TRANSPORT and ROAD
RESEARCH LABORATORY

Department of the Environment

TRRL REPORT LR 438

TEMPERATURE FREQUENCY DISTRIBUTIONS IN FLEXIBLE ROAD PAVEMENTS

by

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Crowthorne, Berkshire
1972

CONTENTS

Ownership of the Transport Research Laboratory was transferred from the Department of Transport to a subsidiary of the Transport Research Foundation on 1st April 1996.

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ABSTRACT

The deformation of flexible pavements under load is known to be temperature dependent. This report presents an analysis of pavement temperatures at varying depths for two sites in Southern Britain. It gives frequency distributions for selected months of the year of record from each site for varying depths, and shows how these distributions can be adjusted by means of long term averages of air temperature to suit varying sites.

1. INTRODUCTION

The flexural strength of flexible pavements has been shown by Monismith[1] and others to be extremely temperature dependent. Laboratory tests[2] have measured the deformation of flexible pavements under known loadings for varying temperatures. This report presents an analysis of temperatures for two flexible slabs at two sites in Southern Britain in the form of monthly frequency distributions for varying depths. Selected records most likely to be of use to Engineers are given in the Tables. The complete record of frequency distributions for each month and each depth is given elsewhere[3].

2. LAYOUT OF SITES

2.1 Alconbury

Four dummy road slabs each 2.3 m x 2.3 m (7 ft 6 in x 7 ft 6 in) were laid side by side as part of a full scale pavement design experiment at Alconbury Hill, Huntingdonshire.[4] The construction is as shown in Fig 1. Thermocouples were installed as shown in Fig 2 and connected to a strip chart multipoint temperature recorder. Originally 16 thermocouples were connected but this was later reduced to the 12 shown. The records of temperatures from the thermocouples in Sections 2 and 3 were selected as most fully covering the range of depths necessary for the analysis since digitising time was limited and the records from thermocouples Nos 4, 6, 7, 8, 9 were analysed for the complete 12 month period. Records from the remaining thermocouples in all four sections were analysed for July 1969 and February 1970 to give a winter and summer comparison with those chosen for the full analysis. Unfortunately there was no measurement of air temperature on the site.

2.2 Crowthorne

Four dummy slabs each 3.1 m x 3.1 m (10 ft x 10 ft) were laid at Crowthorne, two being of rigid construction and two of flexible construction. The construction of the two flexible slabs is as shown in Fig 3. Thermocouples were installed at the depths shown in Fig 4 and connected to a strip chart multipoint temperature recorder. An air temperature thermocouple was installed at a height of 1.2 m (4 ft) in a meteorological screen set midway between the two slabs. Records from thermocouples No 1, 2, 3, 4 in the bitumen macadam slab and the air temperature thermocouple were analysed for the complete 12 month period. Since records from the asphalt slab were incomplete they were not digitised.

3. METHOD OF ANALYSIS

3.1 Digitising and processing

Records from both sites were in the form of strip charts from multipoint recorders printing out at approximately 5 minute intervals. The charts were checked and 12 months of continuous record for each site selected. For Alconbury the period covered was March 1969 – February 1970 and for Crowthorne September 1969 – August 1970. Unfortunately it was not possible to select the same period for each site due to recorder breakdowns and incomplete records. The selected charts were checked manually for clock regularity and record losses due to power failures and were then time marked in 24 hour and whole month periods.

The chart traces were converted to digital output on punched paper tape using a trace reading table. Readings were taken at 20 minute intervals for each trace digitised, comprising approximately 2000 readings for each trace per month of record. Temperature frequency distribution diagrams for each thermocouple and each calendar month were prepared from the tapes using the Laboratory's ICL 4.70 Computer. These show the percentage time of occurrence of the slab temperatures within $3^{o}C$ temperature bands for each hour of the day. The hourly values were also summed to give the frequency distribution for the whole day. These were then checked and copied in the form shown in the Tables. The tables give the distribution of temperature for each month and depth.

3.2 Air temperature comparison

A problem in drawing conclusions from the frequency distribution diagrams is that only 12 months data are available. To convert to long term averages a comparison between slab temperatures and air temperatures, for which long term averages exist, must be made. No air temperatures were available at Alconbury and only a short period of record at Crowthorne. Temperatures for the period of analysis were therefore calculated for each site from the records of 6 Meteorological Office stations known to have reliable data and long term averages. The stations selected for Alconbury were Cambridge (Botanical Gardens), Wittering and Cardington. These three stations form a triangle with Alconbury approximately in the centre. The stations selected for Crowthorne were Heathrow (Airport), Abingdon and South Farnborough. These again form a triangle around Crowthorne. The monthly 'mean' air temperature as published by the Meteorological Office is the monthly average of the recorded daily maximum and minimum temperatures. It is not therefore a true mean. For the Crowthorne site complete air temperature records were available and both the true mean and Meteorological Office 'mean' were calculated and are included in Table 1. The average difference was $0.4^{o}C$. For 7 months the Meteorological Office 'mean' was the higher and for 5 months the true mean was the higher. In the text the Meteorological Office 'mean' is shown in parenthesis to differentiate it from the true mean. The 'mean' monthly temperatures and equivalent 30 year 'mean' for each station were calculated

from mean maximum and mean minimum for each month. The 'mean' temperatures for Heathrow are an average 1°C higher than South Farnborough and Abingdon. This may be due to the built up nature of the area, but since there was no other station in the area the records were accepted. These calculated monthly 'means' and long term 'means' are shown in Table 1 together with the mean monthly temperatures for varying depths in the slabs.

4. ANALYSIS OF RESULTS

4.1 Temperature distribution and adjustment

The frequency distributions shown in the Tables give a representation of the distribution of temperature for varying depths within the slabs for the period of record. For converting to long term averages a monthly mean temperature for each depth and month was calculated and used for comparison with 'mean' air temperature. These are included in Table 1. In Figs 5 and 6 the relationships between 'mean' air temperatures and mean slab temperatures are shown. There is quite a scatter on the individual points but this is to be expected for the following reasons:

(a) The monthly 'mean' air temperatures are not from data recorded on site but calculated from records from 3 other stations.

(b) As shown above the 'mean' air temperature differs on average by nearly half a degree from the true mean air temperature.

(c) As well as the radiation balance and air temperature, the temperature of a road slab depends on heat losses to air moving over the surface, the evaporation of rainfall, and snow or ice cover.

