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THE PERFORMANCE OF A FLEXIBLE PAVEMENT CONSTRUCTED ON A STRONG FABRIC

by

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ABSTRACT

The structural behaviour under traffic of a bituminous pavement containing a strong woven fabric between the sub-base and a clay of low strength was compared directly with a control pavement of similar construction but without fabric.

The presence of the fabric did not affect the development of rutting in the wheel paths or the deflection of the road surface as measured by a deflection beam. Also the permanent vertical strain in the soil, the transient vertical stress and strain in the soil and the transient longitudinal and transverse strain at the bottom of the bituminous layer were not influenced by the fabric. Insufficient measurements were made to draw a firm conclusion about its effect on the transverse strain in the soil.

The fabric made construction of the road easier in the very poor weather conditions encountered when the road was built and it prevented the granular sub-base from mixing with the clay. On the section without fabric the sub-base penetrated into the clay to a depth of about 70 mm when it was compacted.

1. INTRODUCTION

Fabrics made from synthetic polymer fibres have been used in the UK for more than a decade as an aid to constructing roads over soft ground. They appear to act as a separating layer between the granular sub-base and the soil, preventing inter-penetration of these materials and thereby improving the effectiveness of the sub-base. However present knowledge of the structural contribution of fabrics laid at formation level in roads with a conventional bituminous road-base is limited.

Information from several road construction works in which fabrics were used was discussed by Ruddock (1977) who suggested that the presence of fabrics reduced rutting in unsurfaced granular roads. These observations were confirmed by Potter and Currer (1981) in a pilot-scale experiment at TRRL in which the structural behaviour under traffic of a granular road containing a heavy melt-bonded fabric was compared with that of a similar pavement without fabric. The pavements in the latter experiment consisted of 350 mm of wet-mix macadam road-base laid on a Gault clay subgrade of 2.5 per cent California Bearing Ratio (CBR). In addition to the reduction in rutting, the permanent vertical strain in the clay and at the bottom of the wet-mix was reduced by the inclusion of the fabric. The transient horizontal strain in the clay was also reduced although the transient vertical stress and strain were unchanged. The transient deflection measured under a slowly moving lorry wheel, as described by Kennedy, Fevre and Clarke (1978), was not influenced by the presence of the fabric. The results of the experiment were judged to be sufficiently encouraging for TRRL to collaborate with the Construction Industry Research and Information Association (CIRIA) in a more realistic full-scale trial.

The trial was in two parts; the first was designed to examine the structural behaviour under traffic of unsurfaced granular pavements containing various types of fabric of different strengths and of sections containing no fabric. The results of this part of the trial have been reported in detail by Ruddock, Potter and McAvoy (1982); broadly they supported the findings of the earlier TRRL experiment. The second part of the trial compared the structural behaviour of a conventional bituminous pavement containing a strong woven fabric between sub-base and soil with that of a similar pavement with no fabric. The construction of these two pavements and their behaviour under traffic is the subject of this report.

2. CONSTRUCTION OF THE PAVEMENTS

The test sections were constructed on Ministry of Defence land at Sandleheath in Hampshire where the subgrade was known to have a low strength. This feature was considered to be essential in order to increase the chances of producing measurable differences in the behaviour of the bituminous pavement resulting from inclusion of the fabric.

The layout of the complete trial including the granular pavements is shown in Figure 1. The bituminous section containing the fabric is numbered 1A and the control section 2A. Both sections were 10 m long and 4.25 m wide.

The subgrade was prepared by removing the light vegetation and topsoil to obtain the required profile. During this period the weather conditions were very poor and the site was flooded, first by heavy rain and then by melting snow. Extra drainage channels were dug along the full length of the road on both sides to remove the water. Because of the wet conditions movement of plant was only just possible. Preparation of the subgrade was consequently extremely difficult and the finished levels were poor.

When the formation was prepared the CBR of the subgrade was measured to a depth of 300 mm using the cone penetrometer technique described by Black (1979), on a grid of 2 m by 3 m. Soil samples were taken at the same positions to determine moisture content. The results of these tests are given in Table 1 and show that the CBR's at the surface were very low and variable; they reflected the poor conditions encountered during subgrade preparation. After the CBR measurements and soil samples had been taken, access to the prepared formation was prohibited and the subgrade was sheeted with polythene to protect it from further bad weather. The polythene was removed only for the installation of stress and strain gauges, described in Section 3.

TABLE 1

Mean CBR's and moisture contents of subgrade

Depth below formation mm	CBR %		Moisture content %		CBR %		Moisture content %	
	Mean	Coefficient of variation %	Mean	Coefficient of variation %	Mean	Coefficient of variation %	Mean	Coefficient of variation %
	SECTION 1A WITH FABRIC				SECTION 2A WITHOUT FABRIC			
0	1.05	42.6			0.7	33.0		
75	2.6	23.5			2.1	13.1		
150	2.8	20.2	27.4	8.0	2.6	14.3	29.8	12.1
225	3.2	21.7			3.4	19.2		
300	4.1	29.8	27.4	8.1	4.3	19.9	28.4	8.8

The fabric used was a woven multifilament polyester with an ultimate strength of 83 kN/m and an extension at failure of 14.7 per cent tested as described in BS2576, British Standards Institution (1977). The Type 1 sub-base was crushed Croft granite from Leicestershire conforming to the Specification for Road and Bridge Works, published by the Department of Transport (1976).

