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TRIALS OF A MODIFIED SPECIFICATION FOR COMPACTING DENSE ROADBASE AND BASECOURSE COATED MACADAM

by

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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

Previous research has led to the formulation of revised specification clauses for the compaction of dense roadbase and basecourse coated macadams which, if implemented fully, should result in improvements in compaction in the critical wheelpath zones of about 3 per cent; this would bring about a worthwhile improvement in pavement performance. The revised specification has been applied in four contracts for the construction and reconstruction of motorways. Improvements in compaction of between 1 and 2 per cent were obtained suggesting that, in practice, the specification was being only partly implemented.

Comparison of these results with densities achieved in a laboratory compaction test to establish the practical or refusal limit of compaction shows that there is considerable scope for additional compaction on site. Improved compaction is discussed in terms of the major controllable factors in the compaction operation, ie method of rolling, laying temperature and layer thickness. If the benefits of levels of compaction close to refusal are to be realised this will normally require the maintenance of laying temperatures close to the permitted maximum, avoidance of thin layers and more effective compaction plant used according to the amended specification.

1. INTRODUCTION

Bituminous materials, in common with other road materials, need to be well compacted to give good performance. The present specification[1] for compaction of bituminous materials in the United Kingdom defines the type and overall weight of roller, limiting values of thickness of the compacted layers, and temperature limits for materials both at delivery on site and at rolling. Neither the number of rollers nor the number of passes is specified but materials must be compacted to a thickness within specified tolerances and, in the case of surfacing layers, to an acceptable surface regularity. Much, however, is left to the discretion of the rolling driver.

In contrast many countries employ end-result specifications in terms of density to ensure that good compaction is achieved. This type of specification focusses attention on the state of compaction and appears to provide incentive for contractors to use more sophisticated and expensive laying and compaction equipment than normally used in the UK.

In general, compaction of bituminous materials in the UK has been considered satisfactory and poor performance has rarely been ascribed to inadequate compaction. However, a co-operative programme of research between the Asphalt and Coated Macadam Association and the Transport and Road Research Laboratory has indicated[2] that there is potential for increasing the density of dense roadbase and basecourse macadam in the critical wheelpath zones which determine the structural performance of pavements. An early finding was that the pattern of rolling normally adopted by roller drivers leads to a characteristic initial variation in density across the laid width as shown in Figure 1; the number of roller passes in the near-side wheelpath is less than half that at the centre of the laid width and this results in differences in void contents between the wheelpath and the centre of about 3 per cent. It has furthermore been shown that little or no densification occurs in dense roadbase macadam under traffic[3]. The performance of this material is therefore determined by its initial properties at the time of construction and thorough compaction in the critical wheelpath zones during construction is essential.

Continuously graded coated macadams are more difficult to compact than gap-graded rolled asphalt and, because there is evidently scope for improving the compaction of roadbase and basecourse macadams, recent developments have been directed towards investigating ways of improving compaction of coated macadams in the field. This line of research is attractive because the cost of compaction in the United Kingdom is only a few per cent of the cost of the laid material[4] and there are also prospects of worthwhile cost savings as a result of the superior performance obtained from better-compacted bituminous macadams[5]; performance studies have shown that improvements in the stiffness of bituminous macadams (ie in their load-spreading ability), in their resistance to deformation and, indirectly, in their resistance to fatigue are brought about by improved compaction. Increasing compaction by 3 per cent in the wheelpaths should enable reductions to be made in design thickness of about 8 per cent for a given design life, or, alternatively, should lead to substantial increases in the service life of the pavement.

Recent trials[3] have shown that the use of one of the two rollers normally on site, to roll the edges of the laid material only, improves compaction in the wheelpath zones; a tandem roller used in this way gave the greatest improvement. The results of these trials and those of studies of the cooling rates of laid materials have been combined to formulate improved compaction procedures[6] which should expedite the compaction process and ensure that greater compactive effort is applied in the wheelpath zone before the material has cooled excessively. Appendix 1 gives the amended specification for compaction that was drawn up by the Department of Transport on the recommendation of TRRL. The amended specification has been implemented on four motorway contracts to observe its operation and this Report describes the results obtained.

2. SPECIFICATION TRIALS

Engineering Intelligence Division of the Department of Transport made the necessary arrangements on the contracts where the specification was to be implemented. It was agreed that a Clerk of Works would be present to inspect the compaction procedure on each of the several areas within each contract where the density achieved was to be measured. Most layers were compacted without Laboratory staff present because it was thought that their presence might influence the compaction operation. In such cases the sites were visited after several layers of roadbase had been laid and cores were taken so that densities of all layers could be determined. Six cores were removed from the middle of the laid material and six 600 mm from the edge which was taken to be the nearside wheelpath. The densities of the core layers were determined at the Laboratory using the gamma-ray core scanner[7] and layer thicknesses were measured. In order to extend the information obtained from cores on a comparative basis, densities of the uppermost layer were also measured wherever possible at positions across the laid width using a nuclear backscatter gauge[8]. On two of the contracts it was also possible to determine, before the specification trials were begun, the compaction achieved using conventional rolling procedures.

Where compaction was observed by TRRL staff, measurements were also made of laying temperatures, roller passages, weather conditions and other data considered relevant. Measurements of the densities achieved were also made as described above.

Information concerning the composition of the materials was obtained from the materials engineers on each contract and some analyses were also carried out by TRRL where required.

With the exception of the heavy vibratory roller employed on Contract 4, all rollers used in the trials were of the three-wheel or tandem types complying with the current specification.

3. RESULTS

A summary of the results is given in Table 1.

3.1 Contract 1

Four trial areas were studied on this motorway contract; in all trial areas the roadbase and basecourse was dense bitumen macadam containing limestone aggregate.

3.1.1 Area 1. Two roadbase layers and a basecourse layer were compacted in the conventional manner using two three-wheel rollers over a 1,000 metre length of pavement. This area was used to establish the typical compaction achieved as a basis for assessing the effectiveness of the modified rolling procedures employed in the later trial areas of this contract.

The difference in density between the wheelpath and middle of the laid width is between 2 and 3 per cent for all three layers; this is typical of that found in general practice[2].

3.1.2 Area 2. A 300 m length of pavement was rolled with a three-wheel and a deadweight tandem roller. The surfacing contractor reported that although the edge-rolling technique was executed according to the modified specification, the first 30 passages were not completed within 30 minutes of laying because it was thought that the material would move excessively under the roller; the air temperature during compaction was very high (about 25^{o}C) and in these conditions the period specified for completing 30 passages is extended to 60 minutes.

The density of material in the wheelpath was found to be close to that of material at the middle of the laid width, the average difference for the three layers being less than one per cent.

