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FINAL REPORT OF THE WORKING PARTY ON THE SLIPPAGE OF ROLLED-ASPHALT WEARING COURSE

Pavement Design Division
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ABSTRACT

A Working Party was set up under the auspices of the Department of the Environment, the County Surveyors' Society and the Asphalt and Coated Macadam Association to determine the causes of failure of a number of rolled-asphalt wearing courses by sliding relative to the basecourse; failures normally occurred shortly after the completion of the construction of new roads. Most of these failures were reported in the eastern part of the country from Nottinghamshire northwards as far as Aberdeen in Scotland.

After considering the incomplete and sometimes apparently inconsistent evidence from 56 slippage failures an interim report was published in 1976 with the aim of initiating action that would help to reduce the incidence of failures. To identify with greater authority the factors affecting the risk of slippage and their interaction, proposals were made for further research. A programme of full-scale testing under controlled conditions has since been undertaken by the Transport and Road Research Laboratory and the results published in LR 813, together with some data from road construction sites.

A slippage failure is associated with the presence of a plane of weakness at or near the bottom of the wearing course. The present report confirms the important part played by the stiffness of the road structure in the development of such a plane; it recommends that the stiffness should be improved by making every effort to protect the subgrade during construction from the effects of moisture and from undue disturbance by construction traffic and by ensuring the structural adequacy of the unbound granular materials in the pavement. The rolling of the asphalt wearing course at too high a temperature is another factor that increases the risk of developing a plane of weakness, and a range of temperatures during laying is recommended. Whenever possible, wearing courses should not be laid on basecourses at temperatures close to freezing point.

1. INTRODUCTION

A Working Party was set up under the auspices of the Department of Transport (then Department of the Environment), the County Surveyors' Society and the Asphalt and Coated Macadam Association to determine the causes of failures of a number of rolled-asphalt wearing courses that have occurred shortly after the completion of construction.

The composition of the Working Party is as follows:–

Mr J H Nicholas (Chairman)	TRRL
Mr T J Smith	Department of Transport
Mr C E Hingley	ACMA and BQSF
Dr K R Peattie	ACMA
Mr A Windmill	ACMA
Mr B Cox	CSS
Mr J J Stansfield	CSS

Mr J T Turrill	CSS
Prof. P S Pell	University of Nottingham
Dr F Liversedge	BTIA/RBA
Mr N W Lister	TRRL
Mr F A Jacobs	TRRL
Mr J C Jacobs (Secretary)	TRRL

In addition the following have attended meetings by invitation of the Working Party.

Dr C Kennedy	TRRL
Mr L Swanson	TRRL
Mr M White	ACMA
Mr W R Edge	CSS

An interim report was published in 1976[1] with the aim of initiating action that would reduce the incidence of failures. It was recommended that special care should be taken with both the composition and construction of unbound layers of a pavement structure, and that precautions should also be taken to minimise hardening of the binder in the wearing course during manufacture and laying. Information available at the time the interim report was written was incomplete and often inconsistent. Specific proposals for future research were therefore also included to remedy this situation.

Research has since been undertaken by the Transport and Road Research Laboratory and the results published in LR 813[2]; they identified major causes of slippage failure.

The present report gives the final recommendations of the Working Party. The risk of slippage failure should be greatly reduced by their implementation.

2. MAJOR FACTORS CONTRIBUTING TO SLIPPAGE FAILURE

Observations at road construction sites made it clear that a slippage failure occurs only if a plane of negligible shear-strength is present at or near the bottom of the wearing course, close to the interface with the basecourse. Such a plane does not necessarily lead to a failure; if conditions are suitable after the road has been opened to traffic, a bonding may occur. Nevertheless the development of a plane of weakness is the critical event in the slippage process and its prevention is essential if future slippage failures are to be avoided. Such a plane is produced during the construction of the road pavement, usually when the pavement is built in winter and on pavement structures of above-average flexibility. Pilot-scale studies under controlled conditions involving full-size pavements constructed by conventional machinery at the Transport and Road Research Laboratory demonstrated that the following factors (not necessarily in order of importance) significantly affected the risk of development of a plane of negligible shear-strength.

1. Stiffness of any layer of the pavement under the wearing course (particularly the roadbase) or of the subgrade. Low stiffness will increase the risk.

2. The temperature of the wearing-course asphalt during rolling. A temperature towards the top of the present permitted range for delivery will increase the risk.

3. The temperature of the basecourse immediately prior to laying the wearing course. A low temperature will increase the risk.