Immediately before the sub-base was laid the fabric was placed on the subgrade. The Croft granite was then tipped from the delivery lorries and spread by a tractor excavator working on the sub-base platform. It was compacted to a nominal thickness of 300 mm in one layer by a hand controlled Bomag vibrating roller followed by an 8 tonne Vibroll roller. The mean dry density was 2.17 Mg/m^3 as determined by the sand replacement method described in BS 1377, British Standards Institution (1975); the mean moisture content was 5.4 per cent. The thickness of the sub-base was calculated at each of the grid points from optical level measurements taken on the top of the prepared subgrade and subsequently on the top of the sub-base. The measured thickness varied considerably over the test sections, mainly as a result of the variation in subgrade level.

The dense bitumen macadam (DBM) was mixed to the Department of Transport (1976) basecourse specification using granite aggregate and filler from Bardon Hill Quarry. The aggregate grading, binder content and supply and rolling temperatures were all within specification. The material was laid in two layers by a Blaw Knox PF90 paver and compacted, again according to the Department of Transport (1976) specification to a nominal thickness of 160 mm using an 8 tonne three wheeled deadweight roller. The thickness of the DBM was determined from the optical level measurements and was found to vary in each section. The thickness increased steadily across the road so that the DBM in one wheel path was thicker than in the other and the thickness reduced near the ends of the sections abutting the granular approach roads. These changes in thickness were taken into account when assessing the performance of the fabric.

3. INSTRUMENTATION

During construction, gauges of the types described by Ruddock, Potter and McAvoy (1982) were installed along a 4 m length of one wheelpath in each section; they measured vertical stress and vertical and transverse strain in the subgrade and longitudinal and transverse strain at the bottom of the roadbase. Thermocouples were installed at three depths within the DBM to monitor the temperature gradient. Figure 2 is a cross-section of the road showing the numbers and the layout of the gauges in the test section with the fabric. The arrangement of the gauges in the control section was identical except that the inductive coils attached to the fabric in section 1A were placed at the top of the subgrade.

Reference positions for optical levelling to monitor the transverse profiles and hence the rutting of the road surface were provided in each section by metal studs embedded in the road surface at 300 mm intervals across the road and at four equidistant positions along the road. The eight studs in the centre of the wheel paths on each section were also used as references for the deflection beam measurements.

4. TESTING PROGRAMME

As part of the earlier work on the granular roads at this site the sub-base was subjected to 30 passes of a Bedford lorry. The results of these measurements have been reported in detail by Ruddock, Potter and McAvoy (1982).

The DBM sections were trafficked by a 2 axle Leyland lorry fitted with dual wheels on the rear axle. The tyres were of radial ply construction (1100 x 22.5) inflated to 110 psi. The lorry was loaded with concrete blocks held in position by baulks of timber and the individual wheel and axle loads were weighed on several occasions to check that the blocks had not moved. The speed of the lorry was maintained between 5 and 8 km/h for all of the trafficking.

The first period of trafficking was started in the spring directly after the two test sections were constructed and was stopped in the early summer when the strength of the subgrade was known to increase and therefore reduce any contribution that the fabric might make to the structural performance of the road. At the end of the trafficking period the lorry, with its rear axle loaded to 9940 kg had traversed the test sections 4600 times, equivalent to a loading of 10500 standard 8.2 tonne axles.

Trafficking was resumed early in the following spring with the lorry carrying a heavier load of 13840 kg on the rear axle. By early summer when the trafficking was again stopped, the lorry had traversed the test sections an additional 7700 times, equivalent to a further 63500 standard axles.

5. OBSERVATIONS OF PERFORMANCE

The influence of the fabric on the structural behaviour of the road was assessed by comparing the transient deflection under load, the development of permanent deformation and cracking of the road surface and measurements from the gauges installed in the two test sections. The transient stresses and strains were recorded on every twentieth pass of the lorry and other parameters were measured after every two hundredth pass.

The measurements indicating the structural condition of the road depend on the thickness and properties of the road layers and the strength of the soil foundation. As noted earlier the thickness of the bituminous macadam was measured at sufficient locations during construction and when the testing was complete to take account of differences in thickness. This variation in thickness made it possible to assess the effect of the fabric on the structural behaviour of bituminous pavements for a range of thickness of DBM.

5.1 Transient stress and strain

The effect of the fabric on the transient vertical stress and strain in the subgrade was assessed directly by comparing measurements at locations where the thickness of the dense bituminous macadam and the sub-base were similar in each section. Having regard to the variability in thickness the small differences shown in Figure 3 between the vertical stress and strain measured under the fabric and in the control section are not regarded as significant.

Figure 4 shows the effect of fabric on the transient stress and strain in the subgrade for a range of thickness of DBM at a time when the trafficking was equivalent to 60000 standard axles: the temperature of the DBM was constant at 14°C. These results confirm the previous observation that vertical stress and strain were not greatly affected by the presence of fabric. Too few results were obtained to show its effect on the transverse strain.