3.1.3 Area 3. This trial area was used to repeat the work carried out in Area 2 but under cooler, more typical, conditions. The difference in density between the wheelpath and the middle of the laid width is between 2 and 5 per cent, considerably greater than found in Area 2. Site staff reported that although over 30 roller passages were completed within 30 minutes of laying, there was some delay before the first passages were executed because of a tendency for the material to crack when rolled at normal temperatures; the behaviour of the material in this area was attributed to a locally weak foundation. Furthermore, the roadbase was laid in 3 layers because of level problems not associated with rolling and the upper two layers were thinner than usual (45–70 mm); they would therefore cool at an accelerated rate and this could account for the lower measured densities.

3.1.4 Area 4. TRRL staff attended to gain a first-hand impression of the operation of the modified rolling procedure on a 50-metre length of the uppermost layer of roadbase. Rolling was carried out with a three-wheel roller and a deadweight tandem. Material temperature when laid was close to the maximum permitted delivery temperature of 130°C and the weather was warm and sunny; under these favourable laying conditions the specification allows an extended rolling period of 60 minutes during which time the number of passages completed was 37, that is, 8 more than the minimum permitted. The densities in the wheelpath are nearly the same as those of the middle of the laid width indicating a more uniform level of compaction than that found with conventional rolling.

3.2 Contract 2

The trial was carried out in areas of a motorway reconstruction contract. The roadbase and basecourse macadam contained 100 pen bitumen and either limestone or basalt aggregate as indicated in Table 1.

3.2.1 Area 1. To obtain evidence of the compaction achieved using conventional rolling, a 100-metre length of the nearside lane was rolled by two three-wheel machines without TRRL staff present. The difference in density between the wheelpath and the middle of the laid width in the two roadbase layers is between 2.5 and 3 per cent; this is typical of previous results obtained with conventional rolling[2]. The compaction of the basecourse, however, is more uniform, the density difference being about 1.5 per cent.

3.2.2 Area 2. A 100-metre length of pavement was rolled to the modified specification using two three-wheel rollers. A Clerk of Works supervised the rolling. Density differences in the two roadbase layers are 1.0 and 1.5 per cent, somewhat less than those found in Area 1.

3.2.3 Area 3. Two roadbase layers were cored over a length of 50 metres where TRRL staff had been present to observe the compaction of the uppermost roadbase layer. The material of this layer was compacted to the modified specification by a three-wheel and a deadweight tandem roller. The tandem completed 44 passages in the first 30 minutes after laying, more than the minimum of 36 required, and a considerable number of additional passages were made after this 30-minute period. Passes in the wheelpath were almost equal to the number achieved at the middle of the laid width. Weather conditions were far from ideal – it was dark and the air temperature was 4°C. However the density differences for both layers, at between 1.0 and 1.5 per cent, are again less than those of Area 1 and reflect the better uniformity of rolling across the laid width achieved by the modified procedure.

3.2.4 Areas 4 and 5. The uppermost layers of these two areas were compacted with TRRL staff present. Area 4 comprised a 60-metre length of paving and Area 5 a 40-metre length and compaction was to the modified specification using a three-wheel roller and the tandem that had been used on Area 3. Laying temperatures were typical for this type of material. In both areas the observed number of roller passages completed within 30 minutes of laying exceeded the minimum required by the specification. Densities achieved in the wheelpath are within one per cent of those at the middle of the laid width; indeed, in the uppermost layer of Area 5 the wheelpath zone is at the higher density.

3.3 Contract 3

Only one trial area was studied on this motorway reconstruction contract. TRRL staff were present to observe the compaction of a 300 m length of basecourse to the modified specification by two three-wheel rollers. The temperature of the material when laid was close to the maximum delivery temperature allowed.

In the 30 minutes following laying 32 passages were completed; this just exceeds the required minimum. The weather was cold and windy with an air temperature of 5°C and occasional sunny periods; despite these conditions the density difference between the wheelpath and the middle of the laid material is only 1.5 per cent, that is less than the typical difference found with conventional rolling.

3.4 Contract 4

The laying and compaction of a layer of roadbase in two consecutive trial areas laid 6 metres wide was observed by TRRL staff on a motorway reconstruction contract that incorporated the modified rolling specification. Rolling was carried out using an 11-tonne Aveling-Barford VSA roller and a conventional deadweight three-wheel roller; the VSA is a three-wheel roller with a full-width front roll capable of vibration. In both trial areas the VSA roller carried out over 80 per cent of the total roller passages and all the passages that were completed within 30 minutes of laying.

Area 1 involved a 100 m length of material on which the VSA roller completed half of the number of passages with vibration. In Area 2, which was a 70-metre length of paving one of the objects was to discover whether vibration resulted in improved compaction; the rolling procedure was therefore planned to be the same except that no vibration was to be applied.

In Area 1, 68 passages were executed within 30 minutes of laying, considerably more than the required minimum of 45 passages. In all 190 passages were applied in a period of 140 minutes. The average mid-depth temperature of the material had fallen from 120°C to 60°C within 100 minutes of laying so that many of the final passages made little significant contribution to the compacted state finally achieved.

In Area 2, 40 passages were completed within 30 minutes of laying and a total of 114 passages after 80 minutes. Fewer passages were performed in this area, the number completed after 30 minutes being slightly lower than the minimum of 45 specified.

In both trial areas the compaction achieved in the wheelpath slightly exceeds that at the middle of the laid width; an example of the distribution of roller passes in Figure 2 shows that the increased compaction in the wheelpath corresponds to a maximum of roller passes applied towards the edges of the laid width.

Laying temperatures varied from 105°C to 135°C in these two areas and Figure 3 shows that this corresponds to considerable variation in the degree of compaction between the various positions at which cores were taken; it is clear that where cooler material was laid there was insufficient time available to achieve a high state of compaction. The weather was overcast with little wind and an air temperature of 8°C, not untypical of moderate winter-laying conditions.

4. DISCUSSION OF TRIAL RESULTS

4.1 Improvement in compaction in relation to density at the centre of the laid width

In previous publications[2,3,5,6] it was argued that it must be practically possible to improve compaction in the wheelpath zones towards or beyond the peak levels found at the middle of the laid width; hence the major aim of the modified specification was to improve compaction in the wheelpaths and, by so doing, the uniformity of compaction across the whole laid width: Figure 4 gives density profiles obtained with a nuclear backscatter gauge on three of the trial areas and illustrates the improved uniformity of compaction obtained with the modified specification.

However, it is realised that the improvements in wheelpath density described by comparison with peak densities at the middle of the laid width are not necessarily related to the full potential for further compaction of the material. A test, recently developed at the Laboratory, for establishing a refusal level of compaction at which further compaction is unlikely has therefore been used to establish the scope for further compaction of the materials laid in the trial areas. The test is described in a separate Report[9].

Figure 5 confirms that, although wheelpath density in a given area is related relatively closely to density at the middle of the laid width, the difference between the two values is not necessarily an indicator of the standard of compaction achieved, ie of what is possible as defined by the refusal value.

An overall evaluation of the effectiveness of the modified specification is best given by comparing the average densities, expressed as percentages of the refusal values, in the wheelpath zones for the different types of rolling.

