Guideline for thin layer hot mix asphalt wearing courses on residential streets

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* These manuals have been withdrawn and their contents incorporated in a manual entitled: *The use of modified binders in road construction* published by the Asphalt Academy.

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Preface

The purpose of this manual is to present a set of general guidelines to assist clients, consultants, paving contractors and asphalt manufacturers to design, construct and manage the quality of thin hot mix asphalt wearing course layers on roads carrying light (predominantly passenger car) traffic, mostly in residential areas. In these locations the layers would normally be expected to meet functional requirements, rather than to contribute significantly to the structural capacity of the road pavement.

It should be noted that the guidelines presented in this document do not cover high speed, high volume applications served by e.g. stone mastic asphalt, or proprietary products such as ultra-thin friction courses. It is evident that such proprietary products, possibly accredited by Agrément South Africa and covering a wide range of service applications, are increasingly entering the SA market. However, it is not the intention of this manual to capture such practice, nor to make recommendations on the design and quality management procedures appropriate to such products.

The current application in the design and construction of thin layer asphalt which are more germane to layers that contribute to structural capacity, are critically appraised and, where appropriate, alternative methods and procedures proposed. In doing so, it is anticipated that a more uniform, rational approach to the design and construction of such layers would be furthered.

Note that superscript references in the text direct the reader to documents in the list of References on page 40.

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Introduction

Definitions

1. Thin layer hot mix asphalt

Within the scope of this document thin layer hot mix asphalt is defined as those layers that:

- Carry moderate to light traffic on residential streets and function as a surface treatment offering a direct contact stress interface between traffic and the base layer of the pavement. These layers mainly afford protection against traction and braking forces imposed by vehicular traffic, rather than contributing measurably to the structural capacity of the pavement;
- Have sufficient resilience to provide a durable surface in the face of prevailing transient deflections;
- Protect the underlying pavement layers against the ingress of water, thereby protecting the integrity of layer materials; and
- Provide an appropriate degree of skid resistance through finished texture.

To underline the function of such layers to meet service rather than structural requirements, such layers are often referred to as functional asphalt layers to differentiate them from thicker layers that contribute to the structural strength of the pavement. Consequently such layers should be constituted to optimise their functional performance characteristics, and appropriate quality management procedures should be instituted to achieve this objective.

2. Layer thickness

Currently in South Africa the majority of thin layer asphalt has been laid at thicknesses of between 20mm and 30mm. More recently proprietary products have been laid at thicknesses of less than 20mm in a variety of applications.

Accordingly, irrespective of mix type or usage, asphalt layers of specified thickness less than 30mm are considered to serve predominantly functional requirements, and fall within the ambit of thin layer asphalt.

Often layers of specified thickness of 25mm or less are referred to as ultra-thin layers. As these are also expected to serve functional needs, they are considered in this guideline as a subset of thin layer asphalt.

Scope

This document will cover the following topics:

- A review of current practice in the design and construction of thin layer asphalt in SA and abroad, and recommendations on appropriate applications for such layers;
- The influence of existing pavement conditions;
- A review of risks involved;
- Guidelines on mix selection and design;
- Guidelines on construction; and
- Quality control pertinent to thin layer asphalt.

Where appropriate current practices and procedures applied to thin layer asphalt will be critically appraised and alternative methods proposed.

As stated above, proprietary products are considered to be beyond the scope of this document, and are not specifically dealt with. However, many of the guidelines given are relevant and could be applied to the use of such products.

Also, other applications meeting moderate to high levels of functional performance criteria on high-speed rural roads require specialist attention and are not covered in the manual. For the latter and structural asphalt, reference should be made to *Interim Guidelines for the design of hot mix asphalt in South Africa*[1].

Current practice

In South Africa widespread use has been made of 20-30mm thin asphalt on low speed roads in residential areas. Most of the mixes have consisted of continuously graded asphalt using aggregates with a nominal maximum aggregate size (NMAS) of either 13.2mm or 9.5mm. As performance of these layers was generally considered to be variable, and the consistent achievement of good compaction has often proved to be difficult, a review of the technology associated with the design and construction of these layers appears to be justified.

This manual will address this need and propose methods that should ensure that adequate, cost-effective layers can be laid with a high level of confidence.

Thin asphalt layers (i.e. < 30mm) are most suited as a surfacing for new residential works and for the overlay of both urban residential and city streets. The performance of this layer does not contribute significantly to the structural capacity of the pavement. However, when compared to a chip seal surface treatment, it clearly provides a superior ride, a more even surface in residential areas where the street is an extension of the living area, and also provides a more durable surface (in many cases lasting 20-30 years).

Asphalt layers less than 20mm have only been used on a very limited scale in South Africa. Driven by economics, there is a perceived need in the residential situation to provide an alternative to seal surface treatments, reseals and slurry overlays. Further, the advantages of improved ride, appearance and durability are seen as prerequisites. Yet the product must compete cost-wise with the seals and slurries.

In the following sections this manual provides guidelines for the use of thin layer asphalt to meet functional, rather than structural requirements. Hence it should be clearly understood that it's expected performance characteristics cannot be judged against those of conventional HMA, which are deemed to contribute to the structural capacity of the pavement. Rather, any comparisons made should be against the properties of other surface treatments.

The designer of the mix should also take the following into consideration:

- The surface texture of thin layer functional asphalt will not necessarily be suited to high speed heavy traffic;
- It should improve rideability, but by how much will depend largely on the rideability of the underlying layer;
- Thin layers will be very susceptible to rapid cooling, which will militate against the achievement of adequate compaction.

Note: The above means that extra care should be taken in both the design and construction procedures to ensure that adequate densification will be achieved[11].

Existing pavement condition

It is clearly understood that HMA construction and performance is dependent on the condition of the underlying pavement. Thin layer asphalt is even more strongly dependent on this condition, and the following aspects are most important:

- Surface unevenness/roughness – applies to new layers and overlays;
- Pavement structure – applies to new layers and overlays; and
- Pavement distress – applies to overlays.

Generally thinner paved layers yield better final ride quality, provided that good paving practices are applied. A rough guide is that a thin, paver-laid mat will reduce the unevenness of the top layer by about 50%, making it vital that the relative surface evenness be established before selecting an appropriate surfacing. It is recommended that the surface be assessed using a 3m straight edge to establish a simplistic roughness rating based on a visual inspection supplemented by a ride quality assessment.

If the ride quality is a priority and the surface unevenness considered to be excessive, then levelling layers should be constructed prior to paving of the final layer.

Pavement support is essential in providing a sound platform on which the asphalt can be compacted. Because the asphalt is significantly stiffer than the underlying granular layer works, thin layer asphalt is likely to be overstressed where there is poor support. The pavement should be assessed and classed as either "stiff, flexible or very flexible" (after TRH 12 Table 20)[12].

Where the asphalt is to be applied as an overlay, a visual condition inspection of the road should be made as recommended in TRH 12. It is important that a clear picture be established of the extent and degree of the various forms of distress including rutting, cracking and failure.

A pro forma pavement condition summary form is given in Appendix B.

For new pavements a realistic estimate should be made of the condition of the base on which the surfacing is to be laid. For example, on an urban development where lower quality finishing of the base may be acceptable, it is unlikely that there will be an even base surface without some slacks. In addition the base might well be only G4 or even G5 quality and the pavement could well be either flexible or very flexible.

Risk assessment

The use of thin layer asphalt carries with it certain inherent risks. Firstly, it should be appreciated that, as the layer does not contribute significantly to the structural capacity of the road pavement, any defects or inherent weaknesses in the underlying layers are bound to impact on the thin layer's integrity and performance. Secondly the layer should be viewed as a surface treatment and its properties assessed as such and compared with other surface treatments on this basis. In particular the items assessed under Existing Pavement Condition Summary (Appendix B) are critical to the performance of thin layers expected to provide functional properties. In addition the following circumstances will affect its construction and performance:

- Weather conditions during construction;
- Climate (e.g. dry region, winter rainfall, etc.);
- Mix compactibility;
- Traffic and speed;
- Functional level.