These must inevitably introduce some scatter in a relationship between 'mean' air temperature and slab temperatures. There is however a sufficiently good relationship to adjust the measured temperature frequency distribution for months when the 'mean' monthly air temperature differs significantly from the long term 'mean'.

In Figs 5 and 6 the two extreme depths for each slab are shown, the curves being fitted by least squares, the other depths giving lines between these extremes. Because of the method of analysis adjustments to the temperature frequency distributions can only be made by shifting the temperature scale by 3°C units. In no case is more than one 3°C shift required.

4.2 Depth of construction

Comparison of Figs 5 and 6 would seem to indicate that for the colder months of the year the mean monthly temperatures of the asphalt surfaced slabs at Alconbury are as much as 3.5°C warmer than the bitumen macadam slab at Crowthorne.

Table 1 shows that the air temperature throughout the year for the two sites is very similar and unlikely to cause an appreciable difference in slab temperature. Table 3 would indicate that the surfacing material used ie asphalt or bitumen macadam, seems to have little effect on the temperature. Table 2 shows that differences in site exposure, soil type and soil moisture between the two sites seem to make a small difference, the Crowthorne slab being up to 1.3°C warmer in February, and up to 1.0°C cooler in July.

A straight comparison of temperatures from the 305 mm asphalt and 142 mm macadam slabs at Crowthorne from digitised records was impossible due to incompleteness of records from the asphalt slab. However daily maximum and minimum temperatures for both slabs were taken off by hand for the months available for two comparable depths within each slab and these results are shown plotted in Figs 7 and 8, the curves being fitted by least squares. It appears from these two figures that the deeper 305 mm asphalt slab is approximately 2°C warmer than the shallower 152 mm macadam slab throughout the year and this difference in temperature due to depth of construction would seem to be confirmed by the figures in Table 4.

5. CONCLUSIONS

The monthly distributions of temperature and mean slab temperatures are summarized here and given in more detail elsewhere.[3]

There would seem to be a sufficiently good relationship between 'mean' air temperature predicted from records of nearby stations and mean slab temperatures to adjust the monthly distributions at various depths to the long term 'mean' for the two sites[3] or alternatively to arrive at typical distributions for any other site in Southern Britain for which long term temperature data are available. A site similar to that at Crowthorne with a 152 mm (6 in) Bitumen Macadam slab has been installed in Scotland and records from this site should give data for checking whether the distributions will be applicable for other parts of Britain.

It is possible that there is a temperature effect due to depth of construction. This is particularly noticeable in the colder months where temperatures of the deeper slabs tend to be up to 3°C warmer than the shallower slabs. There is no noticeable difference of temperature between bituminous macadam and asphalt surfaced slabs of the same depth. Since records were incomplete it has not been possible to prove that there is a difference of temperature due to depth of construction but it is suggested that further records be collected from the Crowthorne site to give sufficient data to prove or disprove this hypothesis.

6. ACKNOWLEDGEMENT

The Alconbury Hill temperature site was installed by the Pavement Design Section and the Crowthorne site by the Climate and Environment Section both sections forming part of the Design Division of the Road Research Laboratory. The analysis was carried out as part of the programme of the Climate and Environment Section, (Section Leader Mr L H Watkins).

7. REFERENCES

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TABLE 1

Mean Monthly Temperatures

CROWTHORNE

	Macadam Slab Temperatures				Air Temperatures			
					Observed		Calculated	
	Surface	44 mm 1¾ in	82 mm 3¼ in	133 mm 5¼ in	True Mean	'Mean'	'Mean'	Long Term 'Mean'
Jan	2.5	2.7	2.8	2.7	3.6	3.4	4.3	3.8
Feb	2.4	2.6	2.7	2.7	3.0	2.9	3.5	4.1
Mar	4.2	4.4	4.4	4.1	3.1	3.6	4.0	6.3
Apr	9.0	8.9	8.7	8.5	5.6	6.1	7.2	9.0
May	19.5	18.8	18.4	17.7	12.2	12.4	13.6	12.0
Jun	25.7	25.2	24.9	24.3	16.6	16.1	17.4	16.3
Jul	22.2	21.8	21.6	21.2	15.4	15.3	16.3	17.2
Aug	22.1	21.9	21.7	21.3	15.6	15.8	16.9	16.8
Sept	17.9	18.1	17.9	17.7	13.8	14.3	14.8	14.4
Oct	13.9	14.1	14.1	14.1	12.0	12.9	13.4	10.6
Nov	4.7	5.5	5.7	6.0	5.0	5.5	6.0	7.0
Dec	1.6	2.1	2.4	2.4	3.2	2.5	3.3	4.8

ALCONBURY

	Asphalt Slab Temperatures (Slabs 2 and 3)						
	19 mm ¾ in	38 mm 1½ in	102 mm 4 in	203 mm 8 in	356 mm 14 in	'Mean'	Long Term 'Mean'
Jan	5.5	5.4	5.4	5.4	6.1	3.6	3.3
Feb	4.6	4.6	4.7	4.4	5.5	3.2	3.7
Mar	5.1	5.0	4.9	4.5	4.7	3.4	5.9
Apr	12.8	12.5	12.0	10.8	10.5	7.6	8.5
May	18.3	18.0	17.5	16.0	15.8	12.0	11.5
Jun	23.6	23.4	22.6	20.7	20.5	13.8	14.7
Jul	25.9	25.7	25.1	23.9	23.5	17.4	16.6
Aug	21.6	21.3	21.1	20.2	20.7	16.4	16.2
Sep	18.5	18.3	17.8	17.4	17.6	14.3	14.1
Oct	14.8	14.7	14.4	14.4	14.8	13.1	10.2
Nov	7.0	6.4	6.6	6.8	8.7	5.7	6.6
Dec	4.2	4.1	4.3	4.4	5.6	3.1	4.5

TABLE 2

Comparison of Asphalt Slab Temperatures at Alconbury and Crowthorne (Monthly means)

	ALCONBURY (Slabs 2 and 3)			CROWTHORNE (305 mm Asphalt)		
	38 mm 1½ in	102 mm 4 in	'Mean' Air	'Mean' Air	57 mm 2¼ in	121 mm 4¾ in
Feb	4.6	4.7	3.2	3.5	6.5	6.5
July	25.7	25.1	17.4	16.3	25.1	24.1
	Corrected for differing air temperature					
Feb	5.2	5.2			6.5	6.5
July	24.1	23.7			25.1	24.1

TABLE 3

Comparison of Asphalt and Bitumen Macadam Slab Temperatures at Alconbury (Monthly means)