4.2 Improvement in compaction in relation to refusal values

Figure 5 demonstrates the wide range of compaction levels achieved, from about 89 to over 99 per cent of refusal density. Where TRRL staff were present at trials carried out in a wide range of weather conditions, layer densities are at least 94 per cent of refusal.

For the 6 layers rolled conventionally the average density achieved is 93.5 per cent of refusal. The figure for the 11 layers rolled to the modified specification but where TRRL staff were not present is 94.4 per cent. This represents an overall improvement of about one per cent despite the fact that two of the layers included were the most poorly compacted of all for reasons that are given in Section 3.1.3. The average compaction level in the wheelpath zone of the 7 layers compacted to the modified specification, and with TRRL staff present, is 95.7 per cent. A frequency distribution of layer densities in the wheelpath zone for each mode of rolling is given in Figure 6. This indicates that application of the modified specification resulted in an average improvement in the density achieved in the wheelpath zones of between one and two per cent. The average densities at the middle of the laid width are nearly the same irrespective of the rolling procedures used; therefore the main improvement brought about by the modified specification was to raise the compaction of the wheelpath zones to approach the level normally achieved at the middle of the laid width with conventional techniques.

4.3 Influence of temperature, layer thickness and weather

The temperature at which bituminous materials are rolled is of great importance in determining their compacted state. Rolling temperature is known to be influenced by the temperature at which the material is laid, the layer thickness and the weather conditions during rolling. The importance of these factors is indicated in Figure 7[10]; this gives profiles of temperature within the bituminous layers 30 minutes after laying, ie at a time when rolling would normally still be in progress and at the time limit given in the modified compaction specification for work carried out other than in hot summer weather; the results are computed using a program developed at the Laboratory[11].

Comparison of Curves 1 and 3 with Curves 2 and 4 illustrate the superior heat-retaining capacity of thick-layer construction under different conditions. The importance of weather conditions and initial laying temperature is also illustrated in Figure 7; the two curves corresponding to the 90 mm layer show that the mid-depth temperature 30 minutes after laying under normal conditions would be 95°C whereas that of material laid cold in wintry conditions would be 60°C.

Although these factors were not studied directly, the results obtained in several trial areas confirm their importance.

a) Figure 3 shows the improvement in compaction under wintry conditions brought about by increasing the laying temperature of a layer of material of thickness just less than the maximum of 105 mm presently permitted. The refusal density also indicates that there is scope for further improvement beyond that obtained when the laying temperatures were close to 130°C.

b) The relatively poor compaction in Area 3 of Contract 1 was partly attributable to constructing the roadbase in three thin layers rather than in two thicker ones.

c) The highest levels of compaction achieved in the trials were by intensive rolling in Areas 4 and 5 of Contract 2 in very warm windless sunny weather with air temperatures of about 20°C and with medium-to-high laying temperatures. In Area 4 material laid at 125°C in a relatively thick layer of 145 mm was compacted to 99 per cent of refusal density in comparison with 98 per cent achieved in material at 100°C compacted in a layer of more conventional thickness, 95 mm.

Example a) indicates the scope for further compaction even under favourable laying temperatures and in Example c) the most favourable temperature and thickness conditions combined with an optimum pattern and intensity of rolling were required to approach refusal density. The evidence from these trials and other work of the Laboratory[12] points to the fact that under the most favourable conditions of material and ambient temperature it is difficult to approach full wheelpath compaction in materials laid in conventional thicknesses using conventional rollers.

4.4 Comments on compaction procedure

In the four cases where TRRL staff were present to observe rolling and where one of the rollers was a tandem, the recommendation that the tandem should be used exclusively to roll the edges was ignored. Nevertheless improved compaction levels were consistently achieved in the wheelpath zones; this was the result of using two rollers to apply a greater than normal number of effective passages towards the edges.

A number of instances were observed where rolling stopped almost immediately after paving finished. Small areas of material in the vicinity of the paver were occasionally left to cool for up to an hour with little or no prior compaction before being rolled. For example in trial Area 1 of Contract 3, the paver stopped for the operators to have lunch; the roller drivers immediately stopped rolling although the last 10 metres of material had received 13 roller passages only. A core removed from the wheelpath zone of this area had a density 5 per cent lower than the average of the wheelpath cores taken elsewhere indicating that cold and windy weather conditions would not allow such a delay in rolling without a severe adverse consequential effect on the level of compaction achieved. Arrangements should be made for the roller drivers to continue working after the paving machine has stopped.

Even where considerable effort was made to carry out as much rolling as possible, inefficient use of the rollers resulted in considerable lack of uniformity of compaction along the trial areas. There was a tendency for the length of roller passages to increase as the laying progressed resulting in markedly fewer passages towards the ends of trial areas; similar observations were also made in previous work[6]. To provide uniformity of compaction it is essential that the length of roller passages is maintained reasonably constant.

4.5 General

Although the increase in the level of compaction in the critical wheelpath zones brought about by the implementation of the modified specification is encouraging, the results of the present studies suggest that further worthwhile improvements are possible with present machinery if more attention is paid to the execution of uniform and intensive rolling procedures; in general the rollers available on site are not efficiently or fully utilised. There are additional benefits to be gained from compacting thick layers at temperatures well in excess of the minimum presently specified, using more effective plant. Consistent achievement of densities close to refusal will however require close control of a method specification, or, possibly, a specification of an end-result type; the latter may be most suited to heavily trafficked roads where bituminous materials of high quality are particularly required.

5. CONCLUSIONS

1. The application of a trial method specification designed to increase the compactive effort in the critical wheelpath zones of the road and, by so doing, to reduce the variation of density across the laid width, has resulted in improvements in compaction of between one and two per cent; the improvements were generally greater when TRRL observers were present on site (but not controlling the compaction operation).

2. The difference between densities in the wheelpath and at the centre of the laid width was generally reduced by the operation of the trial specification reflecting more efficient use of the rollers. However the improvements actually obtained suggest that in practice the specification was being only partly implemented.

3. The results of the refusal tests indicate that there is considerable scope for further improvement in compaction.

4. If compaction close to refusal is to be obtained in general site practice there is a need to use more effective compaction equipment and to exploit the benefits of higher laying temperatures and thicker lifts, particularly in adverse weather conditions.