Old asphalt surfaces where the asphalt is lean and open need to be checked for permeability and stripping. Sealing over such surfaces can result in trapping of water in the old layer with consequent failure. Where the permeability of the new thin layer asphalt permits some water ingress this can also result in further stripping of the old layer and/or delamination.

Risk evaluation tables have been suggested in Appendix C. The intention is not to provide a rigorous statement of risk but rather to give the user an indication of the degree of risk associated with unsatisfactory performance, and to suggest additional measures to improve the situation. This assessment, together with economic and socio-political considerations, should allow a more informed choice of an appropriate surface treatment. For example, for a pavement in a residential area where a low level of functional criteria based on economic constraints is appropriate, a moderate to high risk might be acceptable. Such acceptance would have to be on the understanding that some unsatisfactory outcomes might occur. A worked example is presented in Appendix D showing the use of the **Pavement Condition Summary** and the **Risk Evaluation Tables**.

Mix design guidelines

As the design of thin layer asphalt is not specifically dealt with in the *Interim Guidelines for the design of hot mix asphalt in South Africa (IGHMA)* this manual will cover guidelines for a rational general approach to the compositional design of asphalt in thin layers. The meeting of functional requirements is intimately tied up with the configuration of the various particles and binder, consequently the spatial composition of such layers will be examined in some detail.

In broad terms the design approach will deal with the following issues:

- Clarification of the performance criteria of thin layer mixes so that more realistic specifications can be set;
- An understanding that the compositional requirements of asphalt for thin layers to meet functional requirements are distinct from those that pertain to conventional (structural) asphalt;
- A set of guidelines to assist the designer in arriving at optimal mix proportions to meet specific site requirements;
- An assessment of the design criteria and methods in the light of the recorded satisfactory performance of thin asphalt layers; and
- A rational approach to quality management from plant to site.

Mix design criteria

The key design objectives should ensure that the functional requirements associated with relatively light traffic in residential or other low speed environments are met. These are:

- Low permeability, through limited and dispersed voids, to protect underlying layers – often granular bases – from the ingress of water;
- Compactibility, given the rapid cooling of thin layers and, hence the limited compaction windows. Two compositional aspects that would require attention are appropriate maximum aggregate sizes and binder grades;
- A surface texture to provide sufficient skid resistance associated with low speeds (< 80 kph). In view of the generally low prevailing

speeds to be accommodated, the skid resistance would be derived from the micro-texture of the asphalt;

- A compliant consistency, being sufficiently flexible and durable to accommodate the transient deflections associated with light, mainly granular, pavement structures rather than meeting structural requirements e.g. stiffness (i.e. load-spreading capacity) and resistance to permanent deformation.

Generally it is recommended that consideration be given to the use of so-called “sand skeleton” type mixes for thin layer asphalt in light traffic urban environments. By this is meant that the load is carried primarily by intergranular friction of the < 2.36mm fraction of the mix. In such cases the volume of mastic is limited to ensure that the integrity of the sand skeleton structure is not adversely affected.

The reason for adopting sand skeleton mixes is that such mixes are inherently flexible, with relative movement under transient flexural stress being distributed among many particles, thereby enhancing fatigue strength and durability.

In such mixes the proportion of coarse aggregate particles e.g. > 2.36mm, is limited to ensure that a stone skeleton, which may adversely affect permeability as well as compactibility during a limited compaction window, does not materialise.

Fine mixes also have a low proportion of interconnected voids, thereby counteracting passage of water through the mix.

The micro-texture associated with sand skeleton mixes, particularly where crusher sand is predominantly used, is appropriate to provide skid resistance for low speed (< 80 kph) applications.

The mix design criteria can be translated to the following design objectives:

1. Low permeability;
2. Ease of compaction;
3. Surface texture for skid resistance;
4. Flexibility (yielding fatigue strength);
5. Durability.

The matrix below demonstrates how fine, sand skeleton mixes in conjunction with softer bitumen grades will advance the achievement of the design objectives.

Design objective	Sand skeleton	Softer grade of bitumen
Low permeability	✓	
Compactibility	✓	✓
Low speed skid resistance	✓	
Flexibility	✓	✓
Durability		✓

Component materials

1. Aggregates

Extensive research and investigations have shown that layer thicknesses should not be less than three times the nominal maximum aggregate size, (NMAS) of the mix, to ensure compactibility and low permeability. In fact a case can be made for this ratio to be as high as four.

Hence, for layers of the thicknesses considered i.e. < 30mm, **it is strongly recommended that the NMAS adopted should never exceed 9.5mm.** (This implies that the 6.7mm sieve is the first one to retain more than 15% of the total aggregate by mass). In such cases the material passing the 2.36mm screen is considered to constitute the fine fraction and, given appropriate proportioning, will provide a sand skeleton to carry the loads.

Where the specified layer thickness is 20mm or less, a NMAS of 6.7mm should be given due consideration. In such cases the fine aggregate will constitute the material passing the 1.18mm screen.

The table below gives the recommended nominal maximum aggregate sizes to be used in conjunction with the layer thickness ranges indicated:

Layer thickness	NMAS
>20 <30mm	9.5mm or 6.7mm
20mm	6.7mm

2. Natural sand

The inclusion of 5% to 10% natural sand is frequently employed to improve workability and thus compactibility. It achieves this for two probable reasons:

- During the compaction process the more rounded sand particles will aid aggregate reorientation and hence densification; and
- It will assist to raise the grading curve of the mix above the maximum density curve (exponent n=0.45) in the 0.30 – 1.15mm sieve size range which is characteristic of sand skeleton mixes.

An additional benefit of the addition of natural sand is a reduction in the cost of the mix as a result of:

- The lower cost of natural sand compared with quarry materials; and
- A reduction in bitumen demand.

A potential disadvantage is that the mix may become tender and prone to shoving under the rollers, especially on steeper gradients.

Note that mixes without natural sand can be made more compactable by increasing the bitumen content and reducing the amount of filler. However, such action may, of course, raise the cost.

3. Active fillers

There is usually no need to use active fillers since:

- The risk of stripping of the bitumen from the aggregate is very low due to light traffic at low speeds; hence the use of lime is not necessary;
- The filler/binder ratio should be kept low, i.e. < 1.2 approximately to improve compactibility.

Additionally, not using active filler will reduce the cost of thin layer asphalt layers.

4. Bitumen

For streets in urban areas with lower levels of functional criteria, requirements of rut resistance and stiffness should not dominate the selection of binder grade and content. Thus the emphasis should be on good compactibility (i.e. compaction achieved with fewer roller passes).

As proper compaction of the mat is critical to the provision of a suitably textured and impermeable layer, it is recommended that the grade of bitumen used in the mix be selected with due care as this will affect the required mixing and lay down temperatures.

In view of the narrow time windows for compaction for a given set of site conditions, the use of a softer grade of bitumen e.g. 80/100 penetration should be given due consideration, mindful of climate conditions. Using this grade would have the effect of lowering the required mixing and paving temperatures by about 10°C compared to, say, those relevant to 60/70 pen bitumen. This will significantly reduce the temperature gradient between the mat and its surroundings which, in turn, could readily increase the compaction window to a more suitable period in which to achieve the required compaction.

Consideration could be given to the use of aliphatic synthetic wax modifiers to extend the compaction window, although such use would have a cost implication and, hence, an influence on cost-effectiveness.

Below are two examples of laying 25mm thick asphalt under typically marginal weather conditions. Compaction window intervals are given for three different mix types.

Note how the specially designed 9.5mm mix using 80/100 pen bitumen, has extended the time in which to achieve compaction to a reasonable period compared to the "conventional" mixes using 60/70 pen. A minimum of 10 minutes compaction time is usually required for an easily compacted mix.