	Asphalt (Slabs 2 and 3)			Bitumen Macadam (Slab 4)		
	38 mm 1½ in	102 mm 4 in	203 mm 8 in	38 mm 1½ in	102 mm 4 in	203 mm 8 in
Feb	4.6	4.7	4.4	4.4	4.5	4.8
July	25.7	25.1	23.9	25.5	24.9	23.9

TABLE 4

Comparison of Bitumen Macadam Temperatures at Crowthorne and Alconbury (Monthly means)

	ALCONBURY (Slab 4)				CROWTHORNE (152 mm Macadam)			
	38 mm 1½ in	102 mm 4 in	203 mm 8 in	'Mean' Air	44 mm 1¾ in	82 mm 3¼ in	133 mm 5¼ in	'Mean' Air
Feb	4.4	4.5	4.8	3.2	2.6	2.7	2.7	3.5
July	25.5	24.9	23.9	17.4	21.8	21.6	21.2	16.3

Deg C°	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	Day
57 - 60																									
54 - 57																									
51 - 54																									
48 - 51																									
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42 - 45																									
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33 - 36																									
30 - 33																									
27 - 30																									
24 - 27																									
21 - 24																									
18 - 21																									
15 - 18															2.8	4.2	1.4								0.3
12 - 15													2.8	4.2	2.8	1.4	2.8	4.2							0.8
9 - 12		4.2	1.4								5.6	13.9	20.8	40.3	43.1	38.9	33.3	9.7	8.3	8.3	2.8				9.6
6 - 9	18.1	11.1	13.9	12.5	9.7	8.3	6.9	8.3	8.3	9.7	11.1	25.0	37.5	38.9	44.4	48.6	47.2	47.2	38.9	29.2	27.8	20.8	18.1	16.7	23.3
3 - 6	29.2	31.9	26.4	22.2	27.8	31.9	31.9	27.8	26.4	36.1	44.4	30.6	26.4	12.5	2.8	2.8	11.1	34.7	45.8	44.4	36.1	37.5	37.5	36.1	28.9
0 - +3	45.8	44.4	52.8	55.6	48.6	43.1	43.1	43.1	44.4	38.9	36.1	30.6	12.5	4.2	4.2	4.2	4.2	4.2	6.9	18.1	33.3	41.7	40.3	40.3	30.8
-3 - 0	6.9	8.3	5.6	9.7	13.9	16.7	18.1	20.8	20.8	15.3	2.8												4.2	6.9	6.3
-3 - -6																									
-6 - -9																									

TABLE 5 102 mm (4 in) Rolled Asphalt Slab at Alconbury 38 mm (1½ in) depth February showing for each hour of the day the number of observations within each 3°C band expressed as a percentage of the total observations for that hour. These are averaged to give in the last column a percentage for the whole day.

Deg C°	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	Day
57 - 60																									
54 - 57																									
51 - 54																									
48 - 51																									
45 - 48																									
42 - 45																									
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30 - 33																									
27 - 30																									
24 - 27																									
21 - 24																									
18 - 21																									
15 - 18															2.8										0.1
12 - 15													2.8	5.6	5.6	6.9	4.2	1.4							1.1
9 - 12	4.2	4.2	2.8							1.4	8.3	18.1	25.0	31.9	37.5	34.7	27.8	15.3	8.3	5.6	4.2	4.2	4.2	4.2	10.1
6 - 9	4.2	4.2	1.4	4.2	4.2	4.2	4.2	8.3	8.3	8.3	11.1	22.2	38.9	44.4	38.9	44.4	50.0	43.1	29.2	20.8	15.3	12.5	13.9	9.7	18.6
3 - 6	33.3	29.2	30.6	31.9	29.2	29.2	33.3	27.8	31.9	36.1	41.7	34.7	19.4	9.7	6.9	5.6	13.9	33.3	50.0	34.7	37.5	37.5	30.6	31.9	29.2
0 - 3	50.0	51.4	56.9	51.4	50.0	50.0	43.1	43.1	38.9	37.5	38.9	25.0	13.9	8.3	8.3	8.3	4.2	6.9	12.5	38.9	43.1	45.8	50.0	48.6	34.4
-3 - 0	8.3	11.1	8.3	12.5	16.7	16.7	19.4	20.8	20.8	16.7													1.4	5.6	6.6
-3 - -6																									
-6 - -9																									

TABLE 6 203 mm (8 in) Bitumen Macadam Slab at Alconbury 38 mm (1½ in) depth February showing for each hour of the day the number of observations within each 3°C band expressed as a percentage of the total observations for that hour. These are averaged to give in the last column a percentage for the whole day.

Deg C°	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	Day
57 - 60																									
54 - 57																									
51 - 54																									
48 - 51																									
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42 - 45																									
39 - 42																									
36 - 39																									
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27 - 30																									
24 - 27																									
21 - 24																									
18 - 21																									
15 - 18																									
12 - 15																									
9 - 12												2.6	2.6	5.1	6.4	7.7	6.4								1.3
6 - 9	3.8	3.8	7.7	5.1	3.8	9.0	11.5	11.5	11.5	11.5	11.5	15.4	37.2	43.6	51.3	51.3	46.2	37.2	29.5	19.2	17.9	15.4	15.4	7.7	19.9
3 - 6	34.6	29.5	23.1	23.1	23.1	17.9	11.5	3.8	3.8	5.1	17.9	32.1	25.6	23.1	15.4	17.9	24.4	39.7	35.9	37.2	28.2	26.9	23.1	32.1	23.1
0 - 3	28.2	29.5	30.8	29.5	29.5	35.9	34.6	43.6	42.3	46.2	42.3	23.1	11.5	7.7	7.7	3.8	3.8	3.8	15.4	24.4	30.8	33.3	34.6	35.9	26.2
-3 - 0	33.3	37.2	38.5	42.3	43.6	37.2	42.3	41.0	42.3	37.2	28.2	26.9	23.1	20.5	19.2	19.2	19.2	19.2	19.2	19.2	23.1	24.4	26.9	24.4	29.5
-3 - -6																									
-6 - -9																									

TABLE 7 152 mm (6 in) Bitumen Macadam Slab at Crowthorne 44 m (1¾ in) depth February showing for each hour of the day the number of observations within each 3°C band expressed as a percentage of the total observations for that hour. These are averaged to give in the last column a percentage for the whole day.

