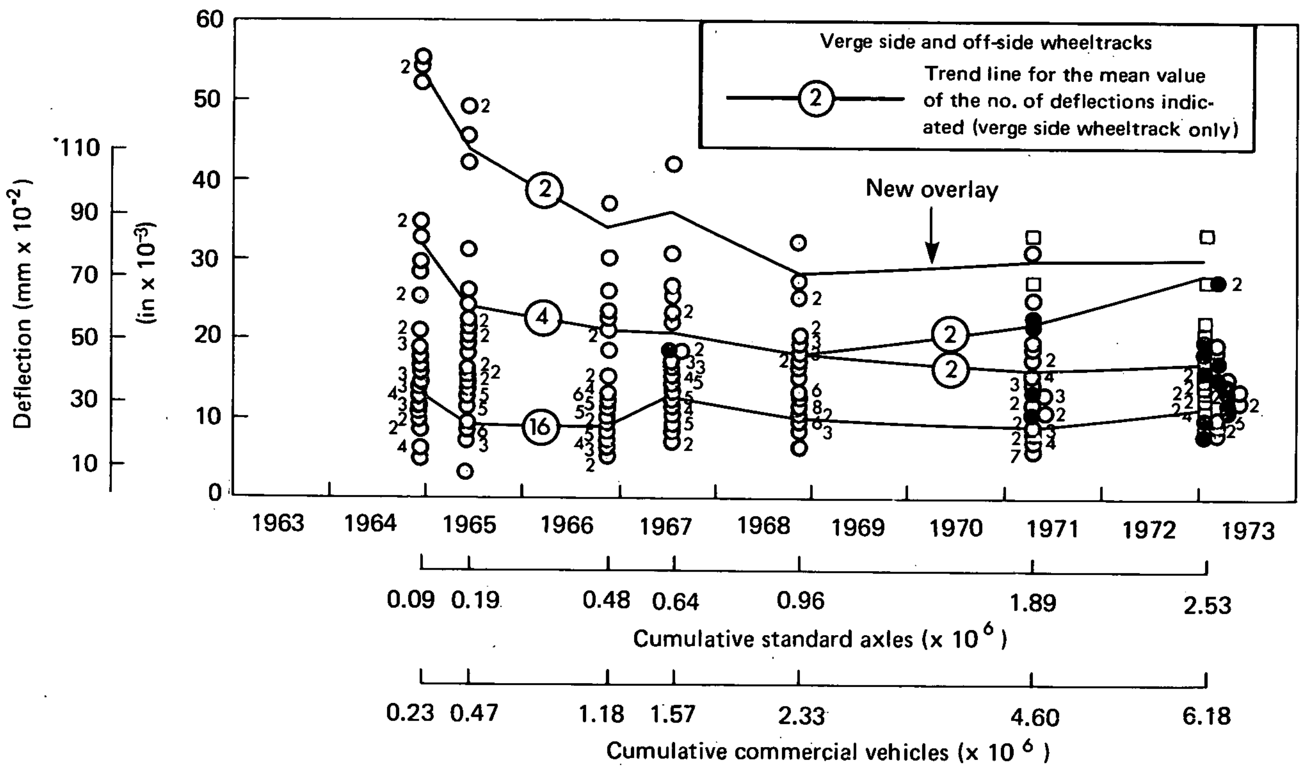

Fig. 4 DEFLECTION HISTORY CHART FOR SITE 5

				CRITICAL		FAILED	
	D \ C	1	2	3	4	5	P
	1	○	●	□	□	■	
	2	○	●	□	□	■	
	3	●	●	□	□	■	
CRITICAL	4	□	□	□	□	■	
FAILED	5	■	■	■	■	■	
	P						■

C – Cracking
D – Deformation
P – Patching

Fig. 5 SYMBOLS USED FOR RECORDING PAVEMENT CONDITION ON DEFLECTION HISTORY CHARTS (Figs 3 and 4)