Example 1:

Layer thickness: 25mm
Weather conditions: Air = 20°C, Base = 25°C, Wind = 10 km/hr

Mix type	NMAS (mm)	Bitumen grade	Lay-down temp °C	Min compaction temp °C	Compac-tion time minutes	% increase relative to COLTO mix
COLTO	13.2	60/70	140	80	8	-
SABS	13.2	60/70	140	75	9.5	17
LT Mix*	9.5	80/100	130	65	11.5	41

** LT Mix - Specially designed mix for application on roads carrying light (predominantly passenger car) traffic.*

Example 2:
Layer thickness: 25mm
Weather conditions: Air = 15°C, Base = 20°C, Wind = 0 km/hr

Mix type	NMAS (mm)	Bitumen grade	Lay-down temp °C	Min com-paction temp °C	Compac -tion time minutes	% increase relative to COLTO mix
COLTO	13.2	60/70	140	80	9.5	-
SABS	13.2	60/70	140	75	11	17
LT Mix*	9.5	80/100	130	65	13.5	40

Note:

In general, the properties of thin mixes, with smaller NMAS, are more critically influenced by variations in their composition than conventional mixes. Tolerances for particle size grading cannot be relaxed compared to those applying to thicker asphalt layers.

In addition, the skeletal structure of these mixes is defined by only selected particle sizes. The smaller the nominal particle size (often 9.5mm and less), the fewer the number of sieves that can be used to monitor grading. As a result, there is less opportunity to correct or improve the grading.

The consistency of the product is therefore more reliant on the consistency of aggregate supplied. Judicious selection of aggregate type and source, combined with preliminary checks on aggregate properties – including shape, hardness, polishing, abrasion and absorption – are therefore important.

All the above require that extreme care should be exercised to ensure that aggregates used in the mix delivered to site are representative of those used to determine the project mix proportions. This aspect is covered comprehensively in Sabita Manual 5: *Guidelines for the manufacture and construction of hot mix asphalt,* and the reader would be well advised to peruse that document.

Mix design considerations

A range of gradings are commonly used for thin layer asphalt surfacings. The exact composition of the mixes depends on specific functional and performance requirements and, as a result, varies from one application to the next with changes in aggregate type (stone, sand and filler) and bitumen content. Conventional laboratory specimen preparation and analysis techniques, such as those associated with the Marshall method, should be used with extreme care in view of the discrepancies in aggregate orientation of laboratory specimens and thin paved layers.

Boundary (edge) effects on the larger aggregate and rapid field cooling of thin layers create these discrepancies. Even the use of VMA correction factors to account for shifts between laboratory and field spatial compositions may prove to be inappropriate. These factors are often only applicable to certain grading types and layer thicknesses, and require verification for alternative mixes.

The spatial relationship between laboratory and field compacted mixes is at best tenuous and, although laboratory specimens can assist in identifying a suitable mix composition i.e. grading and binder content for thin and ultra-thin layers, they will not provide absolute properties such as void content, to be aimed for or monitored in the field. Nevertheless, some guidelines exist for the laboratory mix design.

Conventional fine continuous mixes have been used over many years primarily for sidewalks but also on a limited basis for parking lots and residential areas. The major asphalt producers have experience of these products in most of the urban centres. They should be consulted with regard to optimum mix properties.

Contrary to the typical reliance on post-construction traffic compaction of an asphalt layer to a steady state on high volume roads, on roads carrying mostly light traffic such further densification by traffic is usually minimal if not negligible. Therefore the designer should provide for a situation of i*n situ* voids in the mix not exceeding 7% after compaction. To achieve this readily it is recommended that, in terms of Marshall procedure, the target for voids in the mix is in the region of 3%, definitely not exceeding 4%.

Suggested design procedures

In major urban centres, where the need for thin layer asphalt will be relatively high, established hot mix asphalt plants continue to supply mixes for application on light traffic, low speed situations. In such cases the designer would be well advised to approach such manufacturing plants with a view to review the mixes available and their suitability for the specific application.

Alternatively, where the specific circumstances dictate that a new design needs to be developed, the designer would have to apply rational methods of design that addresses aggregate packing to optimise the composition of the mix to meet compactibility, low permeability and durability requirements, and to counter segregation.

This section will cover both aspects, i.e. mixes in use that have been found by experience to perform satisfactorily when applied as thin layers in light traffic, low speed applications, as well as suggesting a rational approach to design aimed at meeting key functional performance requirements.

Mixes in use

A number of mixes have been used for several years with success in various regions in South Africa for residential streets in urban areas. The designs adopted are based on readily available aggregate materials from consistent commercial sources. Where there is no need to explore new raw material sources, the user may be well advised to contact suppliers in the region to ascertain the salient properties of these mixes, as well as the respective list prices to ensure that an optimal choice is made.

It is not the intention here to present all the details of the various mixes in use, rather some key mix descriptors are given to guide the user.

Composition

In many cases the mixes are made up of crusher products with a limited proportion (< 11%) of natural (or mine) sand added. These mixes may well be described as “sand skeleton” or fine-grained mixes, i.e. the load is carried mainly by the fine particles (< 2.36mm) of the aggregate bound together with a mastic of binder and filler. The gradings could be described as “continuous”, although most deviate sufficiently from the maximum density line (n=0.45) to allow for sufficient binder, while maintaining adequate voids in the mix to prevent flushing of the surface.

Suggested salient mix properties are as follows:

1. Nominal Maximum Aggregate Size: = <9.5mm;
2. “Fine aggregate” i.e. % passing 2.36mm: 46% or more;
3. Binder type: 60/70 or 80/100 penetration grade bitumen;
4. Binder content: Such as to result in 3 – 4.5% Marshall voids, (for a bulk relative density of aggregate of 2.7, binder contents are typically 5.5%);
5. Filler (% passing the 75 micron sieve): 5 – 7%;
6. Filler/binder ratio: <1.3, typically 1.2;
7. Computed film thickness: 7.0 – 8.5 micron.

Typical mix properties

Table 1 details key mix properties of mixes used in the Western Cape, Gauteng and KwaZulu-Natal (KZN).

Table 1: Key mix properties

Region	Western Cape			KZN		Gauteng
Mix ID	CK18	CK2A	ER8	Type B1	A2	Medium RZM
NMAS	9.5	6.7	9.5	9.5	9.5	9.5
Grading						
% Passing						
13.2	100	100	99	100	100	100
9.5	100	100	93	98	99	99
6.7	88	97	80	84	78	86
2.36	48	50	48	47	43	43
1.18	34	35	36	34	35	27
0.6000	26	24	28	27	25	19
0.150	9	12	10	12	11	8
0.075	6.6	7.0	6.8	7.4	7.0	4.7
Aggregate components						
	21% 9.5mm HF[1] 20% 6.6mm HF 49% CD[2] HF 10% natural sand 0% active filler	40% HF 59% CD HF 1% active filler	8% 13mm HF 14% 6.6mm HF 67% CD HF 11% natural sand 0% active filler	19% 9.5 Q[3], T[4] 8% 6.7mm Q 66% CD Q,T 6% natural sand 1% lime	35% 9.5mm Q 55% CD T 10% natural sand 0% active filler	16.5% 9.5mm D[5] 25% 6.7mm D 52% CD D, Dm[6] 6.5% mine sand 0% active filler
BRD Agg. Blend	2.702	2.707	2.700	2.588	2.608	2.902
Mix properties						
Bitumen grade	60/70 or 80/100	60/70	60/70	60/70	80/100	60/70
Bonder cont. %	5.4	6.0	5.3	5.0	5.4	5.0
% VIM[7]	3.7	3.4	3.6	4.5	4.7	4.2
Film thickness m	8.0	8.3	7.2	7.2	7.6	7.7
F/B ratio	1.2	1.2	1.3	1.4	1.3	0.94

Gradings of several mixes currently in use, plotted on the n=0.45 scale for sieve sizes, are shown in Figure 1.

By and large these mixes comply with the suggested properties given above, except that in some cases the % passing the 2.36mm sieve is just below the recommended minimum of 46%, typically in the range 43 – 44%.

[1] HF- Malmesbury rock (Hornfels); [2] CD - Crusher dust; [3] Q - Quartzite, [4] T - Tillite;
[5] D - Dolerite, [6] Dm - Dolomite; [7] 75 blow Marshall.