Deg C°	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	Day
57 - 60																									
54 - 57																									
51 - 54																									
48 - 51																									
45 - 48														2.3	5.7	6.9	6.9	1.1							1.0
42 - 45													1.1	8.0	14.9	13.8	13.8	12.6	1.1						2.7
39 - 42												2.3	14.9	23.0	11.5	11.5	8.0	6.9	12.6	1.1					3.8
36 - 39												12.6	19.5	10.3	12.6	12.6	13.8	14.9	10.3	12.6	1.1				5.0
33 - 36										1.1	11.5	25.3	10.3	8.0	10.3	12.6	11.5	11.5	16.1	14.9	13.8	2.3	3.4		6.4
30 - 33										5.7	24.1	8.0	9.2	4.6	4.6	5.7	11.5	14.9	16.1	14.9	13.8	14.9	6.9	1.1	6.5
27 - 30	9.2								2.3	25.3	13.8	13.8	16.1	16.1	16.1	10.3	6.9	10.3	11.5	21.8	24.1	18.4	12.6	16.1	10.2
24 - 27	25.3	26.4	19.5	5.7				5.7	20.7	17.2	21.8	11.5	13.8	13.8	11.5	12.6	11.5	9.2	13.8	11.5	14.9	19.5	28.7	23.0	14.1
21 - 24	27.6	34.5	29.9	35.6	28.7	21.8	24.1	40.2	44.8	24.1	10.3	17.2	5.7	3.4	3.4	6.9	9.2	9.2	4.6	9.2	12.6	20.7	20.7	28.7	19.7
18 - 21	27.6	25.3	29.9	33.3	44.8	49.4	49.4	34.5	18.4	20.7	12.6	9.2	8.0	10.3	6.9		3.4	4.6	10.3	3.4	6.9	11.5	12.6	20.7	18.9
15 - 18	6.9	10.3	16.1	8.0	9.2	11.5	10.3	9.2	10.3	4.6	5.7		1.1		2.3	6.9	3.4	4.6	3.4	10.3	12.6	12.6	13.8	6.9	7.5
12 - 15	3.4	3.4	4.6	17.2	17.2	17.2	16.1	10.3	3.4	1.1													1.1	3.4	4.1
9 - 12																									
6 - 9																									
3 - 6																									
0 - 3																									
-3 - 0																									
-3 - -6																									
-6 - -9																									

TABLE 8 102 mm (4 in) Rolled Asphalt Slab at Alconbury 38 mm (1½ in) depth July showing for each hour of the day the number of observations within each 3°C band expressed as a percentage of the total observations for that hour. These are averaged to give in the last column a percentage for the whole day.

Deg C°	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	Day
57 - 60																									
54 - 57																									
51 - 54																									
48 - 51																									
45 - 48													2.3	6.9	11.5	11.5	11.5	3.4							1.5
42 - 45													5.7	14.9	14.9	10.3	14.9	8.0	1.1						2.9
39 - 42											1.1	5.7	20.7	14.9	10.3	16.1	12.6	12.6	8.0						4.3
36 - 39											3.4	27.6	12.6	10.3	9.2	6.9	11.5	11.5	11.5	4.6					4.5
33 - 36											23.0	9.2	9.2	8.0	10.3	13.8	10.3	20.7	16.1	20.7	5.7	1.1			6.2
30 - 33										18.4	14.9	9.2	6.9	3.4	9.2	5.7	14.9	12.6	16.1	16.1	17.2	8.0			6.4
27 - 30									4.6	20.7	6.9	13.8	18.4	19.5	10.3	11.5	4.6	5.7	16.1	24.1	26.4	18.4	18.4	5.7	9.4
24 - 27	26.4	17.2	8.0	6.9	6.9	6.9	3.4	6.9	20.7	18.4	18.4	12.6	8.0	9.2	10.3	9.2	6.9	10.3	11.5	9.2	13.8	29.9	26.4	35.6	13.9
21 - 24	21.8	24.1	23.0	16.1	11.5	8.0	12.6	40.2	40.2	20.7	14.9	12.6	8.0	2.3	4.6	8.0	12.6	4.6	5.7	9.2	17.2	17.2	24.1	23.0	15.9
18 - 21	28.7	31.0	41.4	48.3	46.0	42.5	48.3	29.9	18.4	14.9	11.5	9.2	8.0	6.9	4.6		1.1	6.9	2.3	3.4	8.0	11.5	18.4	20.7	29.3
15 - 18	12.6	13.8	10.3	11.5	16.1	21.8	16.1	11.5	11.5	5.7	5.7			3.4	4.6	6.9	6.9	6.9	11.5	12.6	11.5	10.3	9.2	8.0	9.5
12 - 15	10.3	12.6	13.8	13.8	13.8	16.1	17.2	11.5	4.6	1.1												3.4	3.4	6.9	5.4
9 - 12					2.3	3.4	2.3																		0.3
6 - 9		1.1	3.4	3.4	3.4	1.1																			0.5
3 - 6																									
0 - 3																									
-3 - 0																									
-3 - -6																									
-6 - -9																									

TABLE 9 203 mm (8 in) Bitumen Macadam Slab at Alconbury 38 mm (1½ in) depth July showing for each hour of the day the number of observations within each 3°C band expressed as a percentage of the total observations for that hour. These are averaged to give in the last column a percentage for the whole day.

Deg C°	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	Day
57 - 60																								
54 - 57																								
51 - 54																								
48 - 51																								
45 - 48																								
42 - 45														1.1	3.2	3.2	3.2							0.4
39 - 42													2.2	2.2				3.2						0.3
36 - 39												2.2	1.1	8.6	18.3	17.2	11.8	2.2	3.2	1.1				2.7
33 - 36											1.1	2.2	9.7	10.8	1.1	2.2	7.5	15.1	10.8	2.2	1.1			2.6
30 - 33											3.2	11.8	10.8	1.1	4.3	9.7	10.8	10.8	10.8	15.1	3.2	2.2		3.9
27 - 30										3.2	11.8	12.9	16.1	23.7	25.8	24.7	22.6	20.4	20.4	11.8	14.0	3.2	3.2	3.2	9.1
24 - 27	3.2	3.2	3.2	1.1					2.2	11.8	18.3	16.1	11.8	14.0	22.6	17.2	12.9	10.8	11.8	18.3	20.4	20.4	7.5		9.5
21 - 24	9.7	4.3		2.2	3.2	1.1		2.2	15.1	24.7	15.1	16.1	19.4	19.4	9.7	15.1	28.0	33.3	34.4	32.3	24.7	22.6	24.7	24.7	15.9
18 - 21	35.5	33.3	30.1	26.9	19.4	15.1	17.2	30.1	37.6	32.3	41.9	32.3	24.7	19.4	15.1	10.8	3.2	4.3	8.6	19.4	34.4	43.0	40.9	38.7	25.6
15 - 18	51.6	47.3	47.3	45.2	45.2	51.6	55.9	57.0	44.1	28.0	8.6	6.5	4.3								2.2	8.6	23.7	33.3	23.3
12 - 15		11.8	19.4	24.7	32.3	32.3	26.9	10.8	1.1																6.6
9 - 12																									
6 - 9																									
3 - 6																									
0 - 3																									
-3 - 0																									
-3 - -6																									
-6 - -9																									