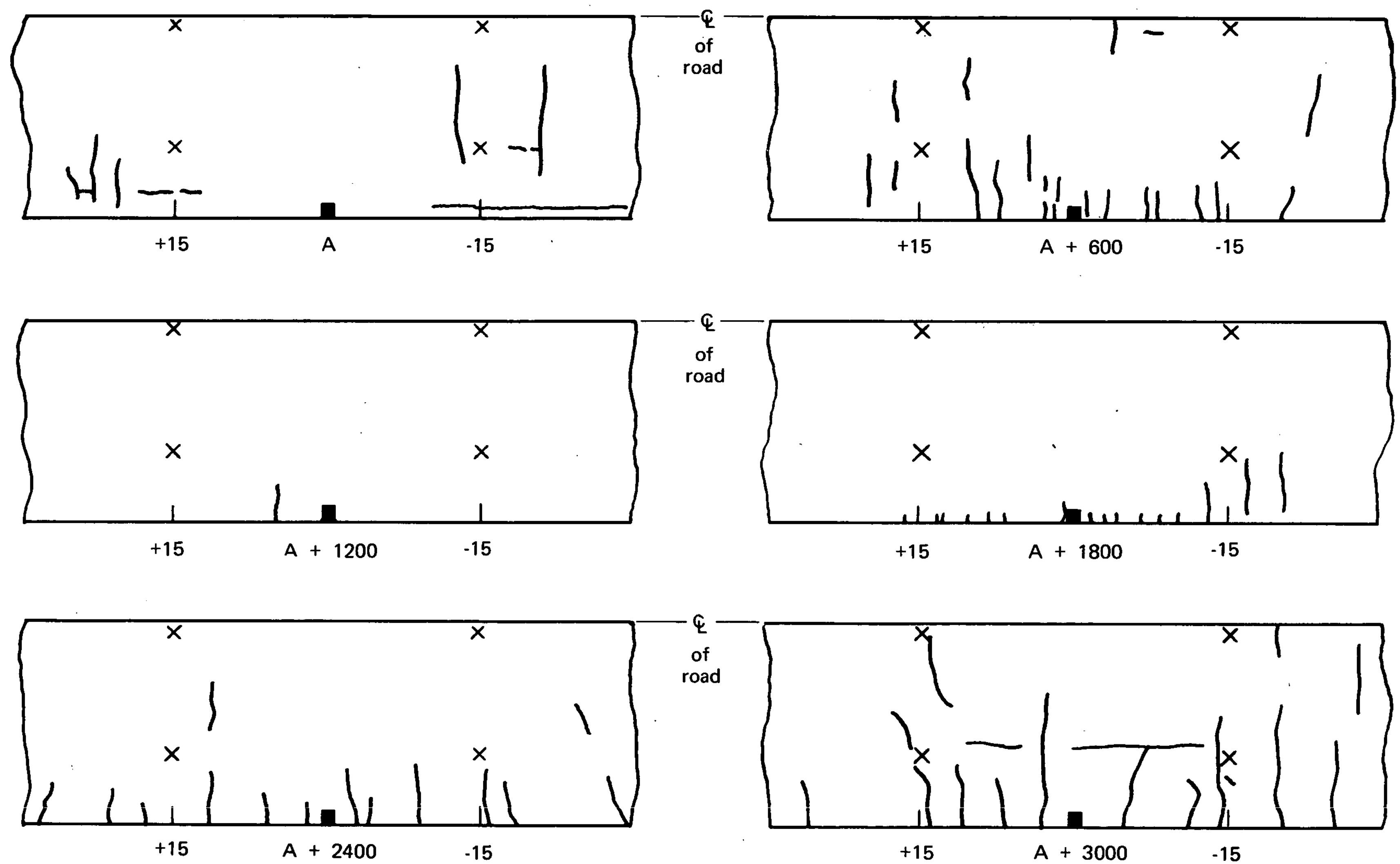

Fig. 6 THE ARRANGEMENT OF CRACKS ADJACENT TO 6 OF THE DEFLECTION TEST POINTS AT SITE 8 AFTER FOUR YEARS SERVICE

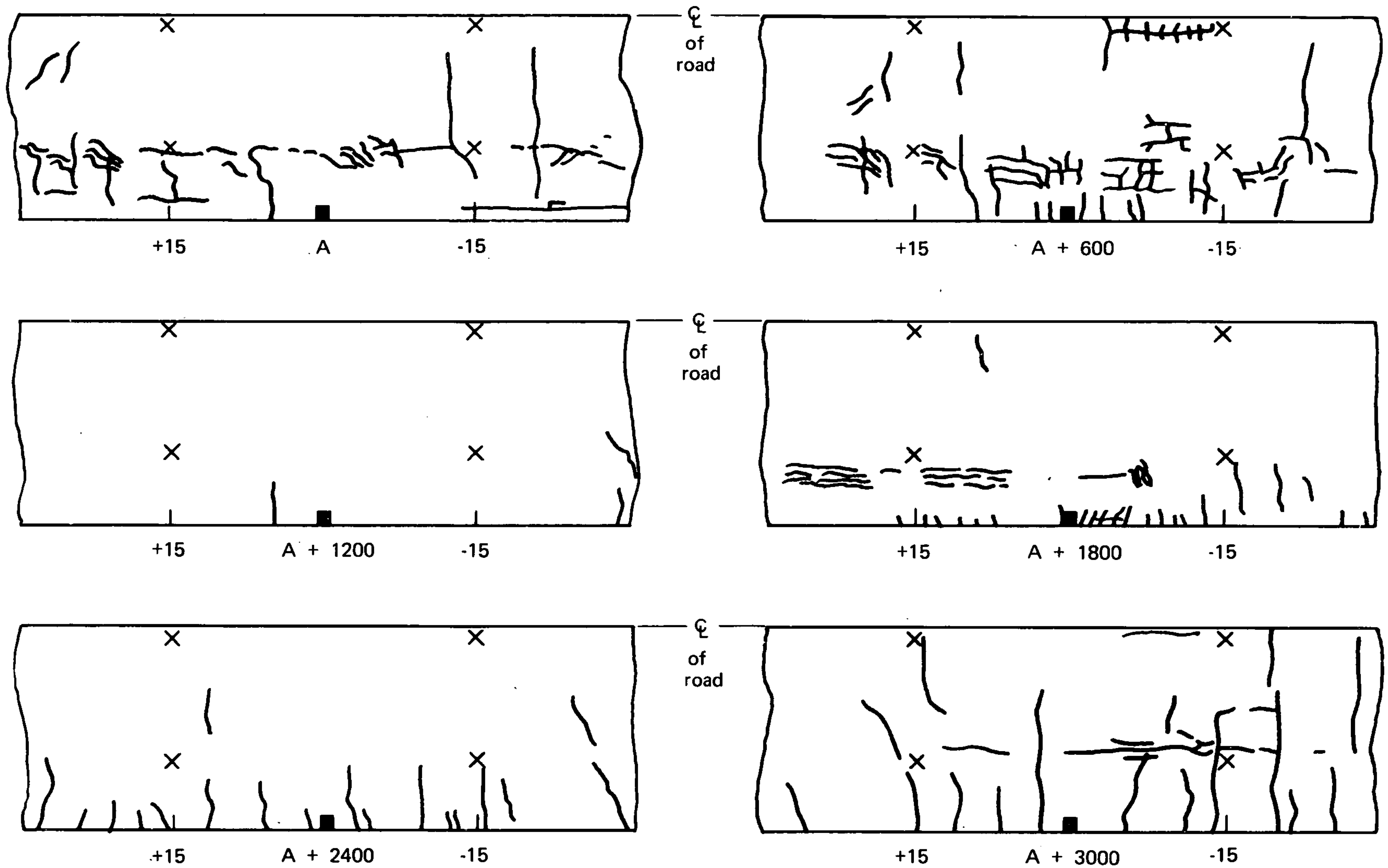