The magnitudes of the transient longitudinal and transverse strains at the bottom of the DBM control the onset of fatigue cracking in the bituminous material. These strain levels are more sensitive to changes in thickness of the bituminous material than the strains in the subgrade and the relatively large change in thickness over the gauges (140 mm to 215 mm) produced longitudinal and transverse strains of between 50 and 150 μm/m in both test sections under the rear wheels of the lorry at a uniform road temperature of 10°C. Although the changing thickness complicated the analysis there was no evidence to indicate that the presence of fabric influenced these strain levels.

5.2 Deflection

The effect of the fabric on the deflection beneath a rolling wheel load was assessed by comparing deflections measured in the wheelpaths at the eight reference positions in each section. As noted earlier, it was necessary to consider the thickness of the DBM and Figure 5 shows the relationship between deflection, standardised to 20°C as described by Kennedy and Lister (1978) and DBM thickness for the two test sections. Results are presented for deflections measured when the road had settled down but before any structural deterioration had occurred and again at the end of the trafficking when there had been considerable rutting and cracking in the thinner structures. Figure 5 shows that the deflections were not influenced by the fabric and that they decreased with increase in thickness of DBM. Even the later measurements on the thinner areas where structural deterioration had occurred and where the fabric would have been most likely to have made a structural contribution showed no consistent effect of the fabric.

5.3 Permanent strain

The permanent strain in the subgrade was monitored regularly by the strain gauges and the inductive coils. In fact, the strains were too small, even by the end of trafficking, for the inductive coils to measure and therefore all the results discussed refer to measurements from the soil strain gauges.

The permanent vertical strains increased steadily during the trafficking and were related to the thickness of the bituminous material in the vicinity of the gauges. At the end of trafficking strain levels were 0.4 per cent under 110 mm of bituminous cover and 0.06 per cent under 220 mm. Direct comparisons of permanent strain between the two test sections were made for thicknesses of DBM greater than 175 mm which was the minimum cover over the gauges in the section with fabric. The permanent vertical strains were not influenced by the presence of fabric.

The transverse permanent strains were less than 0.01 per cent and their values recorded during trafficking depended on the transverse position of the lorry wheels immediately before measuring the strains. No effect of the fabric was noted.

5.4 Permanent deformation and cracking

The development of permanent deformation measured at the road surface depended on the thickness of the DBM. Figure 6 shows this relationship for both test sections at approximately halfway through the trafficking period and also at the end. The rutting tended to be more severe at the ends of the sections adjacent to the approach tracks; this was caused by the reduced support of the approaches and corresponded to the measurements at thicknesses of 116 mm and 130 mm. At the completion of trafficking, surface cracking accompanied the rutting where the thickness of DBM was less than 150 mm and it increased in severity as the thickness decreased. Figure 6 shows that the fabric did not reduce the surface deformation in the wheelpaths.

6. EXCAVATION OF THE PAVEMENTS

After completion of the trafficking programme, cores were cut from the bituminous material to determine density and to give further information on thickness. The densities of the DBM cores were measured by a radioactive core scanner described by Harland (1966). The mean density on each section was the same, showing that the compaction of the DBM was not improved by the presence of the fabric.

Trenches about 600 mm wide were then excavated across test sections at the reference positions and also directly above the gauges. This enabled the condition of the fabric to be inspected and measurements made of the layer thicknesses and the strength and moisture content of the subgrade. The fabric was found to be in good condition with no tears or punctures. On the control section the sub-base had penetrated the clay to a depth of about 70 mm. Penetration was across the full width of the road, clearly indicating that it had occurred during compaction of the road pavement. In practice this meant that to achieve the same levels at the top of the sub-base more material was used in the control section.

In each trench the transverse profile of the surface of the clay was measured using the optical level; the results showed that the subgrade had not rutted in either section. The strength of the subgrade in and between the wheelpaths and also around the stress and strain gauges was then measured using the cone penetrometer. The strengths in the wheelpaths and between the wheelpaths were similar, indicating that there had been no further compaction under traffic. Table 2 compares the mean equivalent penetrometer CBR values and moisture contents measured in the trenches and around the gauges with the mean values measured during construction of the experiment 17 months earlier.

TABLE 2

Mean CBR's and moisture contents of the subgrade

Depth below formation level (mm)	Mean California Bearing Ratio (per cent)					
	SECTION 1A WITH FABRIC			SECTION 2A WITHOUT FABRIC		
	At construction	At completion		At construction	At completion	
		In trenches	Around gauges		In trenches	Around gauges
0	1.05	1.1	0.9	0.7	1.2	0.9
75	2.6	2.3	2.5	2.1	2.2	1.8
150	2.8	2.6	3.2	2.6	2.7	2.5
225	3.2	3.0	4.0	3.4	3.4	3.5
300	4.1	3.5	4.5	4.3	4.3	4.7
	Mean moisture content (per cent)					
150	27.4	26.6	26.1	29.8	25.9	–
300	27.4	27.3	–	28.4	27.2	–

The CBR of the two sections was very similar and had changed only slightly at the soil surface on section 2A since the road was constructed. The moisture content of the clay had reduced slightly with time, with appreciable changes in the control section where the clay had been wetter initially.