TABLE 10 152 mm (6 in) Bitumen Macadam Slab at Crowthorne 44 mm (1¾ in) depth July showing for each hour of the day the number of observations within each 3°C band expressed as a percentage of the total observations for that hour. These are averaged to give in the last column a percentage for the whole day.

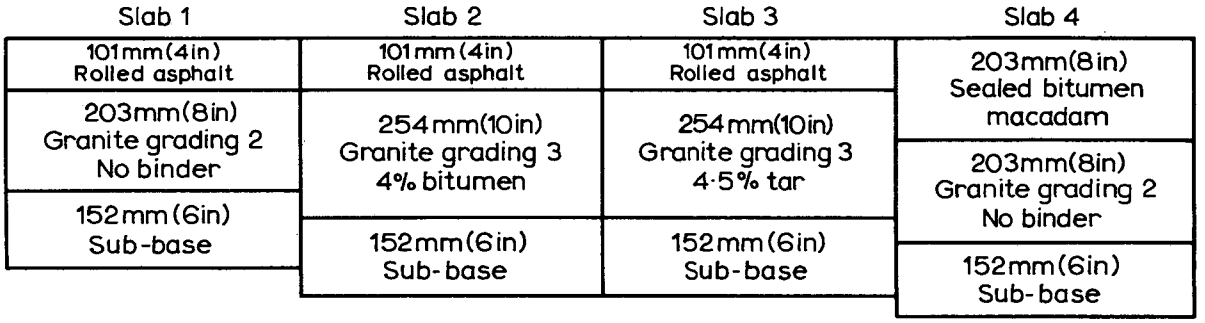
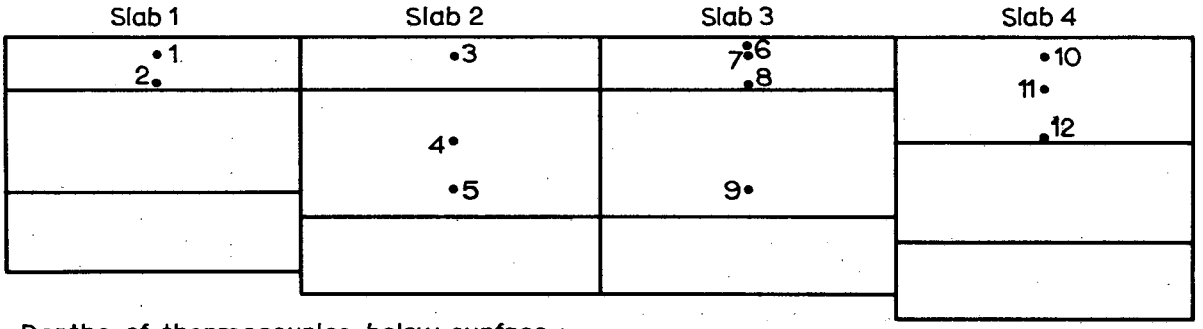


Fig. 1. SECTION THROUGH SLABS AT ALCONBURY (NOT TO SCALE) SHOWING CONSTRUCTION OF EACH SLAB. EACH SLAB 2·3m x 2·3m (7ft 6in x 7ft 6in) IN AREA



Depths of thermocouples below surface :-

No. 1	38mm (1½in)	No. 7	38mm (1½in)
2	102mm (4in)	8	102mm (4in)
3	38mm (1½in)	9	305mm (12in)
4	203mm (8in)	10	38mm (1½in)
5	305mm (12in)	11	102mm (4in)
6	19mm (¾in)	12	203mm (8in)

Fig. 2. SECTION THROUGH SLABS AT ALCONBURY (NOT TO SCALE) SHOWING POSITIONS AND DEPTHS OF THERMOCOUPLES BELOW SURFACE

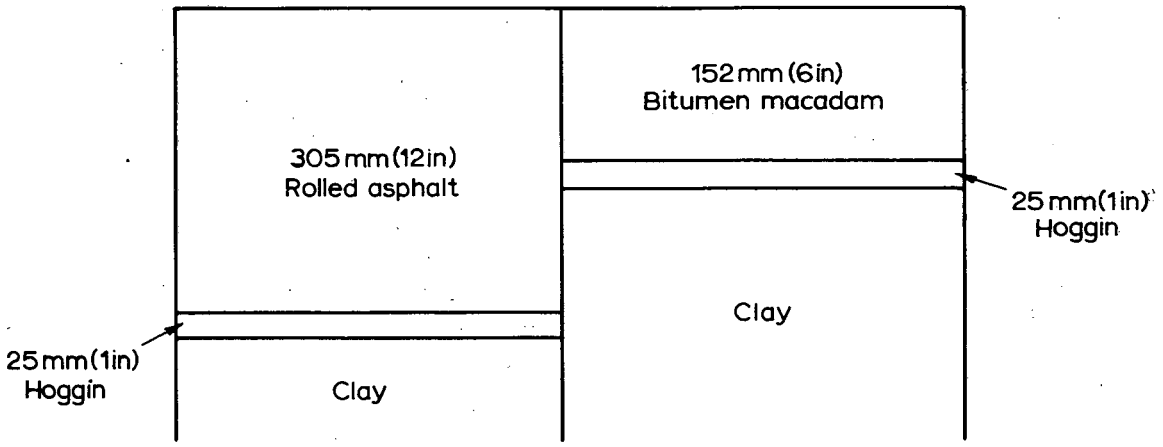
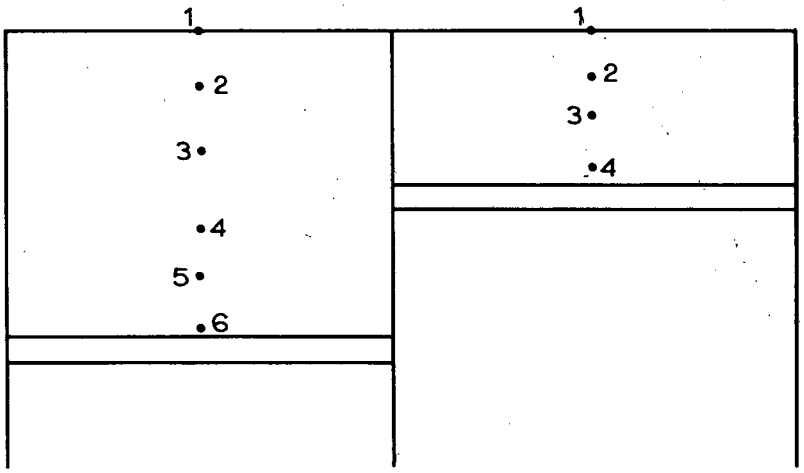