6. ACKNOWLEDGEMENTS

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TABLE 1

Summary of results

Location	Layer	Layer thickness mm	Aggregate	Rolling*	TRRL observers	VMA in wheelpath (per cent)	VMA at lane centre (per cent)	$\rho w^*/\rho c$ (per cent)	$\rho w^*/\rho R$ (per cent)	$\rho c^*/\rho R$ (per cent)
Contract 1 Area 1	1	85	Limestone	A	no	17.7	15.1	97.0	92.7	95.6
	2	105		A	no	18.9	17.1	97.9	90.9	92.9
	3	95		A	no	17.0	15.3	98.0	93.7	95.7
Area 2	1	70		C	no	14.8	14.9	100.2	94.6	94.4
	2	95		C	no	15.5	14.6	99.0	95.3	96.3
	3	110		C	no	15.3	14.0	98.6	95.6	97.0
Area 3	1	70		C	no	20.5	16.4	95.1	88.7	93.2
	2	45		C	no	20.1	17.0	96.3	89.1	92.5
	3	110		C	no	15.3	13.5	98.0	95.4	97.4
Area 4	1	65		C	yes	15.6	14.6	98.8	94.0	95.2
	2	75		C	no	16.9	17.1	100.3	92.6	92.4
Contract 2 Area 1	1	55	Limestone	A	no	16.0	14.6	98.4	96.8	98.4
	2	105		A	no	16.9	14.9	97.6	93.6	96.0
	3	65		A	no	17.4	14.7	96.9	93.2	96.1
Area 2	1	120		B	no	14.8	14.1	99.2	96.2	96.9
	2	130		B	no	14.7	13.7	98.6	96.1	97.4
Area 3	1	115	(Limestone (and Basalt	C	yes	16.7	15.5	98.5	93.7	95.0
	2	115	Limestone	C	no	16.0	15.1	99.0	94.5	95.5
Area 4	1	145	Limestone	C	yes	12.1	11.5	99.3	98.9	99.6
Area 5	1	95		C	yes	13.1	13.9	101.0	97.9	96.9
	2	135		C	no	12.8	12.0	99.1	98.2	99.1

TABLE 1 (continued)

Location	Layer	Layer thickness mm	Aggregate	Rolling*	TRRL observers	VMA in wheelpath (per cent)	VMA at lane centre (per cent)	$\rho w^*/\rho c$ (per cent)	$\rho w^*/\rho R$ (per cent)	$\rho c^*/\rho R$ (per cent)
Contract 3 Area 1	1	75	Basalt	B	yes	16.3	14.9	98.4	94.5	96.1
Contract 4 Area 1	1	95	Basalt	D	yes	15.9	16.1	100.2	96.1	95.9
Area 2	1	100	Basalt	D	yes	17.2	17.4	100.3	94.6	94.4

* A – Conventional rolling with 2 three-wheel rollers (8–10 tonne)

B – Modified specification with 2 three-wheel rollers (8–10 tonne)

C – Modified specification with a three-wheel roller (8–10 tonne) and a tandem roller (8–10 tonne)

D – Modified specification with a three-wheel roller (8–10 tonne) and a vibratory roller (11 tonne)

ρw – Density in the wheel path

ρc – Density at the lane centre

ρR – Refusal density

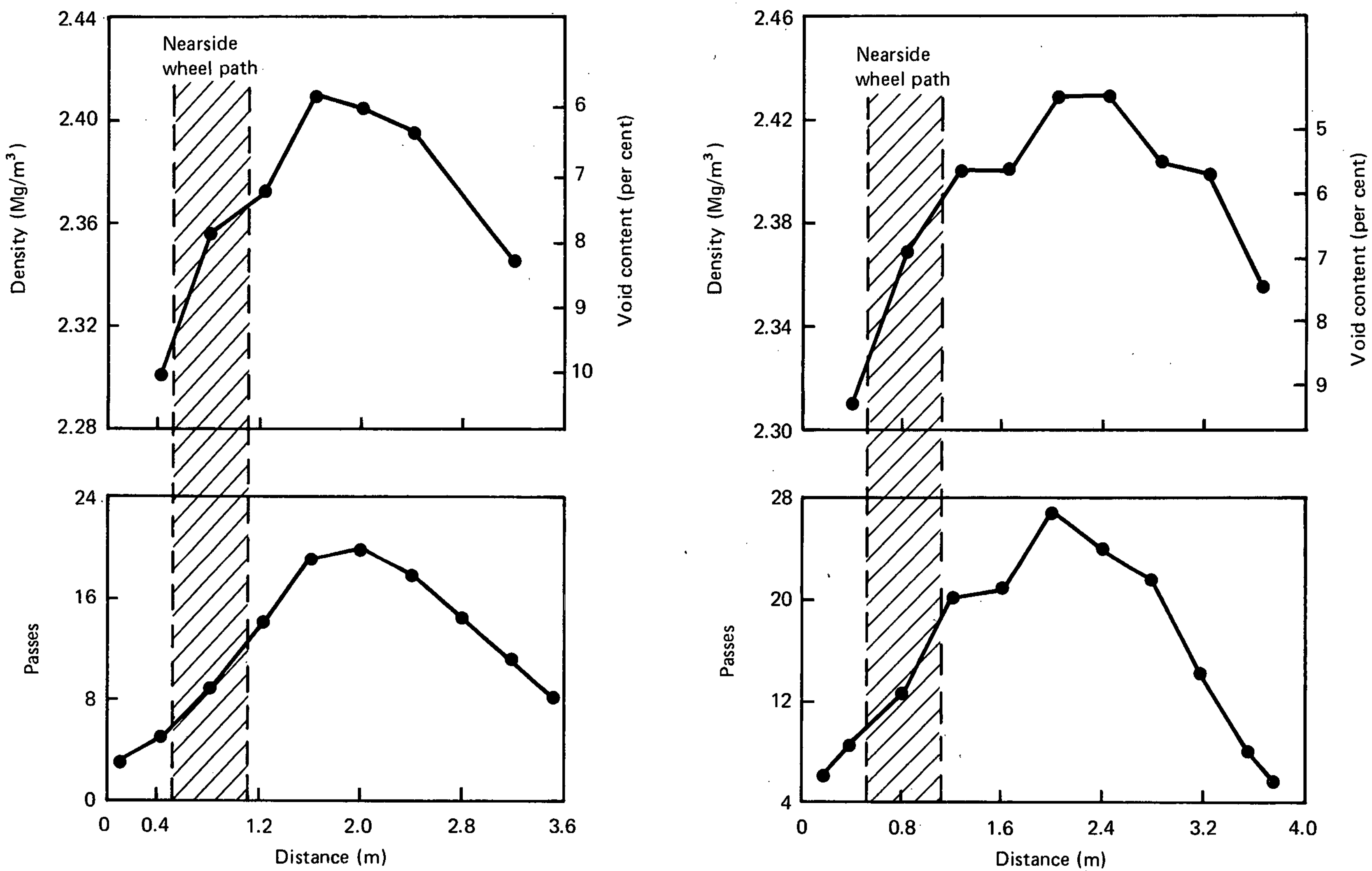

Fig. 1 VARIATION OF DENSITY AND ROLLER PASSES (THREE WHEEL ROLLER) ACROSS THE LAID WIDTH OF DENSE BITUMEN MACADAM ROAD BASE AT 2 SITES