In these tests, a slip-plane developed only when the wearing-course asphalt was laid at a temperature towards the top of the range currently permitted for delivery on a cold basecourse on a pavement structure of low stiffness. No slip-plane developed if one of these requirements was not met. The studies examined the whole likely practical range of pavement stiffnesses and basecourse temperatures but did not extend the range of wearing-course temperatures during rolling to those clearly possible if rolling is begun shortly after delivery at the maximum permitted temperature. One cause of the pronounced hardening of wearing-course binder reported in some instances where slippage failure had occurred, could be that mixing temperatures of wearing-course material towards the top of the permitted range were used at such sites; other possible causes have not been investigated.

A further factor, whose significance is undecided, is the type and temperature susceptibility of binder used in the wearing course. Although there is no direct evidence that in practice pitch-bitumen has performed worse (in the context of slippage) than petroleum bitumen, it seems likely that the greater temperature susceptibility of pitch-bitumen will produce asphalts more sensitive to the development of a slip-plane if they are laid and rolled at unnecessarily high temperatures than similar asphalts made with petroleum bitumen.

Variations in the stiffness of the surfacing in service due to differences in composition of the mixtures will be small even over the whole range permitted in the British Standard, but major changes in the viscosity of the binder such as have been recorded in some slippage failures, could of course significantly affect surfacing stiffness.

Other factors may well contribute in individual situations but these are judged to be of a minor nature. These are:—

1. Composition, type and binder type of the basecourse.
2. The use of a tack coat.

3. RECOMMENDATIONS OF THE WORKING PARTY

Recommendations relating to each factor are given below.

3.1 *Maintenance of adequate structural stiffness*

Adequate stiffness is an essential property of all road structures and therefore the requirements of good construction practice should be strictly followed, eg those detailed in the Specification for Road and Bridge Works of the Department of Transport and the associated Notes for Guidance. Particular points are noted below.

3.1.1 The subgrade: Every effort should be made to minimise the loss of strength of the subgrade that can occur during the construction of the pavement as a consequence of remoulding and wetting-up of the soil. Remoulding to some extent cannot be avoided but its effects can be mitigated by constructing whenever possible in dry weather and taking every precaution to prevent subsequent wetting-up of the subgrade. Laying a sub-base is not necessarily sufficient.

Local areas of serious subgrade weakness can be identified by means of penetrometer testing and simple soil identification tests. A TRRL report is in preparation giving details.

3.1.2 Unbound pavement layers: All practical steps should be taken to achieve a satisfactory stiffness and strength of unbound pavement layers, particularly in the wheel-path zones; the following recommendations to this end are made when using wet-mix material.

a) Good control of the unbound material should be ensured. The present specification limit of 8 per cent material passing the BS 75 μm sieve should normally be strictly enforced. However, where there is good evidence of satisfactory performance of local materials, laid in winter, containing more than 8 per cent passing the 75 μm BS sieve, these may be permitted at the discretion of the Engineer. Attention is drawn to Notes for Guidance on the Specification for Road and Bridge Works, Clause NG 808, Paragraph 2: the contractor should be asked to identify the primary source of supply of material and provide evidence of the manufacturer's ability to produce and supply to the correct grading.

b) For the determination of the optimum moisture content for compaction, the Vibrating Hammer Test is known to give a considerable scatter of results. Consideration should be given to replacing it by the more reproducible and repeatable Modified Vibrating Hammer Test[3]. Inclusion of this test in BS 812 is presently being considered.

   The determination of an optimum moisture content for compaction must be made on material to a grading representative of that which will be supplied on site.

c) Continuous supervision by a site inspector is the most important single factor in controlling moisture content on site. His judgement needs to be supported by frequent sampling and testing in accordance with the technique given in BS 812. A modified sand-bath technique which gives results within 30 minutes of sampling has been developed by the Laboratory for the measurement of moisture content and a report is being prepared.

d) To reduce the risk of moisture migration downwards into previously compacted layers the upper limit of moisture content allowed by the specification must not be exceeded and there is evidence that with some materials figures in excess of 5 per cent could lead to instability, although it is accepted that with certain slags and the more absorptive limestones, a higher moisture content may be necessary.

e) Although the compacted density of granular layers is not specified in the current Specification for Road and Bridge Works its measurement can be valuable in giving confidence as to the structural adequacy of the laid material. The sand-replacement technique or a quick-freezing technique recently developed at the Laboratory is recommended. A report is being prepared which describes the freeze-density technique.

3.1.3 Acceptance test for sub-bases and roadbases: The Working Group cannot recommend a proven method for specifying the adequacy of the road structure below the surfacing by a measurement of in-situ stiffness. It is however possible to use different forms of loading test to support the Engineer's judgement as to the adequacy of the structure.