Fig. 3. SECTION THROUGH SLABS AT CROWTHORNE (NOT TO SCALE) SHOWING CONSTRUCTION OF EACH SLAB. EACH SLAB 3·1m x 3·1m (10ft x 10ft) IN AREA



Depth of thermocouples below surface :-

No. 1	Surface	No. 1	Surface
2	57mm (2¼in)	2	44mm (1¾in)
3	121mm (4¾in)	3	83mm (3¼in)
4	197mm (7¾in)	4	133mm (5¼in)
5	241mm (9½in)		
6	298mm (11¾in)		

Fig. 4 SECTION THROUGH SLABS AT CROWTHORNE (NOT TO SCALE) SHOWING POSITIONS AND DEPTHS OF THERMOCOUPLES BELOW SURFACE

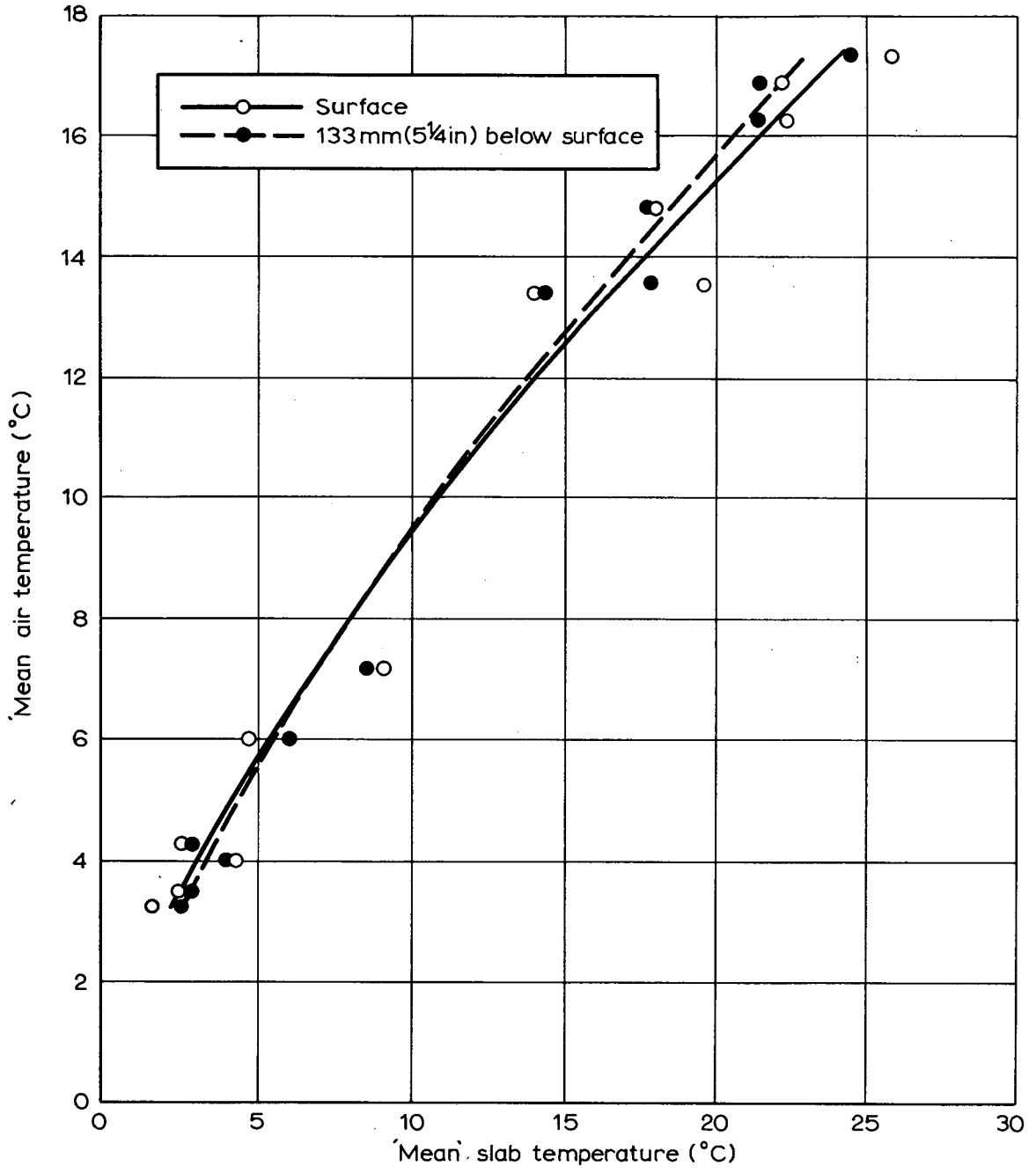


Fig. 5. RELATIONSHIP BETWEEN 'MEAN' AIR TEMPERATURE AND 'MEAN' SLAB TEMPERATURE AT CROWTHORNE FOR SURFACE (○) AND 133 mm (5¼in) BELOW SURFACE (●) IN 152 mm (6in) BITUMEN MACADAM SLAB