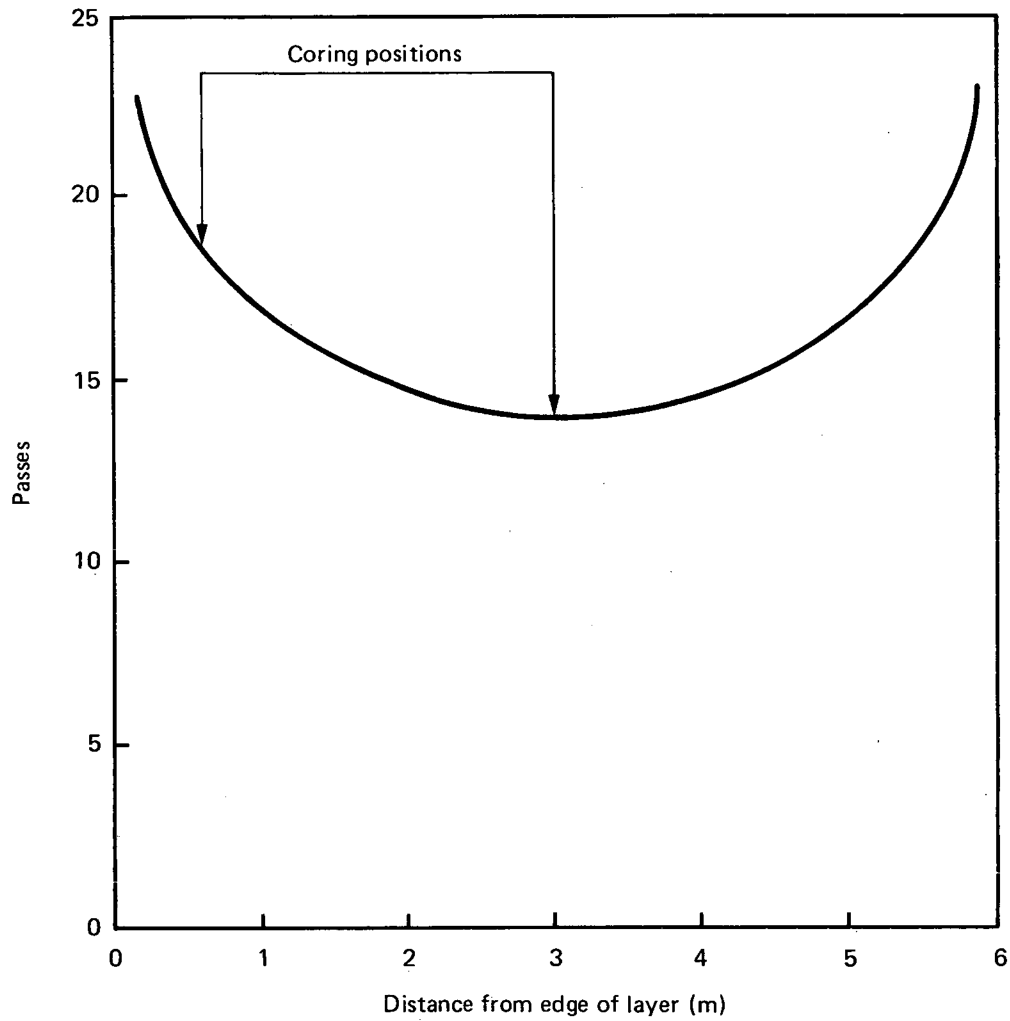

Fig. 2 VARIATION OF ROLLER PASSES ACROSS THE LAID WIDTH IN TRIAL AREA 1 OF CONTRACT 4, USING THE MODIFIED SPECIFICATION

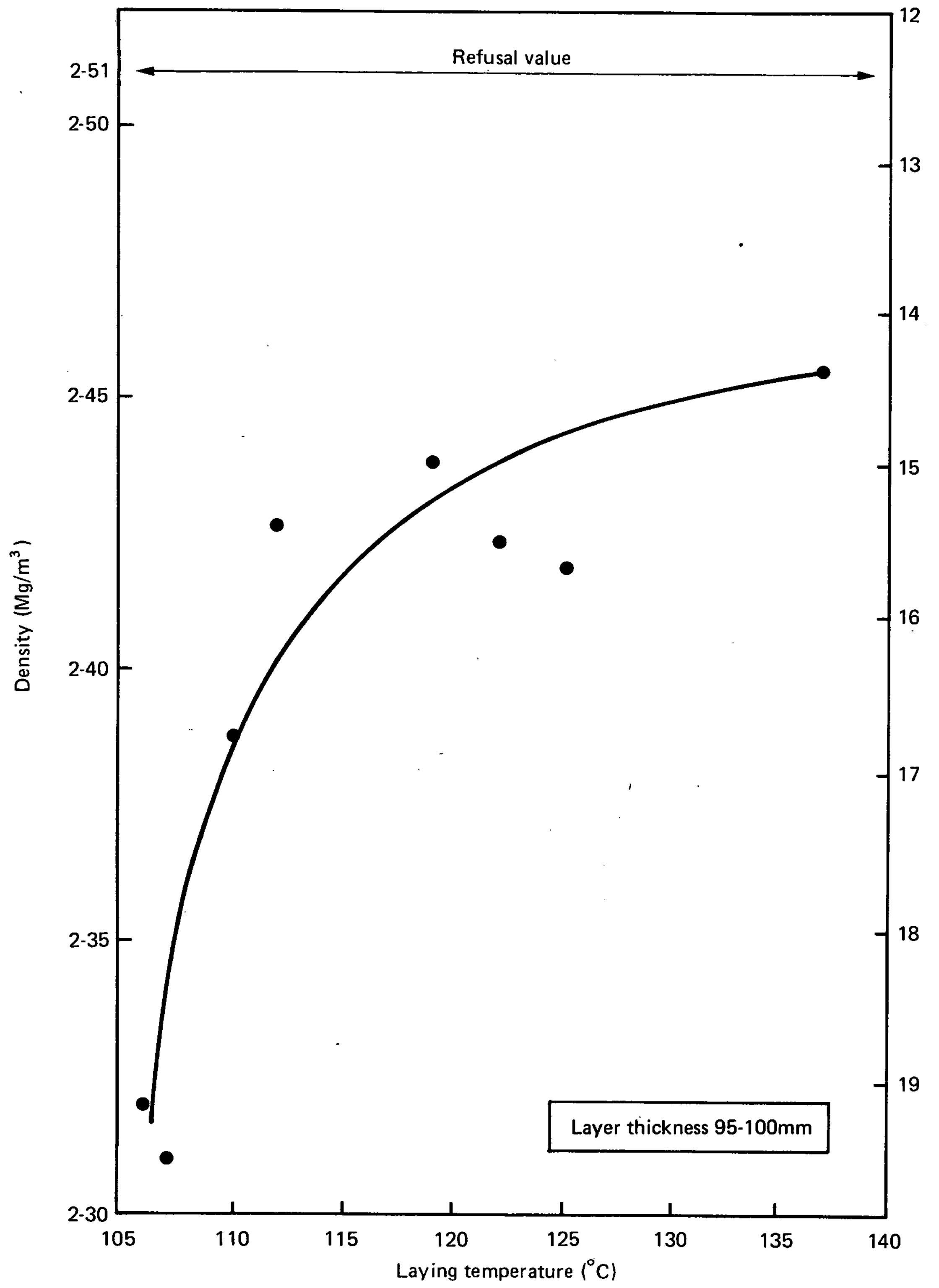

Fig. 3 VARIATION OF COMPACTION WITH LAYING TEMPERATURE IN TRIAL AREAS 1 AND 2 OF CONTRACT 4

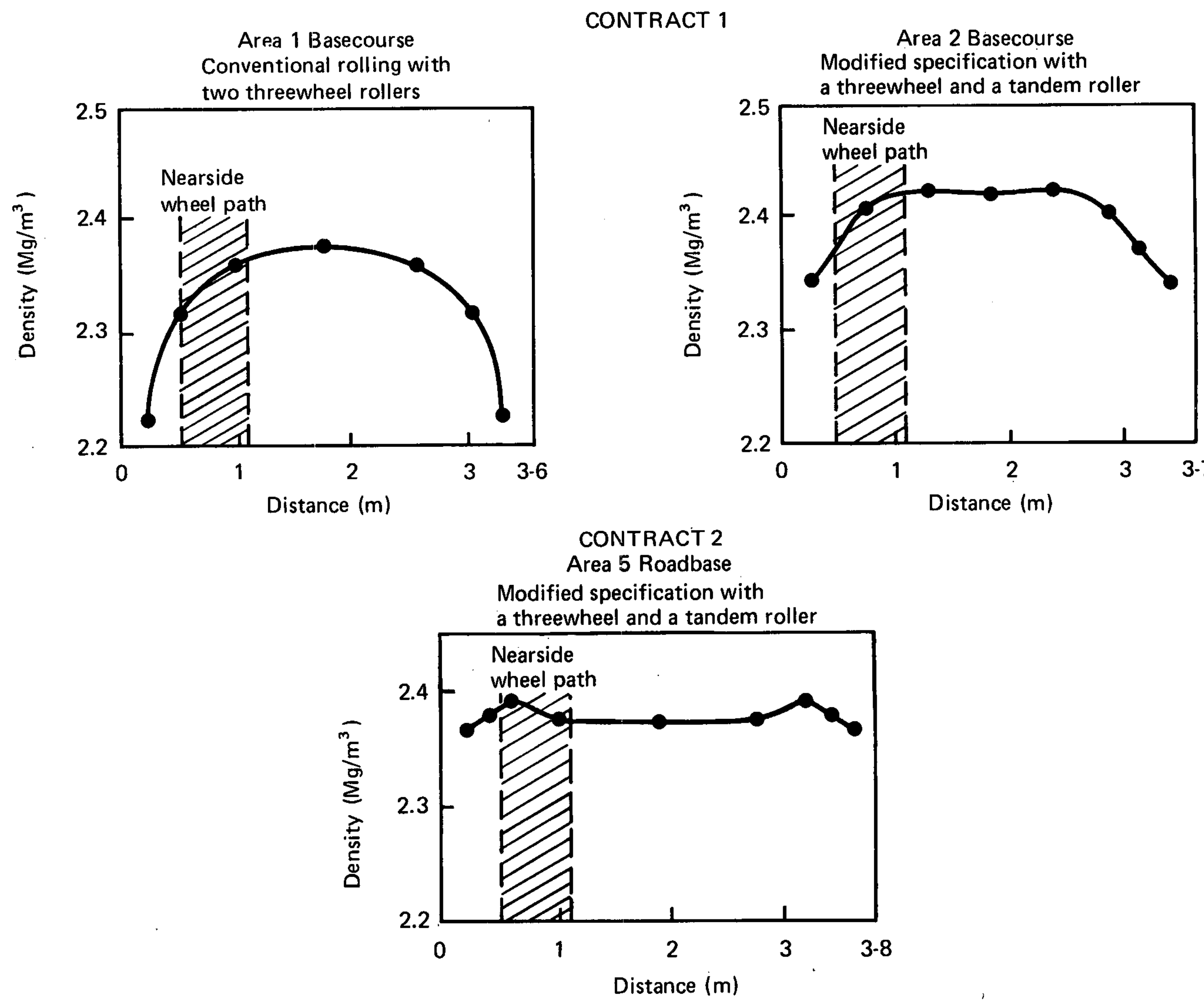

Fig. 4 VARIATION OF DENSITY ACROSS THE LAID WIDTH FOR CONVENTIONAL ROLLING AND ROLLING TO THE MODIFIED SPECIFICATION

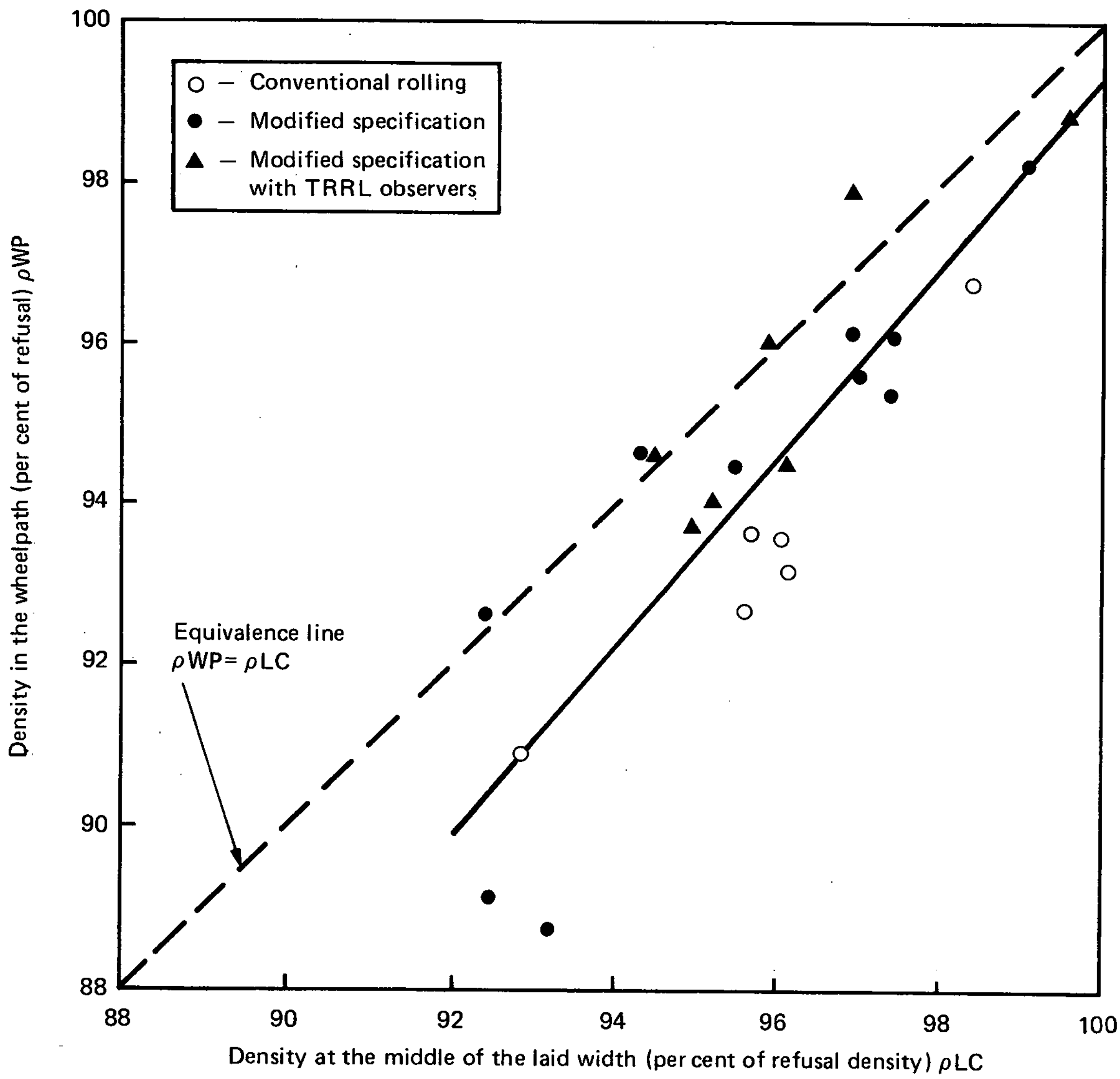

Fig. 5 RELATIONSHIP BETWEEN THE DEGREE OF COMPACTION IN THE WHEELPATH AND THAT AT THE MIDDLE OF THE LAID WIDTH

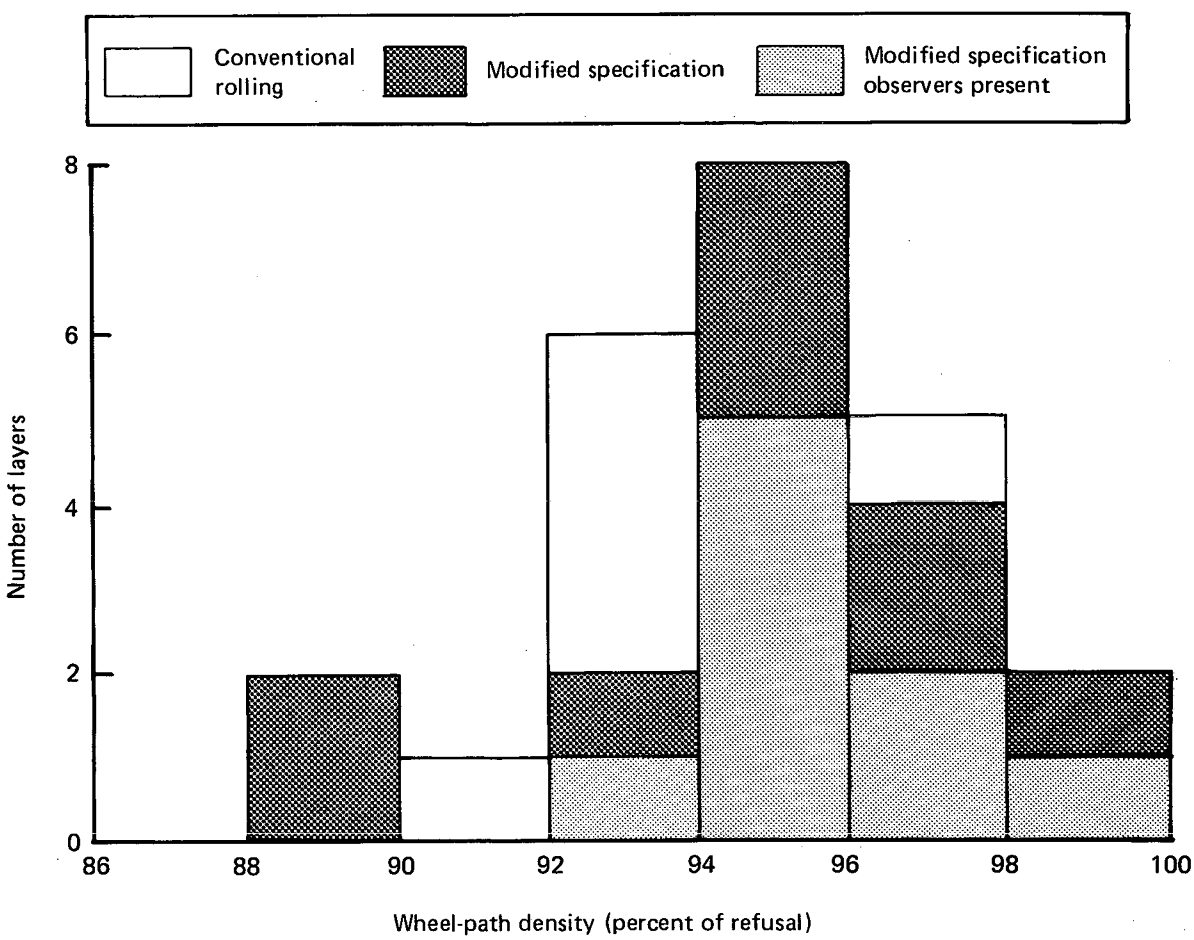

Fig. 6 DISTRIBUTION OF WHEEL-PATH DENSITIES

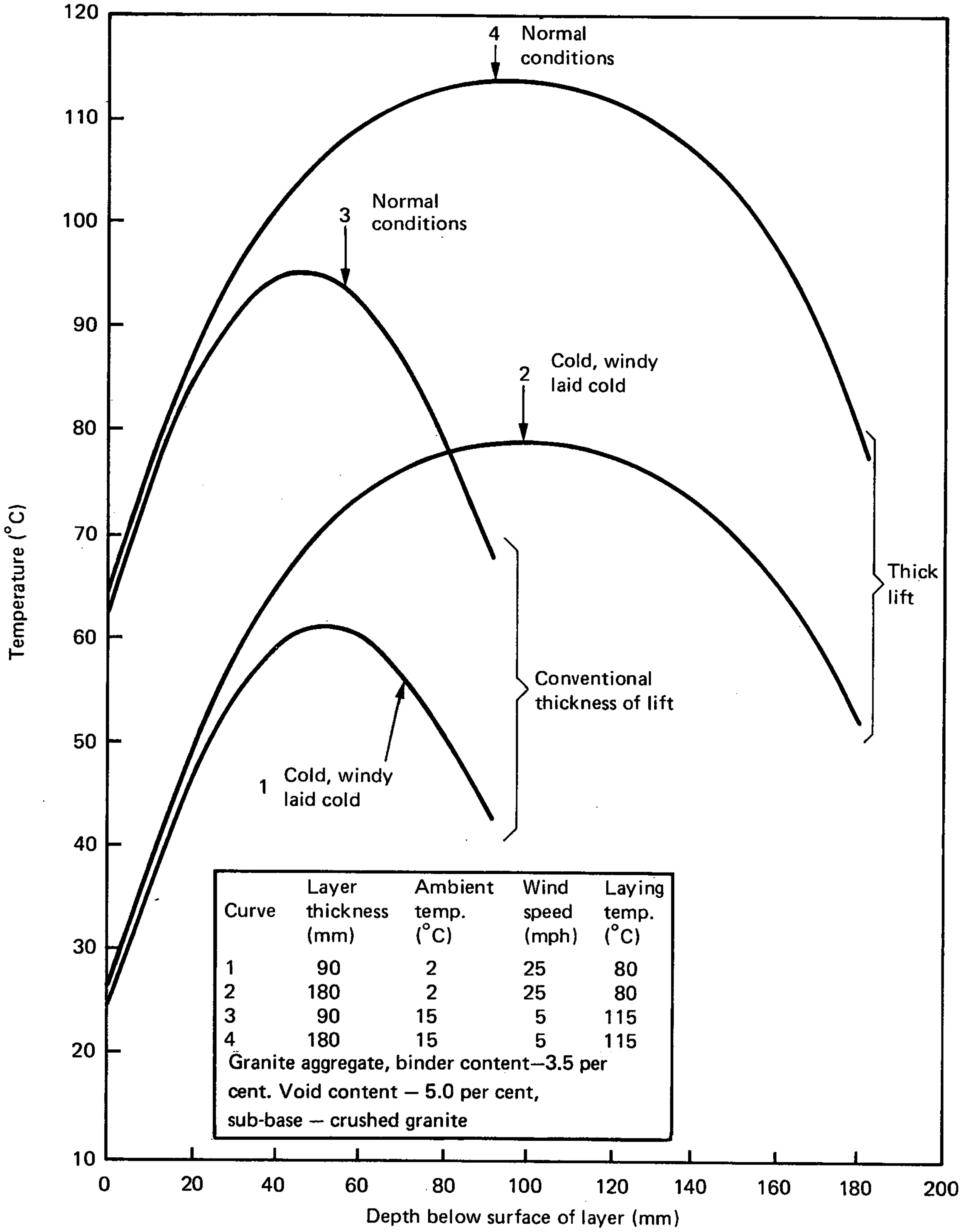

Fig. 7 VARIATION OF TEMPERATURE WITH DEPTH OF BITUMINOUS LAYER 30 MIN AFTER LAYING

8. APPENDIX 1

AMENDED SPECIFICATION CLAUSES FOR BITUMINOUS MATERIALS FOR THE TRIAL COMPACTION OF DENSE ROADBASE AND BASECOURSE MACADAMS

Clause 705 1–3 Not amended

4. The material shall be laid generally in conformity with the recommendations for laying in the British Standard to which it has been made or, where there is no British Standard for the material, in accordance with the laying recommendations in BS 594 but in all cases subject to the following additional overriding requirements.

5. Not amended.

6. Dense roadbase and basecourse macadams complying with Clauses 810S, 811S, 903S and 904S shall be compacted by an 8–10 Mg smooth steel-wheeled roller having a width of roll not less than 450 mm. For a laid width of 4 m a minimum number of 30 roller passages shall be completed within 30 minutes of the material being laid. When the laid