Fig. 7 THE ARRANGEMENT OF CRACKS ADJACENT TO 6 OF THE DEFLECTION TEST POINTS AT SITE 8 AFTER TEN YEARS SERVICE

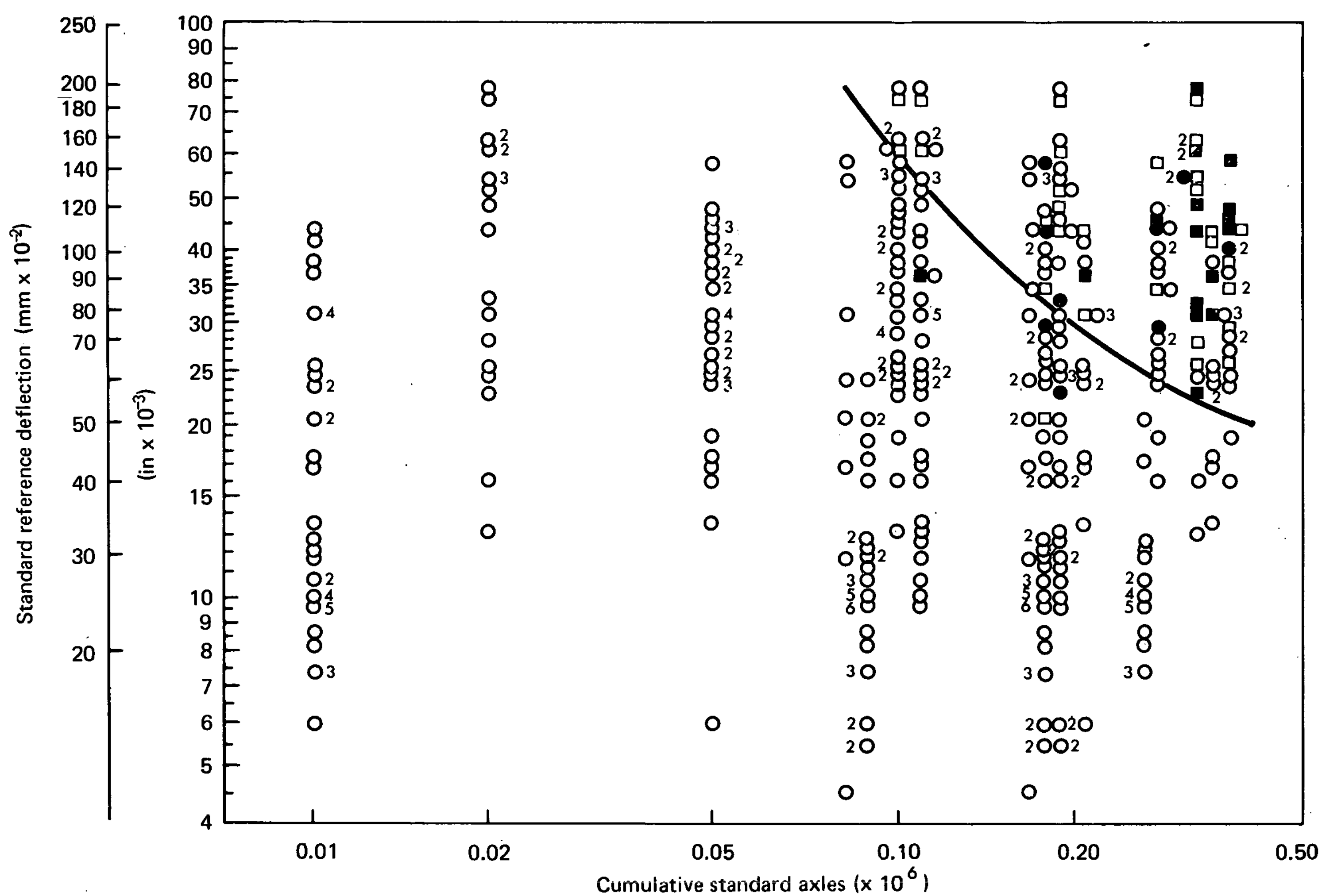

Fig. 8 DEFLECTION CRITERION CURVE (OFFSIDE WHEEL TRACK) FOR BITUMEN MACADAM SURFACING 50mm TO 100mm THICK ON CRUSHED STONE BASES IN THE MALAYSIAN ENVIRONMENT (SUBGRADE CBR >10) SITES 1, 3, 5, 6 & 7