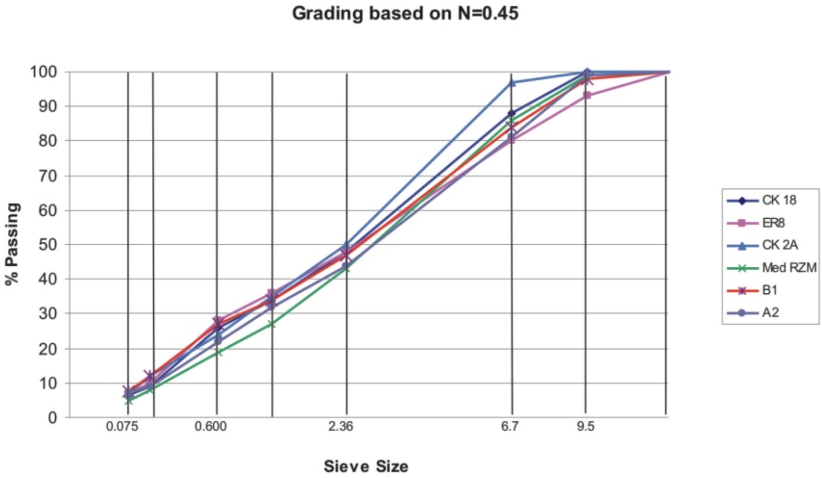

Figure 1: Gradings of several mixes currently in use, plotted on the n=0.45 scale for sieve sizes

Design method

Where the designer wishes to explore alternative aggregate sources or compositions, it is recommended that methods examining appropriate spatial composition and volumetrics be adopted to ensure that the design objectives of durability, imperviousness and compactibility are achieved.

The so-called Bailey Method, based on the packing characteristics of the aggregate, has been introduced and used in South Africa and it is suggested that the designer investigate mix composition using this method as a basis for determining aggregate proportioning.

In this method the aggregate packing is examined on a volume basis as a means of assembling the composition of the mix in terms of the various aggregate fractions. Further laboratory examination, e.g. using methods associated with Marshall or gyratory compaction, is required to establish the optimal binder content to achieve the desired voids in the mineral aggregate (VMA) and voids in the mix.

Certain parameters given in the Bailey Method can also be examined to establish whether the mix is compactible, likely to segregate or is tender. The method can also be applied during quality control processes to ensure that key relationships between the various aggregate sizes are being maintained during manufacture.

It is not the intention to cover the method comprehensively in this manual. For additional information the reader is referred to the TRB publication Transport Research Circular Number E-C044: *Bailey Method for gradation selection in hot mix asphalt mixture design*, October 2002. A brief overview of the method is, however, given in Appendix A to introduce the designer to the main principles and requirements of the method, and to indicate how these can be met by combining the aggregates in various proportions.

Table 2: Comparisons of the various ratios of some of the mixes in general use in terms of Bailey criteria given in Appendix A, where these are available

Region	Western Cape			KZN		Gauteng
Mix ID	CK18	CK2A	ER8	B1	A2	Medium RZM
NMAS	9.5	6.7	9.5	9.5	9.5	9.5
Bailey parameters						
CUW	77	95	67	63	72	80.5
Range (fine graded)	**60-80**	**60-80**	**60-80**	**60-80**	**60-80**	**60-80**
Mix type[6]	F	C/F	F	F	F	F
PCS	2.36	1.18	2.36	2.36	2.36	2.36
NPCS	0.600	0.300	0.600	0.600	0.600	0.600
NHS	1.18	0.600	1.18	1.18	1.18	1.18
CA ratio	0.685	0.712	0.702	0.600	0.779	0.564
Range	0.35-0.50	0.35-0.50	0.35-0.50	0.35-0.50	0.35-0.50	0.35-0.50
Volumetric properties						
% coarse agg v/v[7]	40.9	50.0	35.2	34.0	37.4	41.3
VCA_{mix}	55.3	48.0	55.7	54.9	53.4	53.2
% fine agg. v/v	59.1	47.5	64.8	66.0	62.6	58.7
Diff vol agg -VCA (%)	3.8	2.5%	8.4	11.1	10.2	5.5

[6] *F – fine graded (sand skeleton), C is coarse graded (stone skeleton),*

[7] *Based on the original PCS*

Existing mixes assessed

The chosen unit weights (CUW) adopted for all mixes fall within the range of 63 – 93% of the loose unit weight state, thereby ensuring that stone to stone contact in the coarse fraction is unlikely to occur. The mixes can therefore all be classified as fine-graded or sand skeleton types, as recommended. This configuration of the aggregates is further borne out by the fact that the percentage of fine aggregate, on a volume basis, exceeds the voids in the coarse aggregate (VCA) by 2.5 – 11.1 percentage points, characteristic of sand skeleton type mixes.

The coarse aggregate ratios (CA) all fall within the recommended range and indicate that the mixes are unlikely to be tender. The same applies to the FA_c ratios, indicating that compaction should not present a problem.

Construction

The key factors affecting the laying and compaction of thin layer asphalt are:

- Base quality i.e. density and quality of surface preparation;
- Compactibility characteristics of the mix;
- Cooling of the mat (often the key factor);
- Compaction techniques and equipment.

As a result, the achievement of a suitable density – and hence low permeability – is often more difficult to achieve on thinner asphalt layers. Thus thin layer asphalt construction requires a greater level of attention to good paving practice details. The following paragraphs assume that such practice will be carried out and only refer to particularly sensitive issues.

Pre-treatment

Pre-treatment will be dictated by the actual condition of the existing pavement. The following paragraphs comment on the most common conditions/defects that are likely to be encountered. It is unlikely that new pavements will require much pre-treatment other than a tack coat. However, where e.g. the surface finish does not meet specified requirements, certain remedial measures would be required.

Surface unevenness/roughness

Slacks can be reduced up to about 50%, providing the slack is not more than 15mm to 20mm deep. Paving over these slacks will increase the amount of asphalt required, and in very uneven conditions may cause ponding of surface water and adversely affect ride quality due to the differential compaction of the asphalt.

Slacks deeper than 15mm to 20mm must be taken out either by localised infill, a ‘scratch’ coat, or a levelling layer. Where localised depressions deeper than 10mm occur (such as a service trench) these must be patched prior to paving.

The use of thin layer asphalt over a coarse/rough surface will provide a smoother surface and a quieter ride than a chip surface dressing.

Cracks

For the purpose of pre-treatment, cracking should be divided into two groups namely:-

- crocodile/map cracking;
- single random cracks.

Crocodile/map cracking is usually symptomatic of distress in the underlying layers of the pavement. Where these occur the reason for distress should be established and repairs carried out by either replacing the surfacing and/or constructing a patch extending at least into the base. Failure to do so will result in the distress in such areas rapidly reflecting through the thin asphalt, leading to unacceptable distress.

Localised cracking, where the pavement is still performing structurally, can be patched using a geofabric. These areas should be trafficked for some weeks before paving. Where this is not possible the geofabric should be armoured with grit. Extensive use of geofabric is not recommended.

Single random cracks occur for a variety of reasons which are often difficult to determine. Providing that there is no obvious distress in the adjacent pavement it can be concluded that the crack is not affecting the structural integrity of the pavement. Open cracks should be cleaned out with compressed air and filled neatly with a sealant to prevent water ingress. Excess sealant will result in unsightly blotches on the new asphalt surface. Particularly with thin layers, even after pre-treatment, these cracks are very likely to reflect through shortly after construction.

Potholes

Potholes consist of small (<0.5m diameter) holes in the surfacing usually extending into the base. The adjacent pavement should be in reasonable structural condition. The holes should be cleaned out until sound material is encountered, the edges neatly trimmed, primed and then patched with asphalt. The final patch should also be sealed. Larger holes or where the adjacent pavement is showing structural distress should be handled as detailed in the following paragraph.