width is other than 4 m the minimum number of roller passages shall be adjusted in direct proportion. When the ambient temperature exceeds 20°C the rolling period may be extended to 60 minutes. A roller passage is defined as having been effected when the roller completely passes over any reference line drawn across the laid width at a right angle to the direction of travel. A fractional number of passages shall be rounded up to the next whole number. All other bituminous materials shall be compacted as soon as rolling can be effected without undue displacement and while they have at least the minimum rolling temperature stated in the appropriate British Standard. They shall be uniformly compacted by an 8–10 Mg smooth steel-wheeled roller having a width of roll not less than 450 mm or by a multi-wheeled pneumatic-tyred roller of equivalent weight except that wearing course and basecourse material shall be surface finished with a smooth-wheel roller.

7. Dense roadbase and basecourse macadams complying with Clauses 810S, 811S, 903S and 904S shall be rolled in a longitudinal direction and one quarter of the number of roller passages shall be made with the nearest edge of the roller within 300 mm of each edge of the laid material. If 2 or more rollers are used one shall be a tandem roller and shall be used for the required number of passages on the edges of the laid material. A fractional number of passages shall be rounded up to the next whole number. All other bituminous materials shall be rolled in a longitudinal direction from the sides to the centre of the carriageway, overlapping on successive passages by at least half the width of the rear roll or in the case of a pneumatic-tyred roller, at least the nominal width of one tyre.