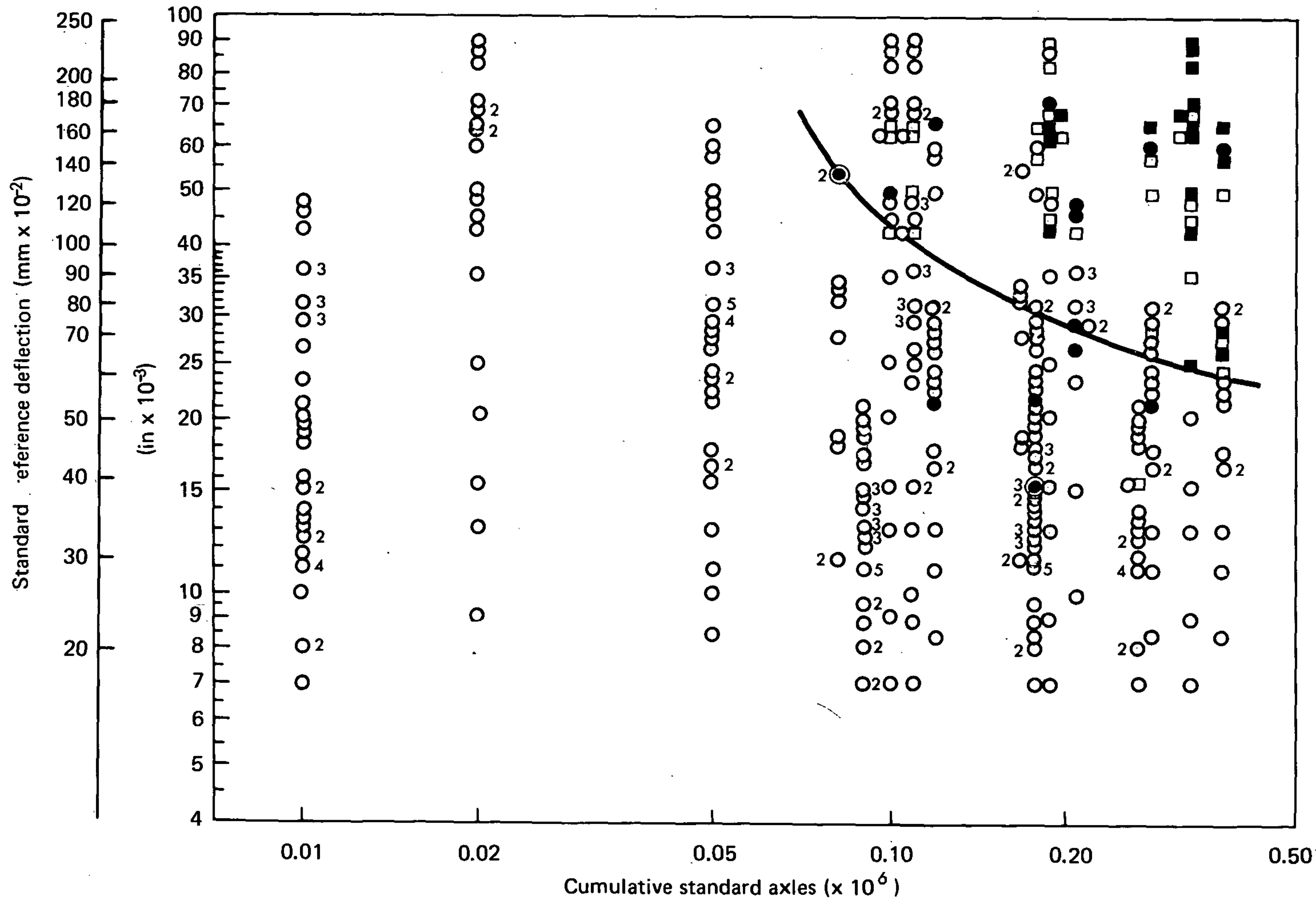

Fig. 9 DEFLECTION CRITERION CURVE (VERGE SIDE WHEEL TRACK) FOR BITUMEN MACADAM SURFACING 50mm TO 100mm THICK ON CRUSHED STONE BASES IN THE MALAYSIAN ENVIRONMENT (SUBGRADE CBR > 10) SITES 1, 3, 5, 6 & 7