Shoving, displacement and failure

These forms of distress occur where the pavement structure is no longer able to carry the traffic. In certain cases tree roots and mole runs can cause severe distortion of the pavement surface. The cause of the distress must be determined and suitable patch repairs carried out.

Lean and dry surfaces

Especially in climatic conditions where water ingress is a major problem, an old permeable surface should not simply be overlaid without suitable pre-treatment. In moderately dry regions the lean surface can be addressed by increasing the tack coat application so that the surface interstices are penetrated and there is a thin film on the surface for bonding.

Dirty surfaces

Any obvious dirt or contamination on an existing surface should be cleaned prior to applying a tack coat and paving. Tacking over a dirty surface will result in slippage failure in the thin asphalt.

Tack coat

The performance of thin asphalt layers is strongly dependent on a good bond with the underlying surface, especially in areas where there are likely to be surface shear forces such as braking and turning movements. The amount of tack coat will depend on the condition of the surface, but as a guide tack application rates should be increased by between 0.1 to 0.2 ℓ/m^2 (net binder) above that used for conventional asphalt. This does not mean that there should be pools of tack, which remains bad practice.

Preparatory work

It is imperative for thin layer asphalt that the base layer is of high quality, dense, sufficiently dry with a high quality finish and sprayed with a tack coat.

Bases on lightly trafficked roads often do not comply with these criteria and it requires a mindset change to ensure adequate returns on the investment in the pavement and its surfacing.

All preparatory work should have been completed and approved before asphalt construction is started. Especially on moisture sensitive bases or old porous asphalt, moisture contents should be checked and no construction should be carried out over wet materials.

Paving equipment

All plant must be in good condition with no oil or fuel leaks.

Paver screed settings and component wear should be checked against the manufacturers' specifications. No work should be carried out until settings are correct and worn parts replaced. A heated screed, thermostatically controlled at about 130^{o}C, helps ensure that the asphalt immediately behind the screed is at a consistent temperature.

A vibrating roller (with high frequency, low amplitude) achieves density with fewer passes than a static roller and is thus recommended for thin layers, due to the short compaction time available (compaction window).

A pneumatic roller is recommended for secondary rolling and closing up the surface as it is more effective at lower mat temperatures than a steel drum roller.

Mixing

Thin layers appear to be more susceptible to small changes in composition. Thus careful control of the mix constituents is essential. Of particular importance is the control of the filler/binder ratio, while mix temperatures can be towards the upper limit of the viscosity range for the grade of binder used, overheating should not be permitted.

Using 60/70 pen bitumen, the asphalt should be mixed at about 160-165^{0}C. It will then arrive on site at between 155 and 160^{0}C, and come out behind the paver at about 140^{o}C. Should 80/100 pen bitumen be used, these temperatures can all be lowered by approximately 10^{o}C.

Insulation covers are strongly recommended for the delivery trucks. This should reduce the surface crust and ensure a more uniform laying temperature.

Weather conditions

The contents and recommendations of Sabita Manual 22: *Hot mix paving in adverse weather* should be understood and applied. The thinner the layer the more critical is this requirement.

For example

- A 25mm mat paved in weather conditions of 13°C air and 18°C base temperatures, and a wind of 20 km/hr, has a compaction window time of only 7 minutes.
- Whereas at 30°C air and 45°C base temperature, and no wind, the compaction window is 14 minutes.

As a rule of thumb, for an easily compactable mix, a minimum compaction time of 10 minutes is necessary for practical reasons. Thus the first weather situation given above indicates that paving should not be permitted.

General construction

The general good practice requirements for asphalt paving must be carefully carried out.

- Paving widths should suit the rollers being used. Due to the limited compaction time, it is recommended that the paving width should not be greater than twice the effective width of the breakdown roller;
- The paving speed should be controlled such that the rollers operate as close as is practical to the screed, ensuring the maximum time compaction window and rolling while the mat is still hot;
- Paving operations should be organised to minimise handwork;
- Handwork should be done at the hottest time of the day using fresh, hot asphalt from a truck;
- Unconfined edges (e.g. at longitudinal joint positions) should be ‘nipped back’ (typically 75mm) and tacked generously with hand applied undiluted emulsion;
- “Bumped joint” construction is recommended when paving next to an adjacent mat.

Rolling techniques

Due to the very limited compaction window, the choice of rollers and rolling techniques is of vital importance. The following should be taken into account:

- Vibratory rollers achieve density most rapidly;
- The breakdown roller should cover the mat width in two roller widths. (If it can only cover the mat in three widths it takes 50% longer to complete its passes. Therefore choose rollers of suitable drum width for the width of the mat being paved.);
- Consider using two breakdown rollers in tandem – this halves breakdown rolling time;
- Pneumatic rollers are best for intermediate rolling as they are still effective at mat temperatures of down to 70^{o}C;
- An ideal rolling train would be two breakdown rollers in tandem with a pneumatic immediately behind them;

- In cold conditions, a second pneumatic roller may be necessary to achieve the required compaction in the severely restricted compaction window. (In such a case, total number of rollers is four. This is another change in the usual approach to compacting thin mats. Frequently the thinner the mat, the fewer the number of rollers that are considered necessary.

Hand work

Where handwork has to be done, rapid cooling presents a problem even if the mix has been designed to mitigate its effects. Therefore it is suggested that the designer should increase mat thicknesses for handwork areas to 40mm.

Quality control

Traditional HMA specification controls such as relative compaction, layer thickness, levels and mix properties have been applied to thin layers for many years. In particular the measurement of field densities has proved to be difficult and, to varying degrees, unreliable. This is especially the case when the layer thickness and/or the nominal stone size to layer thickness ratio decreases.

The achievement of good densification is necessary for the satisfactory performance of the asphalt to achieve integrity and resistance to water ingress. This should to some extent be addressed by measuring permeability in the field. Where thin layer asphalt is constructed, rutting or consolidation of the layer should not be a major consideration.

Level control remains important to achieve adequate ride quality and surface drainage, but on rough uneven surfaces this will result in the average thickness far exceeding the nominal called for. This must be recognised, considered at the design stage and adequate provisions made for in the construction contract.

It remains good practice to monitor and compare the mix constituents (i.e. binder content and grading) with the proposed job mix, with due regard to spatial configuration.

The following controls are recommended for thin layer asphalt. These controls should not be rigidly applied but rather used with understanding to achieve a satisfactory surface treatment product.

Before construction

Depending on requirements, specify special controls for levels and/or thickness.

During construction

- Agree on a paving procedure;
- Identify where correction layers are required;

- Agree on and apply acceptable criteria for paving in unfavourable weather conditions (see Sabita Manual 22: *Hot mix paving in adverse weather,* and Appendix C);
- Agree on delivery temperatures of the asphalt;
- Agree on rollers and rolling patterns after a trial section.

Post construction

- **Surface finish:** The finished surface should have a uniform, well-knit appearance with no obviously permeable areas or signs of segregation;
- **Layer thickness:** With due regard to undulations of the underlying layer, the thickness of the compacted mat should be measured for compliance with the specification;
- **Mix constituents:** The mix composition i.e. component materials, grading, binder content, filler/binder ratio should be regularly assessed in terms of the agreed job mix design;
- **Compaction:** Satisfactory compaction is assessed in terms of agreed rollers and rolling patterns, uniformity of the mat and permeability as per the modified Marvil permeability test (see Appendix E). The following criteria are suggested:
    - If test results indicate "satisfactory" permeability - accept;
    - If results yield uncertainty – the layer should be monitored during the maintenance period and retested at the end thereof;
    - If results indicate unsatisfactory permeability, remedial measures should be considered such as applying a mineral-filled anionic stable mix emulsion, diluted for the correct consistency, by hand squeegee. If this is not viable the work should either be accepted with an extended guarantee or it should be rejected.

Note: Marvil permeability tests can only be carried out on relatively smooth textured surfaces.