7. COMPARISON WITH OBSERVATIONS ON GRANULAR PAVEMENTS

Earlier work on the granular pavements at Sandleheath and at Crowthorne showed that surface deformation and permanent strain in the subgrade were reduced by the use of a fabric, provided that it was not torn. The transient transverse strain in the subgrade was also reduced but the transient vertical stress and strain were unchanged. The surface deflection measured by the deflection beam was also unchanged by the fabric.

The present tests confirmed the observation that a fabric placed between sub-base and soil under a bituminous pavement did not reduce the deflection of the road surface under a rolling wheel load or reduce the transient vertical stress and strain in the subgrade. The permanent deformation of the DBM surface was not affected by the fabric; this result was consistent with the earlier measurements on the granular pavements where the fabric did not begin to reduce the rate of deformation until the surface had deformed to between 20 and 30 mm. It would appear that the fabrics need to be appropriately contoured and tensioned before they can provide restraint and certainly the fabric was not found to be in tension when the bituminous pavements were excavated.

The permanent strains recorded in the subgrade under the bituminous pavements at the end of the trafficking were less than one tenth of those recorded under the granular pavements after the same loading. These low strain levels were not influenced by the fabric.

The average strength of the soil in the wheelpaths of the granular pavements more than doubled near the surface of the clay during the trafficking. In the bituminous pavements where much lower stresses were imposed on the soil only a small increase in strength was observed at the surface of the control section and this was consistent with the drying out of the initially wetter clay in this area.

8. CONCLUSIONS

The structural behaviour of a bituminous road constructed on a clay subgrade of low strength with a strong woven fabric placed between the sub-base and the clay has been compared with a similar pavement without fabric. The following conclusions may be drawn:

1. The presence of the fabric did not affect the rate of development of permanent deformation at the road surface under traffic or the development of permanent vertical strain in the subgrade.

2. The structural quality of the road as assessed by measuring the deflection of the pavement beneath a rolling wheel load was unaffected by the presence of the fabric. Similarly, the fabric did not change the transient vertical stress and strain in the soil or the transient transverse and longitudinal strain at the bottom of the dense bituminous macadam. There was insufficient data to draw a firm conclusion about its effect on the transverse strain in the clay.

3. Perhaps the most important conclusion was that, as expected, the fabric eased the construction of the road in very poor weather conditions and prevented the granular sub-base from penetrating into the clay. On the control section without fabric the sub-base penetrated the clay to a depth of about 70 mm as it was being compacted, so that extra material had to be used to achieve the same levels.

9. ACKNOWLEDGEMENTS

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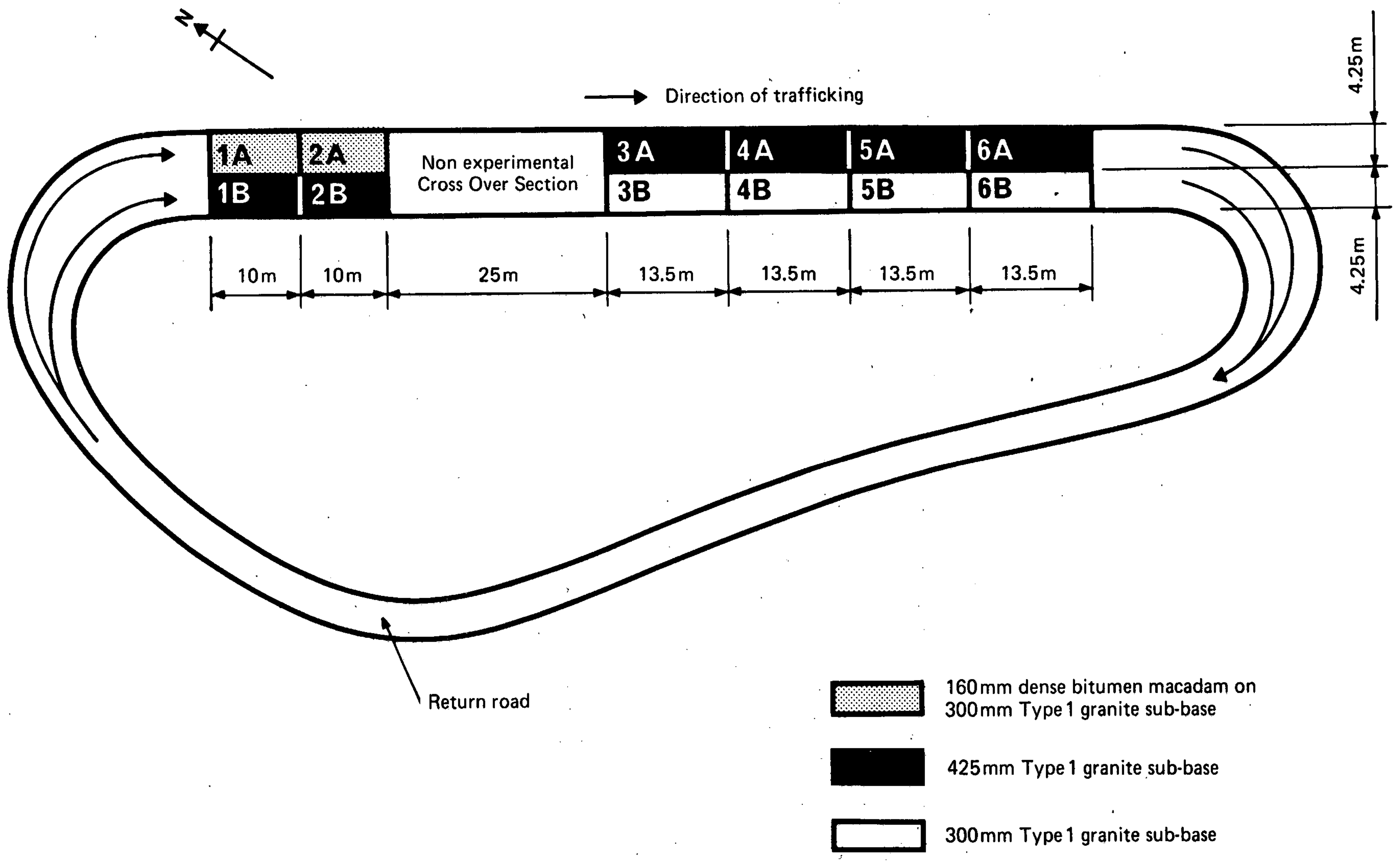