8–17. Not amended.

Clauses 810S, 811S, 903S and 904S of Technical Memorandum H 2/76.

1. Amend "Clause 705" to "Clause 705S".

2–4. Not amended.

Clauses 811S and 903S Additional sub-clauses.

5. Where the binder is 200 pen bitumen the aggregate temperature shall be in the range 110°C–130°C, the binder temperature shall be in the range 120°C–160°C and the delivery temperature shall be in the range 90°C–115°C. The minimum rolling temperature recommended in Table 58 of BS 4987 shall not apply.

NOTES FOR GUIDANCE TO CLAUSE 705S, SUB-CLAUSES 6 and 7

1. The purpose of the amended sub-clauses is to improve compaction of material in the wheelpath zone and this can be achieved by concentrating compactive effort adjacent to the edge of the laid material.

2. The effect on a laid width of 4 m is that 8 passages of the roller are made close to each edge and 14 passages are made as the roller traverses across the width in the normal manner. It has been found that, except under extremely cold conditions, the material does not become incapable of effective compaction in less than 30 minutes and it is therefore unnecessary to specify a minimum rolling temperature. It is permissible to make more than 30 roller passages and under favourable conditions further compaction may be achieved. In hot weather it may not be possible to commence rolling as soon as the material has been laid; in this case the period in which the minimum number of passages must be completed may be extended to 60 minutes.

3. On contracts where high laying rates are being achieved there will be a need to provide 2 or more rollers to attain the specified compaction and in this case at least one should be a tandem roller. Where the scale of work requires the use of only one roller it may be either a 3 wheel or tandem wheel machine and it will be necessary to devise a simple and effective method of ensuring that every part of the laid material is compacted effectively. When the binder is 200 pen bitumen it is necessary to increase the delivered temperature of the macadam by 10^{o}C in order to obtain effective compaction within 30 minutes.

4. The concept of roller passage is introduced in this clause and should not be confused with the expression "roller pass" used elsewhere in the Specification. The specified number of passages is spread across the whole width of the laid material and refers to both axles of the roller passing over any part of a line drawn at a right angle to the direction of travel.

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Comparison of these results with densities achieved in a laboratory compaction test to establish the practical or refusal limit of compaction shows that there is considerable scope for additional compaction on site. Improved compaction is discussed in terms of the major controllable factors in the compaction operation, ie method of rolling, laying temperature and layer thickness. If the benefits of levels of compaction close to refusal are to be realised this will normally require the maintenance of laying temperatures close to the permitted maximum, avoidance of thin layers and more effective compaction plant used according to the amended specification.

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