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11. **Sabita Manual 22:** *Hot mix paving in adverse weather,* Sabita 2007*.*
12. **Draft TRH 12 1997:** *Flexible Pavement Rehabilitation Investigation and Design*, COLTO.
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APPENDIX A: Introduction to the Bailey Method of mix design to determine optimum aggregate packing

In this method it is assumed that aggregate packing is dependent on five primary properties of an aggregate blend:

- Gradation;
- Compaction effort;
- Particle shape;
- Surface texture;
- Strength.

The packing of aggregates in the blend is examined by determining the Loose and Rodded Unit Weights in accordance with the standard method of test: *Unit weight and voids in aggregates,* AASHTO Designation T 19/T 19M-93. The unit weights so determined can then be used to examine, with the use of the dry bulk relative density of the aggregate, the voids available for accommodating other aggregate sizes, depending on the packing characteristics required.

To do so, the method adopts four principles based on volume:

- Establishing the break between coarse and fine aggregates to establish which particles create voids and which particles fill them and, hence which fraction is in control;
- Examination of the packing of the coarse fraction and how this influences the packing of the fine aggregate;
- Evaluation of the packing of the fine aggregate; and
- Evaluation of the packing of the fine part of the fine aggregate.

The break between coarse and fine aggregate is based on the primary control sieve, PCS. For the NMAS of the mixture being the recommended 9.5mm, the PCS is the 2.36mm sieve. Particles retained on this screen would constitute the coarse aggregate, and those passing the fine aggregate.

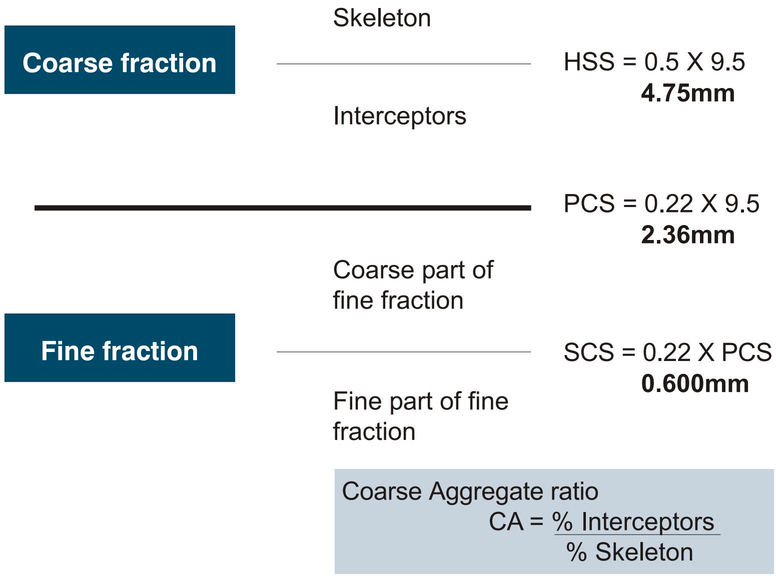

Figure 1: Initial aggregate categories for NMAS 9.5mm

Coarse fraction

A half size sieve HSS is determined as being half the NMAS size, which separates the “skeleton” from the “interceptors” of the coarse aggregate fraction. The skeleton comprises the larger coarse particles (those larger than the HSS) that are somewhat spread apart; the interceptors are the smaller coarse particles (smaller than the HSS) which serve to hold the larger particles apart and support them.

The coarse aggregate (CA) ratio defines the relative proportion of interceptor and skeleton aggregates. High values of the CA ratio (1) may indicate an excess of interceptors resisting lock-up of the skeleton and hence render the mix tender during compaction. Low values of the CA ratio on the other hand may indicate a tendency to segregate.

Fine fraction

To differentiate between the coarse part of the fine fraction and the fine part of the fine fraction a secondary control sieve size SCS is determined. For a PCS size of 2.36mm the SCS size is 0.60mm.

Figure 2 illustrates the various components for a mix with NMAS of 9.5mm.

Sand skeleton (fine graded) mixes

A key point starting point for sand skeleton mixes, such as those proposed for thin layer asphalt, is that the volume of the coarse fraction should be based on 60 - 85% of the Loose Unit Weight condition. In other words, it is unlikely that any stone-to-stone contact will occur and the fine aggregate would be the dominant structure to carry loads and improve workability.

Consequently, in this method the fine aggregate fraction only will be regarded as the entire mix and a new PCS (NPCS) determined. For a mix with an original NMAS of 9.5m, the new NMAS will be 2.36mm and the fraction passing this screen will constitute the entire mix.

In this case the new PCS (NPCS) would be the 0.600mm screen, being the new dividing line between the coarse and fine fractions of the material passing the 2.36mm sieve[*]. The new secondary control sieve (NSCS) would then be the 0.150mm sieve.

Figure 3 illustrates the various components for a fine graded (sand skeleton) mix with NMAS 9.5mm.

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[*] *Generally the original PCS would serve as both the maximum and the NMAS of the new "blend" being considered. However, this may need to be checked.*

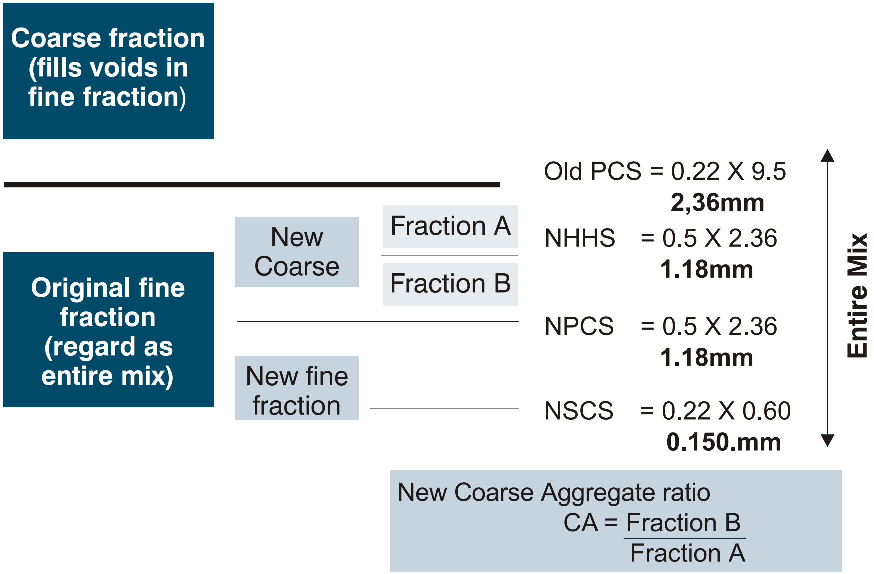

Figure 2: Aggregate categories for NMAS 9.5mm (Fine graded – Sand skeleton)

For the sieve sizes given above the new half sieve size (NHSS) would be the 1.18mm sieve. Particles passing the 2.36mm sieve and retained on the NHSS would correspond with the “skeleton” aggregates referred to previously (Fraction A) while those passing the NHSS and retained on the NPCS would correspond to the “interceptors” (Fraction B).

The new dividing line between the coarse and fine parts of the new fine fraction would be the 0.150mm sieve.

The packing of the aggregates to ensure a sand skeleton can also be confirmed by comparing the volume of fine aggregate with the voids in the coarse aggregate, VCA. The volume of fine aggregate could be expected to exceed the VCA for sand skeleton mixes by 3 – 5 percentage points.

Recommended ratios are as follows:

$$\text{New CA Ratio} = \frac{\%\text{ passing }1.18\text{mm} - \%\text{ passing }0.600\text{mm}}{\%\text{ passing }2.36\text{mm} - \%\text{ passing }1.18\text{mm}}$$

$$= 0.6 – 1.0$$

(Too high a new CA Ratio may reduce the ability of the sand skeleton to lock-up and therefore result in a tender mix).

$$\text{New FA}_C = \frac{\%\text{ passing }0.150\text{mm}}{\%\text{ passing }0.600\text{mm}}$$

$$= 0.35 – 0.5\text{, preferably } >0.4$$

(As the new FA_C ratio increases towards 0.5, compactibility of the mix is improved due to improved packing of the overall fine fraction).