Fig. 1 Site plan

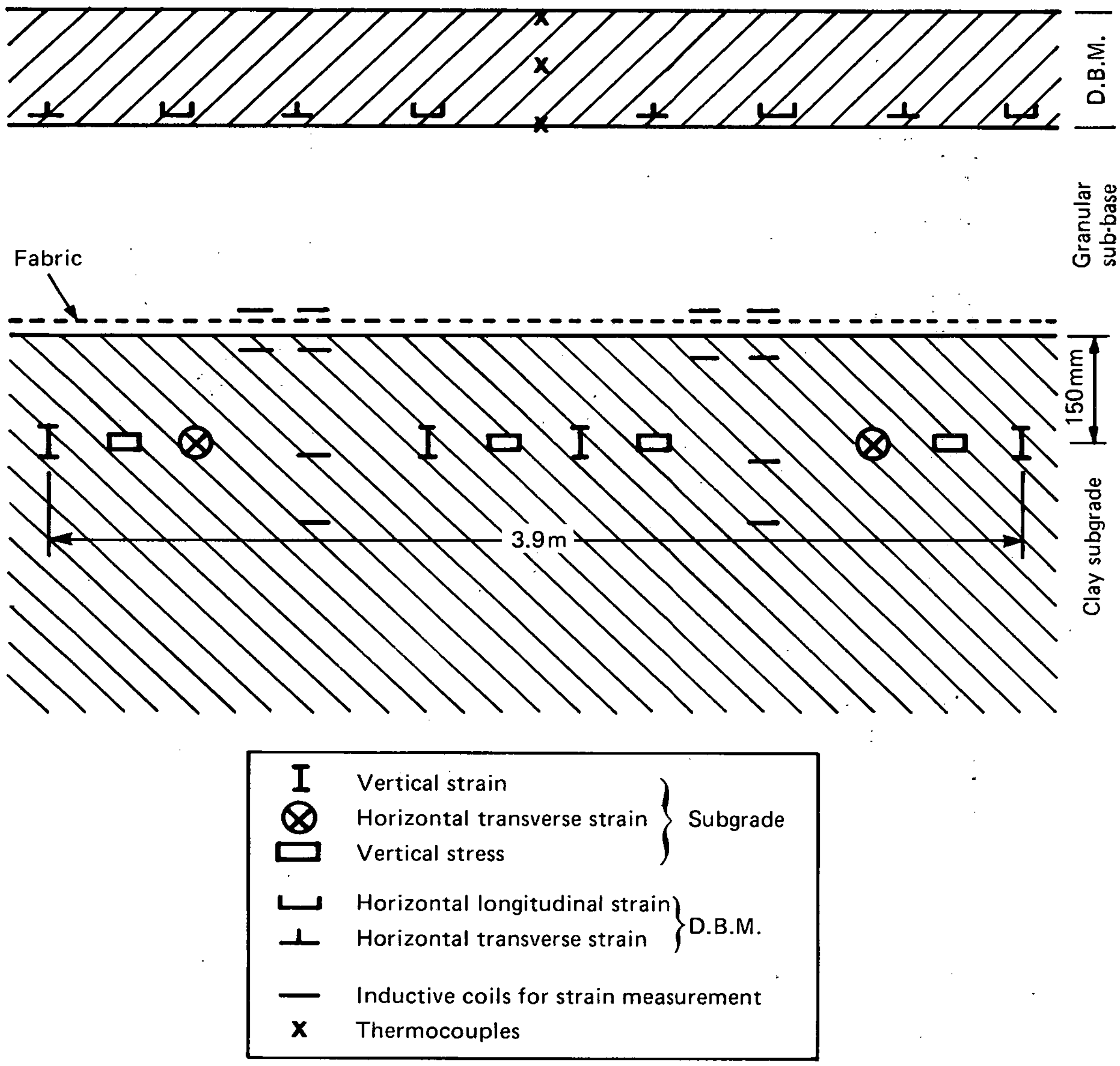

Fig. 2 Instrumentation in a longitudinal section of test pavement

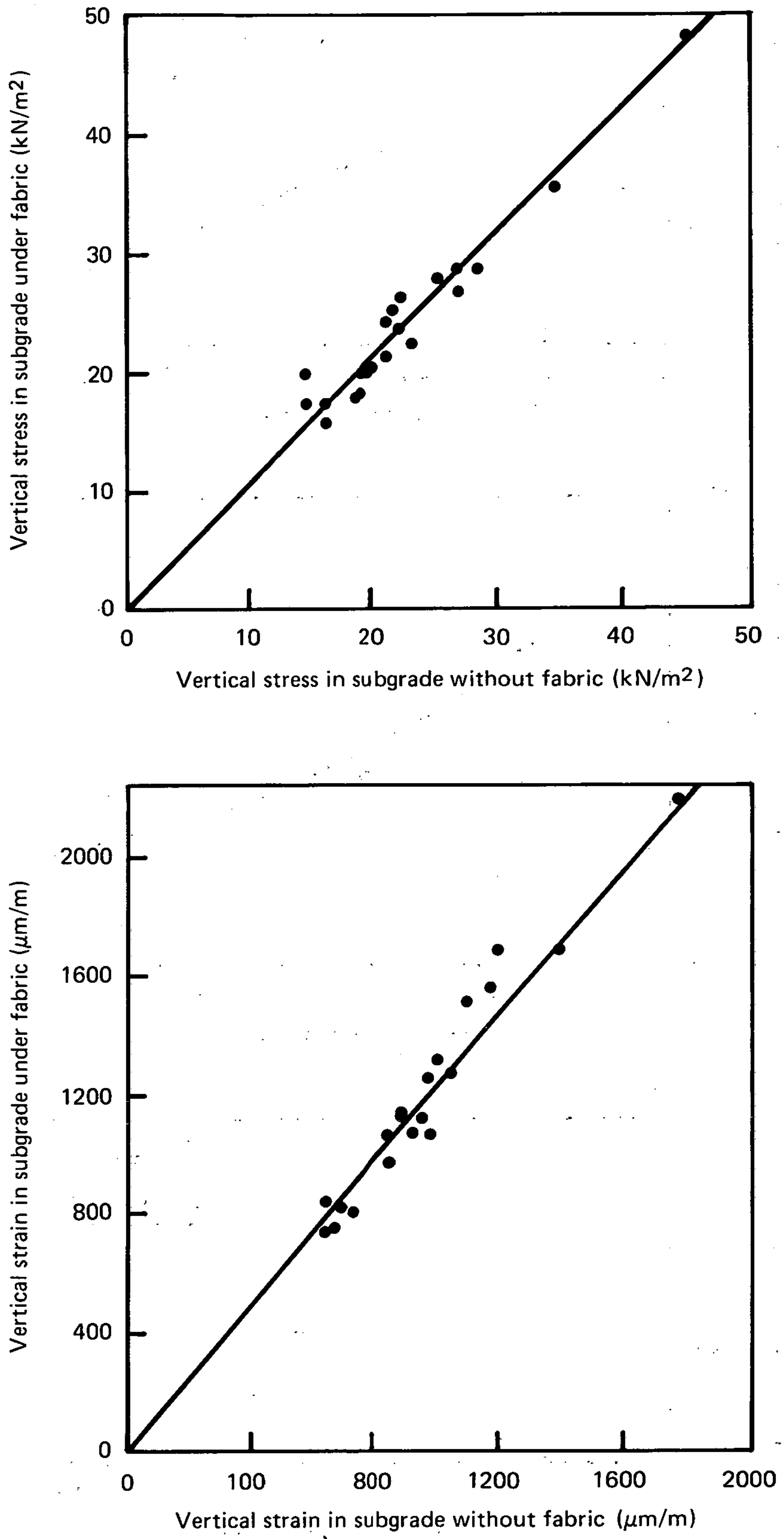

Fig. 3 Effect of fabric on the transient vertical stress and strain measured in the subgrade at different road temperatures