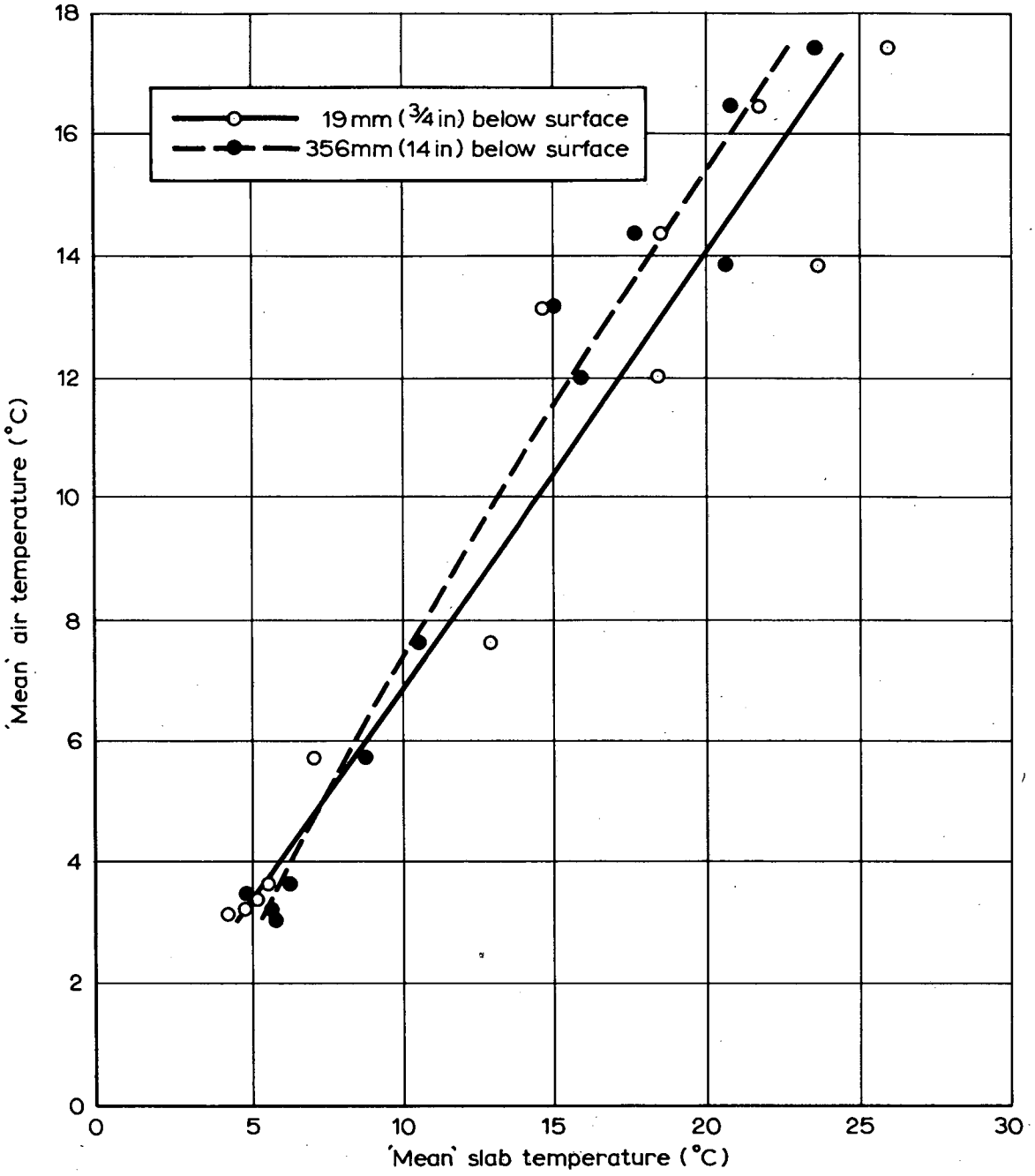


Fig. 6. RELATIONSHIP BETWEEN 'MEAN' AIR TEMPERATURE AND 'MEAN' SLAB TEMPERATURE AT ALCONBURY 19 mm (¾ in) (O) AND 356 mm (14 in) (●) DEPTHS BELOW SURFACE IN 356 mm (14 in) ASPHALT SLAB (SLABS 2 AND 3)