It is useful to note that the original CA ratio still relates to the susceptibility of the mix to segregate.

There are several other recommendations that pertain to compactibility and the tendency to segregate, that need to be taken into consideration, but full reference to these is considered to fall beyond the scope of this document.

Finalisation of design

The above procedure covers a process of optimising the aggregate and filler proportions, following which the designer would continue with design procedures, e.g. Marshall, to determine the other parameters such as bitumen content, voids in the mix, film thickness, filler/binder ratio, VMA and VFB. An iterative process may be required to ensure that a cost-effective design, with suitable functional properties is achieved.

APPENDIX B: Pavement condition summary

Surface finish						
	Even		Uneven		Rough	
Pavement structure						
	Stiff		Flexible		Very flexible	
Underlying layers - soundness, sensitivity to water						
Base or existing asphalt	Good		Moderate		Poor	
Pavement distress						
Cracks - crocodile	None		Localised		Widespread	
Cracks - random	None		Localised		Widespread	
Potholes	None		Localised		Widespread	
Failures	None		Localised		Widespread	
Surface	Lean/dry		Moderate		Fatty/rich	
Pretreatment						
Unevenness	Little		Moderate		Extensive	
Cracks - crocodile	Little		Moderate		Extensive	
Cracks - single	Little		Moderate		Extensive	
Potholes	Little		Moderate		Extensive	
Patches	Little		Moderate		Extensive	

1. Surface Finish

a. Even – Will give a good ride, no noticeable slacks or irregularities;
b. Uneven – Some irregularities or slacks but will probably give a reasonable ride;
c. Rough – Visibly uneven surface which will result in a rough ride.

Comment: It is unlikely that a new pavement will fall into the Rough category.

2. Pavement Structure

a. Stiff – Known deep pavement probably with cemented subbase and good quality pavement materials;
b. Flexible – Moderate thickness pavement with granular materials and fair subgrade support;
c. Very Flexible – Thin pavement structure with lower quality granular materials and/or poor subgrade support.

3. Underlying Layers - Soundness / Water Sensitivity

Base
a. Good – Sound bituminous material or high quality crushed stone;
b. Moderate – Crusher-run or good quality natural material;
c. Poor – Lower quality granular material with plastic fines.

Old Asphalt
a. Good – Tight-knit surface and low permeability;
b. Moderate – Lean surface and occasional areas of higher permeability;
c. Poor – Open surface and /or high permeability and signs of stripping.

Long sections should be subdivided into uniform sections with a summary sheet for each.

APPENDIX C: Risk evaluation

On the **Pavement Condition Summary** form tick the appropriate conditions in the narrow columns below. Under **Points** record the score for each row. Add the scores and record under **Total**.

Pavement Condition Summary Form

		High (3)		Moderate (2)		Low (1)		Points	Total
Sensitivity to water									
Climate or local experience		Wet or high		Moderate		Dry or low			
Underlying layer sensitivity		Poor		Moderate		Good			
Total	**Risk**	**Comments**							
1 - 2	Low	No special measures							
3 - 4	Moderate	Treatment needed to reduce permeability							
5 - 6	High	Consider special measures to prevent water ingress							
Structural performance									
Pavement structure		Very flexible		Flexible		Stiff			
Distress		Extensive		Moderate		Little			
Total	**Risk**	**Comments**							
1 - 2	Low	Pretreat							
3 - 4	Moderate	Pretreat but expect some limited failures							
5 - 6	High	Even with pretreatment there may be several failures. Consider rehabilitation							

Pavement Condition Summary Form (continued)

Visual performance

Surface finish	Rough		Uneven		Even			
Pretreatment	Extensive		Moderate		Little			

Total	Risk	Comments
1 - 2	Low	No special measures
3 - 4	Moderate	Pretreat. NB: Some blemishes will show through, especially random cracks
5 - 6	High	Rough ride unless scratch coat or levelling course constructed

Construction

Air temperature	<18°C		18-24°C		>24°C			
Wind velocity	>15 km/h		<15 km/h		None			
Base soundness	Poor		Moderate		Good			

Total	Risk	Comments
1 - 3	Low	Optimum paving conditions
4 - 6	Moderate	May experience problems with compaction and hence permeability
7 - 9	High	Paving under these conditions is strongly discouraged

APPENDIX D: Pavement condition - worked example

Surface evenness						
	Even		Uneven	X	Rough	
Pavement structure						
	Stiff		Flexible	X	Very flexible	
Base - soundness/sensitivity to water						
	Good		Moderate		Poor	X
Pavement distress						
Cracks - crocodile	None		Localised	X	Widespread	
Cracks - single random	None		Localised		Widespread	X
Potholes	None	X	Localised		Widespread	
Failures	None		Localised	X	Widespread	
Surface	Lean/dry		Moderate	X	Fatty/rich	
Pretreatment						
Unevenness	Little	X	Moderate		Extensive	
Cracks - crocodile	Little		Moderate	X	Extensive	
Cracks - single	Little		Moderate		Extensive	X
Potholes	Little	X	Moderate		Extensive	
Patches	Little		Moderate	X	Extensive	

Notes

1. Surface Finish

a. Even – Will give a good ride, no noticeable slacks or irregularities;
b. Uneven – Some irregularities or slacks but will probably give a reasonable ride;
c. Rough – Obviously uneven surface which will result in a rough ride.

Comment: It is unlikely that a new pavement will fall into the Rough category.

2. Pavement structure

a. Stiff – Known deep pavement probably with cemented subbase and good quality pavement materials;
b. Flexible – Moderate thickness pavement with granular materials and fair subgrade support;
c. Very Flexible – Thin pavement structure with lower quality granular materials and/or poor subgrade support.

3. Base Soundness / Water Sensitivity

a. Good – Sound bituminous material or high quality crushed stone;
b. Moderate – Crusher-run or good quality natural material;
c. Poor – Lower quality granular material with plastic fines.

Comment: For several roads or a long length of road subdivide into uniform sections and provide a summary sheet for each.

APPENDIX D: Risk evaluation – worked example

On the **Pavement Condition Summary** form check the appropriate conditions in the narrow columns below. Under **Points** record the score for each row. Add the scores and record under **Total**. Refer to the comments included in each Table.

Pavement Condition Summary form

<table>
<tr><th colspan="2"></th><th colspan="2">High (3)</th><th colspan="2">Moderate (2)</th><th colspan="2">Low (1)</th><th>Points</th><th>Total</th></tr>
<tr><th colspan="10">Sensitivity to water</th></tr>
<tr><td colspan="2">Climate or local experience</td><td>Wet or high</td><td></td><td>Moderate</td><td>X</td><td>Dry or low</td><td></td><td>2</td><td rowspan="2">5</td></tr>
<tr><td colspan="2">Base sensitivity</td><td>Poor</td><td>X</td><td>Moderate</td><td></td><td>Good</td><td></td><td>3</td></tr>
<tr><th>Total</th><th>Risk</th><th colspan="8">Comments</th></tr>
<tr><td>1 - 2</td><td>Low</td><td colspan="8">No special measures</td></tr>
<tr><td>3 - 4</td><td>Moderate</td><td colspan="8">Low permeability treatment needed</td></tr>
<tr><td>5 - 6
X</td><td>High</td><td colspan="8">Consider special measures to prevent water ingress</td></tr>
<tr><th colspan="10">Structural performance</th></tr>
<tr><td colspan="2">Pavement structure</td><td>Very flexible</td><td></td><td>Flexible</td><td>X</td><td>Stiff</td><td></td><td>2</td><td rowspan="2">4</td></tr>
<tr><td colspan="2">Distress</td><td>Extensive</td><td></td><td>Moderate</td><td>X</td><td>Little</td><td></td><td>2</td></tr>
<tr><th>Total</th><th>Risk</th><th colspan="8">Comments</th></tr>
<tr><td>1 - 2</td><td>Low</td><td colspan="8">Pretreat</td></tr>
<tr><td>3 - 4
X</td><td>Moderate</td><td colspan="8">Pretreat but expect some limited failures</td></tr>
<tr><td>5 - 6</td><td>High</td><td colspan="8">Even with pre-treatment there may be several failures. Consider rehabilitation</td></tr>
</table>