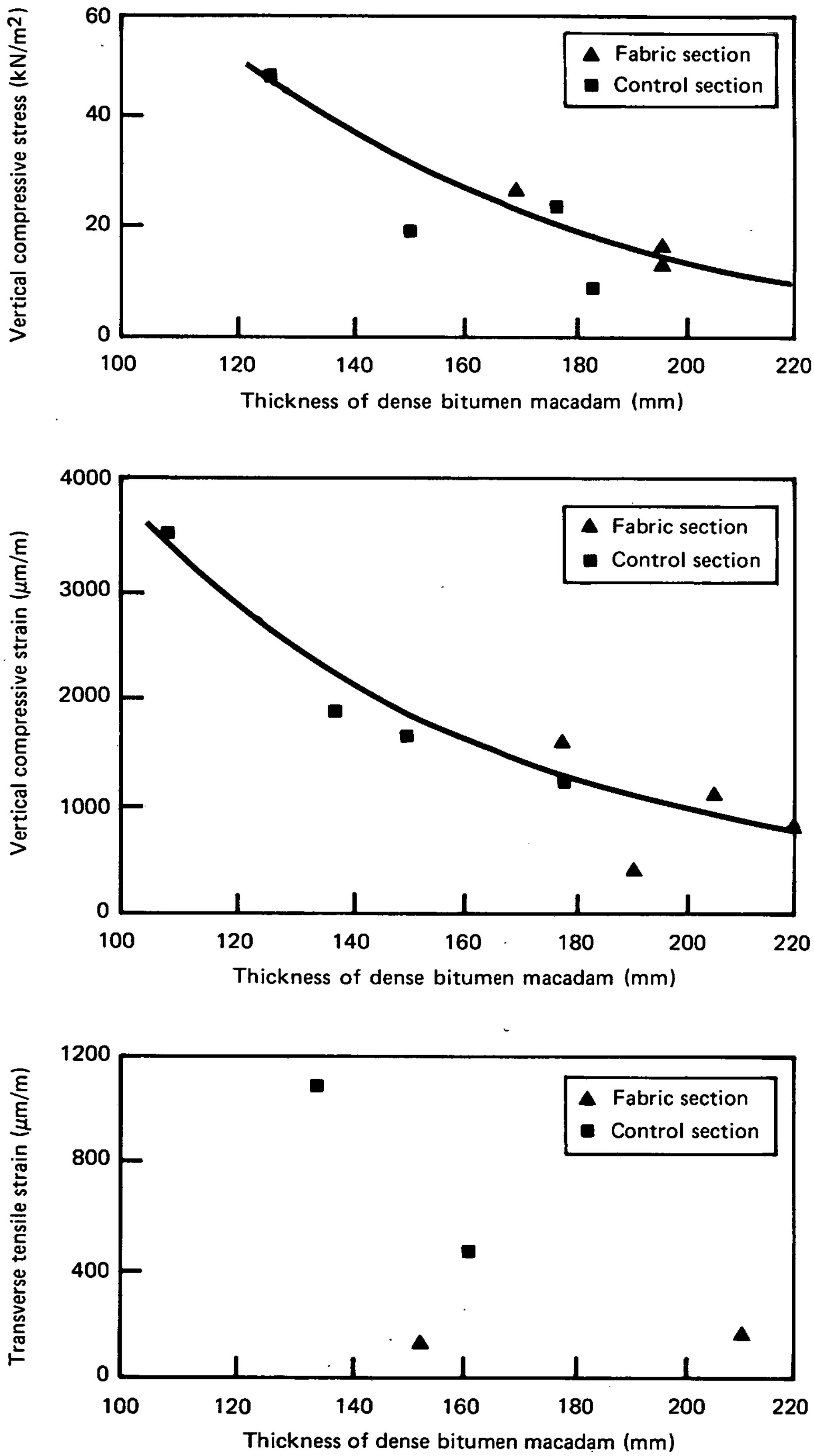

Fig. 4 Effect of fabric and thickness of dense bitumen macadam on the transient stress and strain in the subgrade