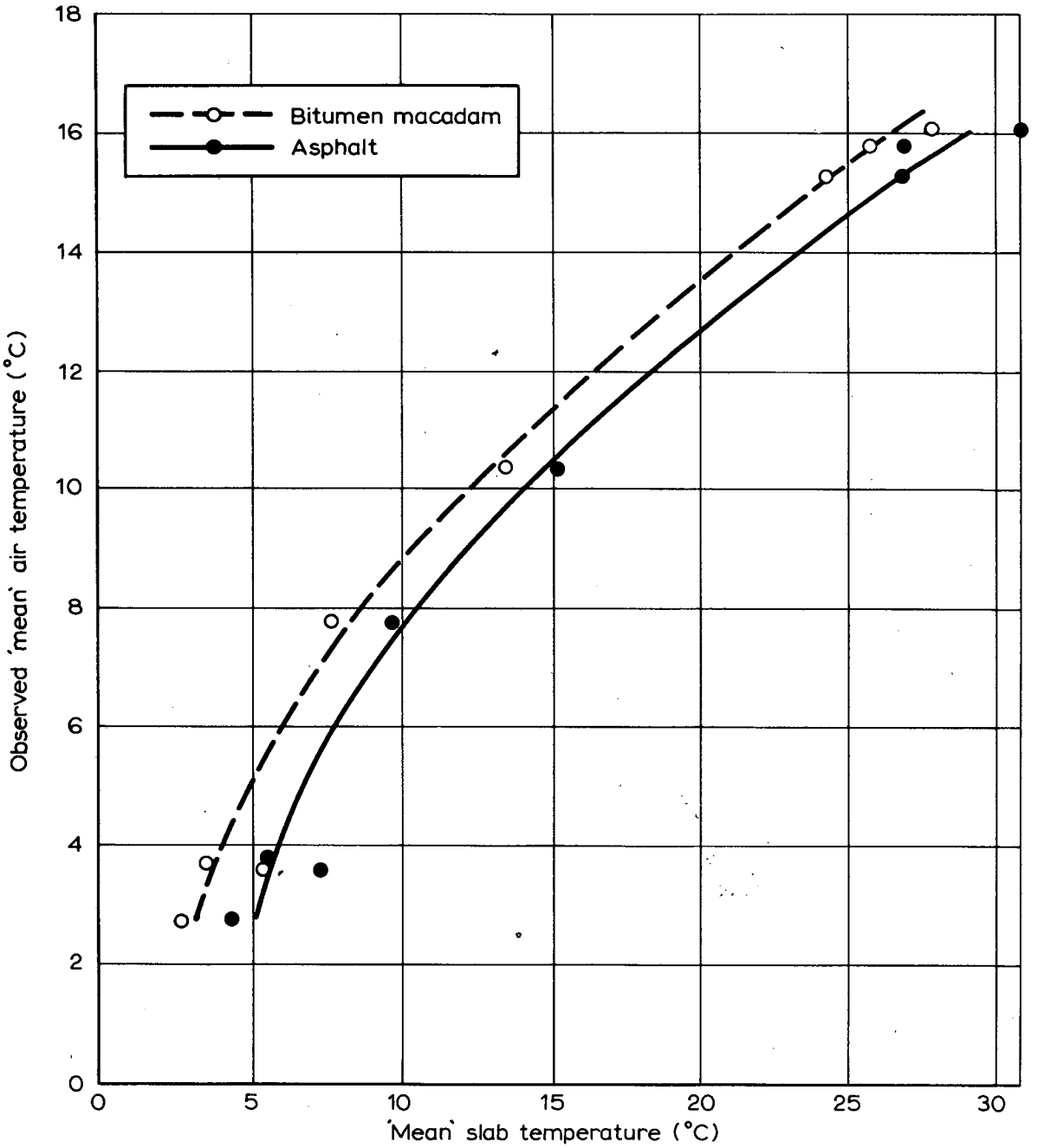


Fig. 7. RELATIONSHIP BETWEEN OBSERVED 'MEAN' AIR TEMPERATURES AND 'MEAN' SLAB TEMPERATURES AT CROWTHORNE FOR SURFACE TEMPERATURES OF 152mm (6 in) BITUMEN MACADAM SLAB (○) AND 305mm (12 in) ASPHALT SLAB (●)

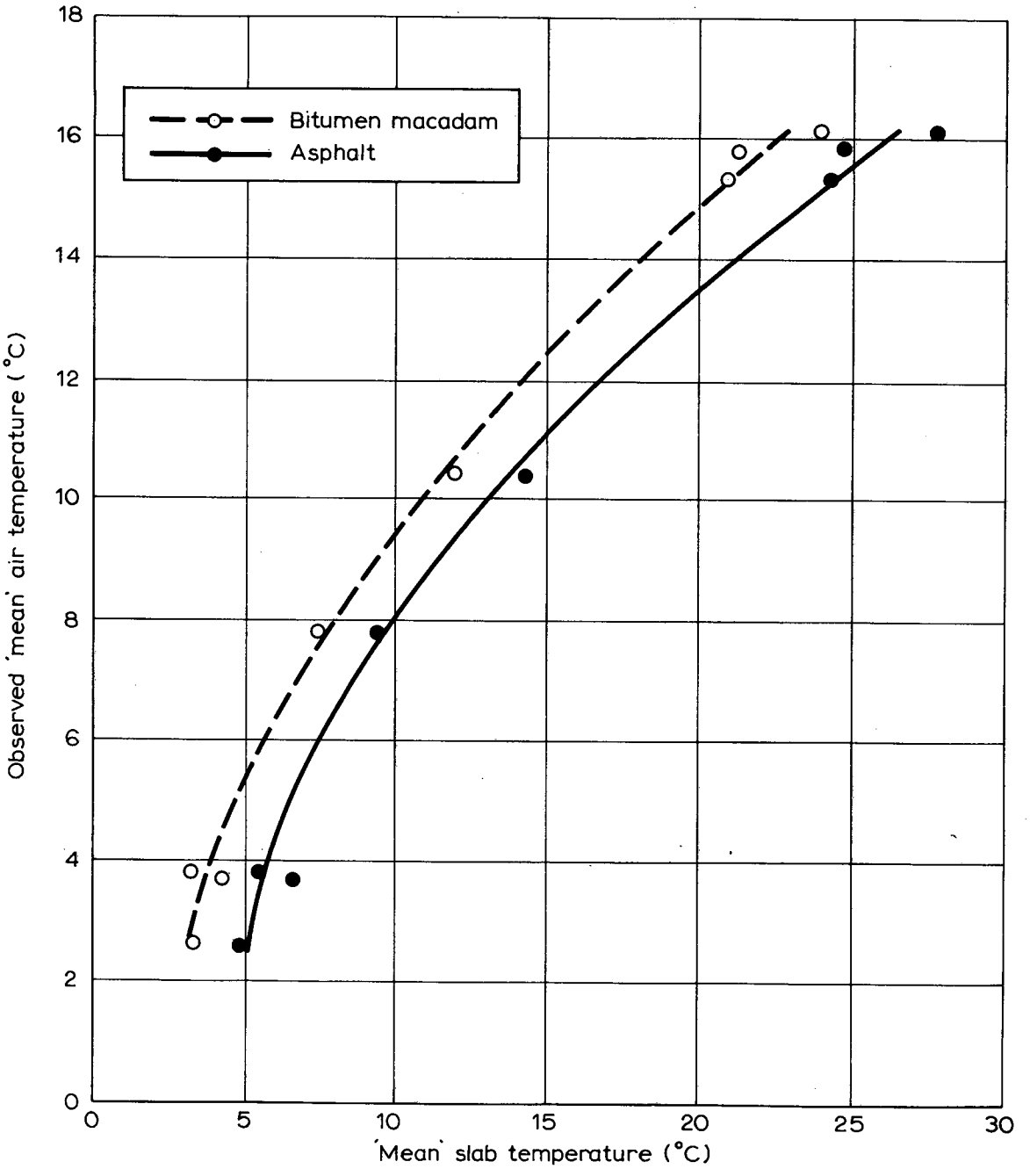


Fig. 8. RELATIONSHIP BETWEEN OBSERVED 'MEAN' AIR TEMPERATURE AND 'MEAN' SLAB TEMPERATURE AT CROWTHORNE FOR 133 mm (5 1/4 in) DEPTH IN 152mm (6 in) BITUMEN MACADAM SLAB (○) AND 120mm (4 3/4 in) DEPTH IN 305mm (12 in) ASPHALT SLAB (●)

(265) Dd.635271 3M 3/72 HP Ltd. So'ton G.1915
PRINTED IN ENGLAND

ABSTRACT

Temperature frequency distributions in flexible road pavements: J FORSGATE: Department of the Environment, TRRL Report LR 438: Crowthorne, 1972 (Transport and Road Research Laboratory). The deformation of flexible pavements under load is known to be temperature dependent. This report presents an analysis of pavement temperatures at varying depths for two sites in Southern Britain. It gives frequency distributions for selected months of the year of record from each site for varying depths, and shows how these distributions can be adjusted by means of long term averages of air temperature to suit varying sites.

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