3.2 *Viscosity of the binder in the wearing course during rolling*

Although the formation of a plane of zero shear-strength has been shown to be related to rolling temperatures and hence to the viscosity of the binder during rolling, it is not possible to monitor viscosity directly. A convenient alternative, sufficiently accurate for practical purposes, is to define viscosity of the binder in terms of a temperature related to its softening point (Ring and Ball) to IP58 or BS 4692.

It is recommended that the maximum permitted laying temperature of the wearing-course material should be 90°C above the softening point (Ring and Ball) of the binder used in the asphalt. In view of the difficulty of measuring temperature accurately in a thin layer of uncompacted material, it is also recommended that this maximum temperature be measured in the material in the paving machine, preferably in the screws but at least in the hopper immediately before the screws. The value selected allows for a fall of 15°C in temperature after laying before the first pass of the roller takes place and ensures that the roller does not begin to compact the mixture until the viscosity of the binder exceeds 10 poise. A 50-penetration-grade bitumen would require a maximum temperature in the paving machine of 145°C giving a maximum temperature at the start of rolling of about 130°C. This is consistent with the specified minimum rolling temperature of 100°C. A 70-penetration-grade bitumen would require a maximum temperature in the paving machine of 140°C, giving a maximum temperature at the start of rolling of about 125°C. This is consistent with the specified minimum rolling temperature of 90°C. A 35-penetration-grade bitumen would require a maximum temperature in the paving machine of 150°C giving a maximum temperature at the start of rolling of about 135°C. This value of 135°C, when associated with the specified minimum rolling temperature of 120°C for this grade of bitumen, would restrict unacceptably the range of laying temperatures, and it is therefore recommended that the minimum rolling temperature of 35-penetration-grade binders should be reduced from its present value of 120°C to 110°C. There is evidence that the use of these limits will permit both satisfactory compaction of the wearing course and also satisfactory embedment of superimposed coated chippings. These suggested limits of temperature are summarised in Table 1.

TABLE 1

Suggested limits of temperature for wearing-course rolled asphalts

Penetration Grade	Softening Point °C (Ring and Ball)	Maximum temperature in paving machine °C	Range of rolling temperatures °C
70	52 max.	140	90–125
50	56 max.	145	100–130
35	62 max.	150	110–135

Note: These temperatures apply only to binders complying with the given penetration and softening point requirements.

3.3 *Temperature of the basecourse*

It is recommended that laying of surfacing on a very cold basecourse material, (below 5°C) should be avoided wherever possible, except on very rigid structures. If circumstances compel such a procedure then pre-heating the basecourse should contribute marginally to reducing the risk of slippage, given compliance with the above recommendation about laying temperatures of the wearing course.

4. TYPE OF BINDER USED IN THE WEARING COURSE

It is possible that slippage problems could be ameliorated by paying attention to the temperature susceptibility of the binder used in the wearing course. One way of reducing temperature susceptibility is by substituting petroleum bitumen for pitch-bitumen. Particularly in adverse weather conditions, such a substitution has advantages.

5. RIDER TO THE REPORT BY THE ASPHALT AND COATED MACADAM ASSOCIATION

The Asphalt and Coated Macadam Association while generally agreeing with the contents of this Report, regrets that it is unable to endorse Section 3.2 and the suggested limits of temperature for wearing course rolled asphalts contained in Table 1.

The Association feels that considering the evidence presented to the Working Party, the Report places undue emphasis on the role of the temperature of the rolled asphalt in the wearing course. In the Association's opinion, the data collected from the sites of slippage failure indicate overwhelmingly that the primary cause of slippage was the presence of roadbases of unduly low stiffness. Wet-mix and unbound granular roadbases would be particularly susceptible to having low stiffness if gradings, in-situ moisture contents and compaction were not entirely satisfactory.

The results of the pilot-scale trials which were carried out at TRRL in a covered enclosure and described in LR 813, suggest that higher than normal wearing course laying temperatures or lower than normal substrate temperatures could be factors contributing to slippage. No actual slippage failures occurred during these pilot-scale trials and slip-planes (ie planes of zero shear strength between wearing course and basecourse) were formed only when rolling of the wearing course which contained pitch-bitumen binder, commenced at a temperature of about 145°C on a cold basecourse laid on a pavement of low stiffness. The Association therefore considers that the temperatures for petroleum bitumens suggested in Table 1 of the Report cannot be adequately justified.

It does not appear that the effect on compaction and retention of coated chippings, particularly on rolled asphalt wearing courses of high stability, of working at these low temperatures in the varying weather conditions encountered in the United Kingdom has been taken into account.

6. REFERENCES

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