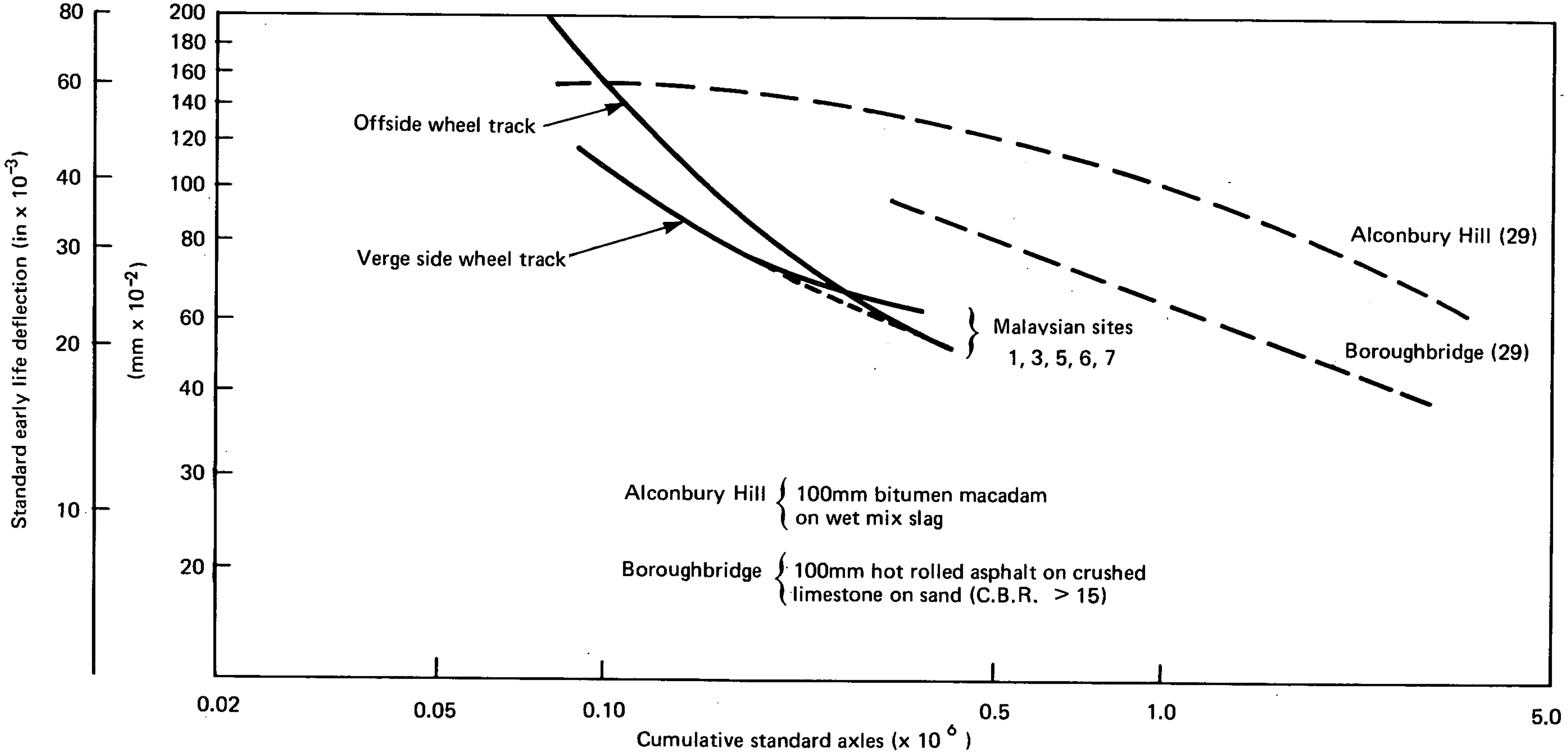

Fig. 10 COMPARISON OF SOME DEFLECTION CRITERIA CURVES DEVELOPED IN THE UNITED KINGDOM WITH THOSE FROM FIVE SITES IN WEST MALAYSIA