Pavement Condition Summary form (continued)

<table>
<tr><th colspan="10">Visual performance</th></tr>
<tr><td colspan="2">Surface evenness</td><td>Rough</td><td></td><td>Uneven</td><td>X</td><td>Even</td><td></td><td>2</td><td rowspan="2">4</td></tr>
<tr><td colspan="2">Pre-treatment</td><td>Extensive</td><td></td><td>Moderate</td><td>X</td><td>Little</td><td></td><td>2</td></tr>
<tr><td>Total</td><td>Risk</td><td colspan="8">Comments</td></tr>
<tr><td>1 - 2</td><td>Low</td><td colspan="8">No special measures</td></tr>
<tr><td>3 - 4 X</td><td>Moderate</td><td colspan="8">Pretreatment. NB. Some blemishes will show through, especially random cracks</td></tr>
<tr><td>5 - 6</td><td>High</td><td colspan="8">Rough ride unless scratch coat or levelling course constructed</td></tr>
<tr><th colspan="10">Construction</th></tr>
<tr><td colspan="2">Air temperature</td><td><18°C</td><td></td><td>18-24°C</td><td></td><td>>24°C</td><td>X</td><td>1</td><td rowspan="3">6</td></tr>
<tr><td colspan="2">Wind velocity</td><td>>15 km/h</td><td></td><td><15 km/h</td><td>X</td><td>None</td><td></td><td>2</td></tr>
<tr><td colspan="2">Base soundness</td><td>Poor</td><td>X</td><td>Moderate</td><td></td><td>Good</td><td></td><td>3</td></tr>
<tr><td>Total</td><td>Risk</td><td colspan="8">Comments</td></tr>
<tr><td>1 - 3</td><td>Low</td><td colspan="8">Optimum paving conditions</td></tr>
<tr><td>4 - 6</td><td>Moderate</td><td colspan="8">May experience problems with compaction and permeability</td></tr>
<tr><td>7 - 9</td><td>High</td><td colspan="8">Paving under these conditions is strongly discouraged</td></tr>
</table>

APPENDIX E: Modified Marvil permeability test

Whereas the Marvil permeability test has been regarded at times as giving erratic results, experience indicates that under certain conditions, it does give a good indication of low permeability in a mat.

On a well designed and properly compacted continuously graded mat laid at a thickness of at least three times NMAS, the Marvil test will invariable show low permeability given that sufficient tests were performed to obtain an adequate average.

For example, a 40mm thick wearing course, using 13.2mm maximum size aggregate, and compacted to, say, 93 - 94% Rice, will give fairly consistent permeability results of less than 3 ℓ/hr.

A proprietary ultra-thin asphalt mix, which is designed as a seal and paved 15mm thick, consistently gives less than 1ℓ/hr using the test.

It is therefore recommended that this test be carried out as part of the quality control for thin dense layers, but performed carefully and assessed judiciously.

The following are recommended amendments to the MARVIL permeability test as described in subsection 8109 (d) (1) *Asphalt and unsurfaced basecourse layers with smooth surfaces* of the General Conditions of Contract for Roads and Bridge Works for State Road Authorities, 1998 Edition issued by COLTO. Note that paragraph numbers are as they appear in the original publication.

(ii) Apparatus

In addition to the apparatus described, a soft circular neoprene spacer approximately 8mm thick having an outside diameter of 280mm and an internal diameter of 175mm shall be provided.

(iv) Test site and apparatus preparation and placing thereof

Replace the third and subsequent paragraphs as follows:

Invert the apparatus and smear the underside of the base with a layer of grease. Place the neoprene spacer on the base of the apparatus seating it firmly on the grease coating. Smear the underside of the neoprene spacer with a layer of grease. Holding both the apparatus and the neoprene spacer turn the apparatus upright and place in the test area pressing it firmly onto the road surface to obtain a seal. Around the base of the apparatus smear a wedge of grease. This allows easy observation (in the form of bubbles) of any water leakage. Place a hammer or other suitable item on the down-slope side of the apparatus to prevent it sliding.

Note: Initially some experimentation may be required to determine the optimum quantities of grease. If the seal is not adequate water will be seen leaking out under the base of the apparatus and on top of the asphalt.

(v) Test procedure

Replace this section as follows:

Fill the apparatus from the top with water to the 0mℓ mark and maintain the water level at this mark for 5 minutes.

With the water at the 0mℓ mark start timing and do not add any more water. Record the time to reach the 50mℓ, 100mℓ and 150mℓ marks subject to the following conditions:

(a) If the water has not reached the 50mℓ mark within 3 minutes stop the test and record the result as <1ℓ/hour;

(b) If the water level lies between 50mℓ and 150mℓ at the end of 3 minutes stop the test, fill up with water to the 0mℓ mark and repeat the test once;

(c) If the water reaches the 150mℓ mark before 3 minutes stop the test and repeat the procedure twice.

(vi) Test results and calculations

Replace the first three paragraphs as follows:

Interpretation of results as per the conditions listed above:

(a) Record the permeability as <1ℓ/hour;

(b) Calculate the permeability for the 50mℓ and 100mℓ levels for both tests. Take the 50mℓ permeability from the second test and report this. Check this value against the first 50mℓ reading. If there is a large difference either note that the result is questionable, or repeat the test;

(c) Under this condition (i.e. high permeability) particularly in very permeable areas, the water may fall so quickly that a reading can only be taken at the 150mℓ mark. Calculate the permeability for each reading and test. Report the permeability for the third test at the lowest level read. As in (b) above check this reading against those obtained in the first and second tests using the same judgement criterion.

Comments

1. The use of the neoprene spacer should significantly speed up the test set-up;
2. The initial 5 minute procedure is intended to saturate the vicinity of the test area. Partially saturated conditions are likely to give rise to a wide range of results depending on the moisture content of the asphalt at the time of testing;
3. Where possible the permeability should be made using the 50mℓ mark (or the next lowest) as large differences in the effective head can alter the results.

Worked examples

$P = 3{,}6\ Vw / T$ in litres per hour

Where:
Vw = volume of water in mℓ
T = time in seconds.

Case I - Highly Permeable

Test 1	10 secs to 150mℓ	Permeability = 54 ℓ/hour
Test 2	12 secs to 150mℓ	Permeability = 45 ℓ/hour
Test 3	12 secs to 150mℓ	Permeability = 45 ℓ/hour

Value reported: 45 ℓ/hour (from Test 3)

Case II - Moderately Permeable

Test 1	50 secs to 50 mℓ	Permeability = 6,0 ℓ/hour
	80 secs to 100mℓ	Permeability = 4,5 ℓ/hour
	155 secs to 150mℓ	Permeability = 3,5 ℓ/hour

Test stopped at 155 secs

Test 2	35 secs to 50mℓ	Permeability = 5,1 ℓ/hour
	90 secs to 100mℓ	Permeability = 4,0 ℓ/hour
	170 secs to 150mℓ	Permeability = 3,2 ℓ/hour

Test stopped at 170 sec. Value Reported: 5,1 ℓ/hour (50mℓ reading Test 2).

Case III - Low Permeability

Test 1	160 secs to 50 mℓ	Permeability = 1,1 ℓ/hour

Test stopped at 180 seconds

Test 2	180 secs to 50 mℓ	Permeability = 1,0 ℓ/hour

Test stopped at 180 sec. Value Reported: 1,0 ℓ/hour (50mℓ reading Test 2)

Case IV - Very Low Permeability

Test 1 50 mℓ not reached in 180 secs

No further tests. Value Reported: <1 ℓ/hour

Apparatus

Figure E1: The Marvil apparatus

Figure E2: Applying grease to the base of the apparatus

Figure E3: Applying grease to the spacer of the apparatus

Figure E4: Lifting the apparatus and spacer

Figure E5: Placing the apparatus

Note hammer to prevent sliding

Figure E6: Applying grease to outer edge

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