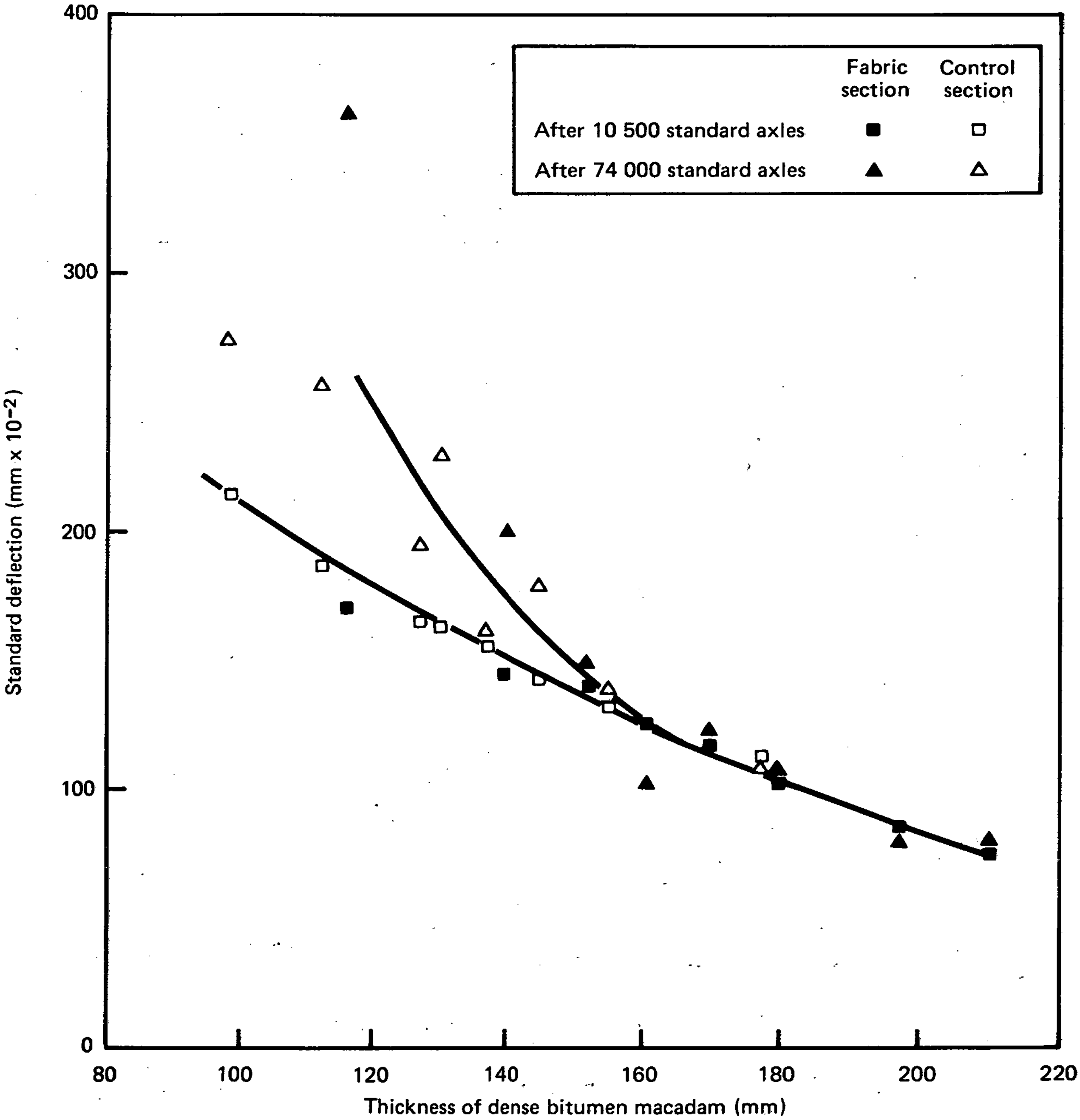

Fig. 5 Effect of fabric and thickness of dense bitumen macadam on deflection

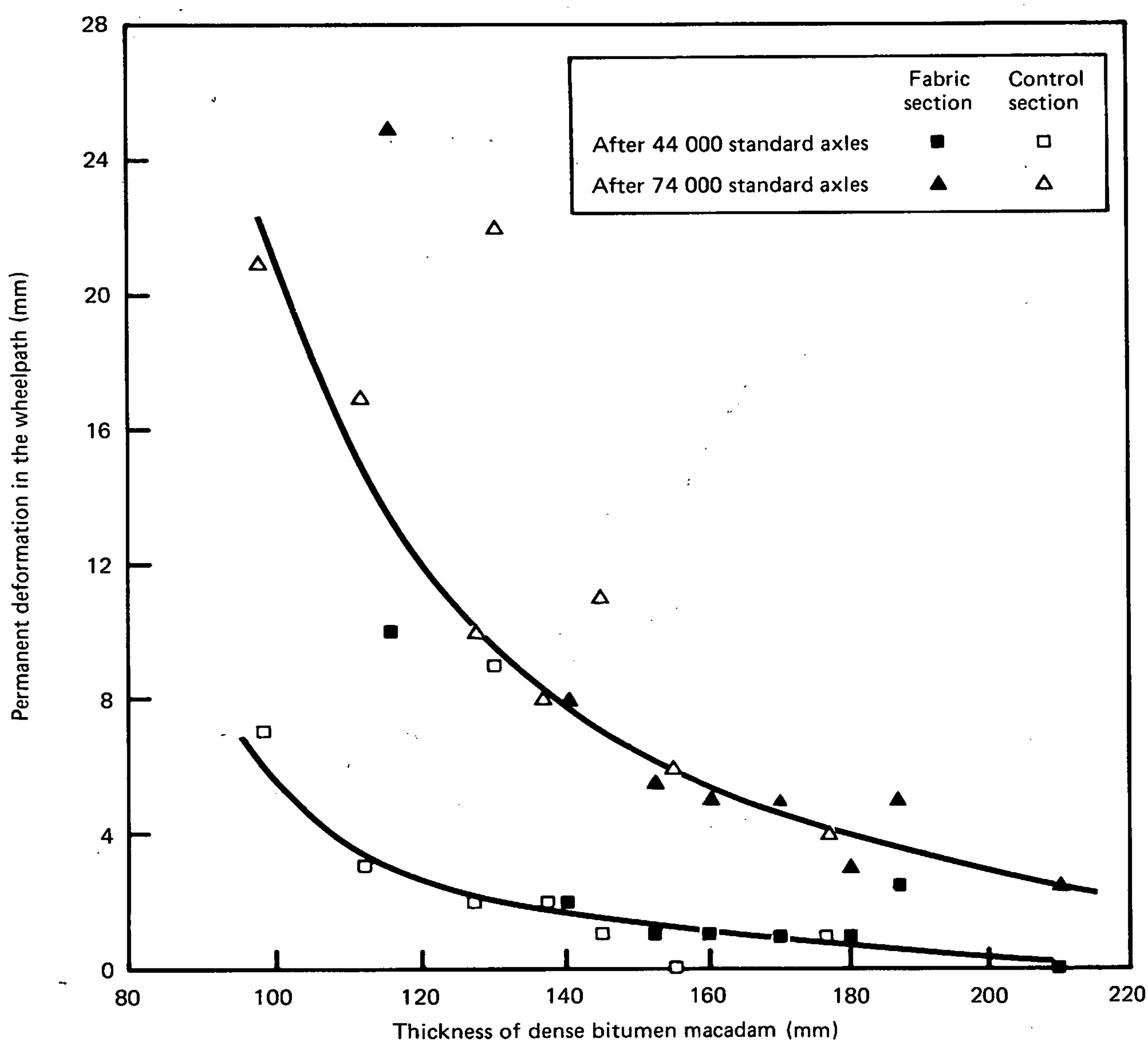

Fig. 6 Effect of fabric and thickness of dense bitumen macadam on permanent deformation

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