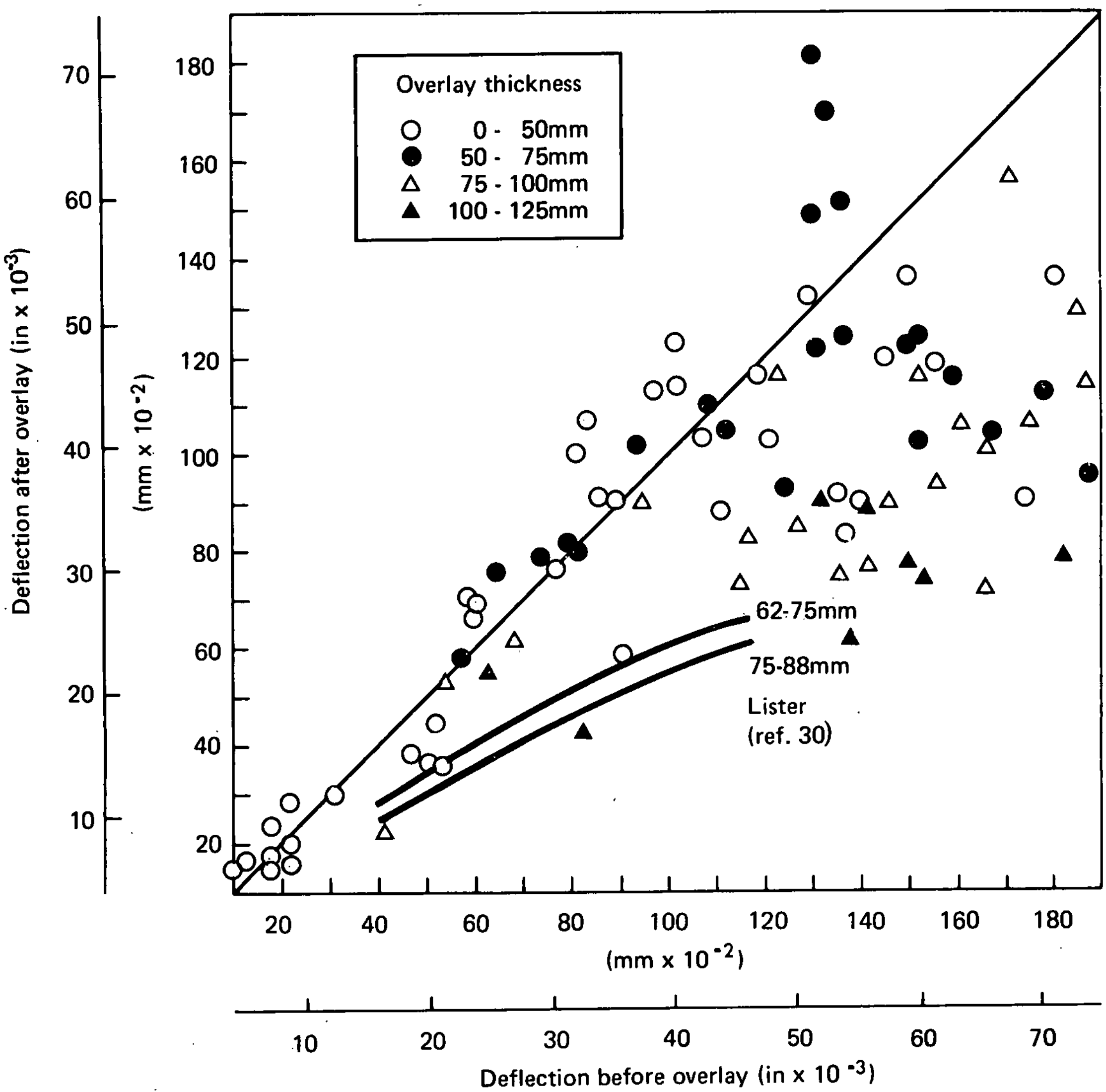

Fig. 11 SITE 1 REDUCTION IN DEFLECTION ACHIEVED BY ADDING AN OVERLAY

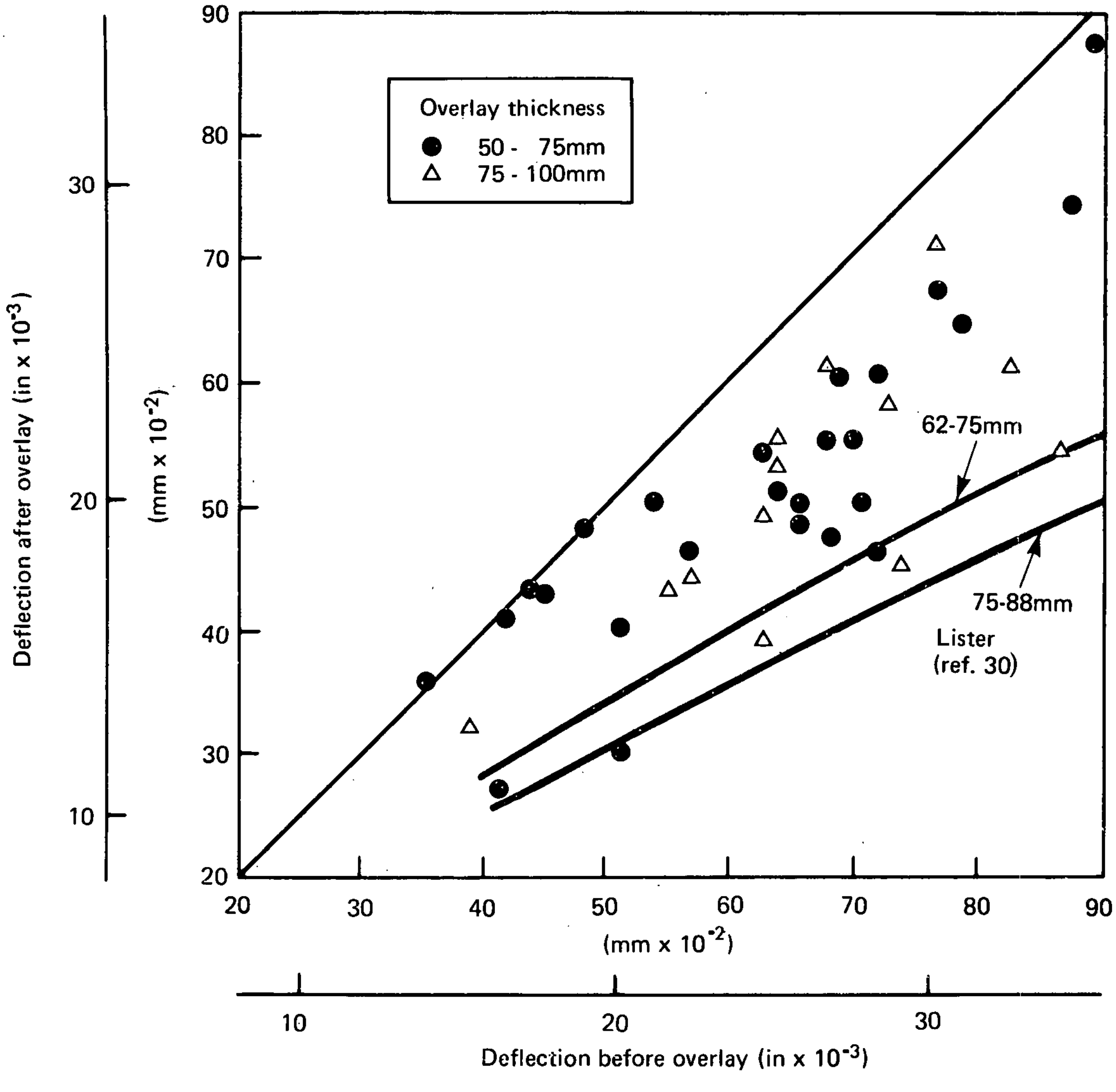

Fig. 12 SITE 4 REDUCTION IN DEFLECTION ACHIEVED BY ADDING AN OVERLAY

8. APPENDIX 1

STANDARD TRANSPORT AND ROAD RESEARCH LABORATORY
METHOD OF MAKING DEFLECTION BEAM MEASUREMENTS

1. Load a 5-ton lorry (or similar) fitted with twin rear wheels to give a load of 6350 kg (14 000 lb) on the rear axle (ie 3175 kg or 7000 lb on each pair of twin rear wheels).

2. Inflate the rear tyres to 585 kN/m^2 (85 lb/sq in). Recommended tyre size 7.50 x 20 with spacing of 45 mm (1¾ inches) between the dual wheels.

3. Mark a point on the road at which the deflection is to be measured, and position the lorry so that the rear wheels are 1¼ m (4 ft) behind the marked point.

4. Insert the deflection beam between the twin rear wheels until its measuring shoe rests on the marked point on the road. If required insert a second beam in a similar way between the other pair of twin rear wheels.

5. It is helpful in positioning the lorry and aligning the beams parallel to the lorry axis if a pointer is fixed to the lorry 1¼ m (4 ft) in front of each pair of twin rear wheels.

6. Check the beam pivot arms for free movement, adjust the footscrews if necessary, and zero the dial gauges whilst gently tapping the frame of the beam.

7. Record the dial gauge reading. (Either zero or some small positive or negative reading.)

8. Whilst the lorry is driven *slowly* forward to a point at least 3 m (10 ft) in front of the shoes of the beams, the frame of the beam should be tapped gently and the maximum and final dial gauge readings noted. Care must be taken to ensure that a wheel does not touch a beam.

9. For each beam calculate the transient deflection of the road surface by adding the difference between the first and maximum dial gauge readings to the difference between the maximum and final dial gauge readings.

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ABSTRACT

Pavement performance and deflection studies on Malaysian roads: J N BULMAN and H R SMITH: Department of the Environment Department of Transport, TRRL Laboratory Report 795: Crowthorne, 1977 (Transport and Road Research Laboratory). Details are given of the performance over a period of eleven years of normally-constructed road pavements in Malaysia. Current pavement-design recommendations are compared with the thickness and quality of the pavements studied. Pavement deflection characteristics are related to performance under traffic, and deflection-criterion curves are given for roads with crusher-run bases and bitumen-macadam surfacings in the Malaysian environment. It was found that typical Malaysian bituminous overlays reduced deflections less than might be expected from experience gained elsewhere. In spite of the high rainfall in the country and the permeable pavement construction employed, it was found that subgrade moisture contents are rarely more than 2 per cent wetter than the optimum moisture content in the British Standard 2.5 kg rammer compaction test and they are usually significantly drier than this. It is concluded that the pavement design recommendations for flexible pavements set out in Road Notes 29 and 31 can be applied with confidence in environments similar to that of Malaysia, and that the use of sub-bases in Malaysia would be advantageous.

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