GUIDELINES FOR THE USE OF THIN LAYER HOTMIX ASPHALT WEARING COURSE ON LOW VOLUME ROADS

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 wearing course layers of hotmix asphalt on low volume roads, mainly in residential areas. In these locations the layers would normally be expected to meet functional requirements, rather that 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 and proprietary products such as ultra-thin friction courses. While 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, 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 of procedures 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.

INTRODUCTION
Definition of thin layer asphalt

Within the scope of this document thin layer hotmix asphalt is defined as such layers that:

1. Carry moderate to light traffic on residential streets, function as a surface treatment that offers a direct contact stress interface between traffic and the base layer of the pavement thus affording protection against mainly traction and braking forces imposed by vehicular traffic, more so than contributing measurably to the structural capacity of the pavement;
2. Have sufficient resilience to provide a durable surface in the face of prevailing transient deflections;
3. Protect the underlying pavement layers against the ingress of water, thereby protecting the integrity of layer materials; and
4. 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 quality management procedures instituted accordingly.

**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 functional requirements predominantly 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:
1. 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,
2. The influence of existing pavement conditions;
3. A review of risks involved;
4. Guidelines on mix selection and design;
5. Guidelines on construction; and
6. 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 proprietary products are considered to be beyond the scope of this document they 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 either the Interim Guidelines for the Design of Hot-Mix Asphalt (HMA) in South Africa \(^1\).
CURRENT PRACTICE

In South Africa widespread use has been made of 20mm to 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 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 to 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 coarse 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 its expected performance characteristics cannot be judged against those of conventional HMA 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. 
  
  Consequently extra care should be taken in both the design and construction procedures to ensure that adequate densification will be achieved.  

"
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. The following aspects are most important:

- Surface unevenness/roughness – applies to new layers and overlays
- Pavement structure – applies to new layers and overlays
- 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%. Thus it is most important that the relative surface evenness be established before selecting an appropriate surfacing. It is recommended that the surface should be assessed using a 3m straight edge and given 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 A.

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 A) 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 B. The intention is not to provide a rigorous statement of risk but rather to give the user an indication of the degree of risk of unsatisfactory performance and 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 is appropriate, based on economic constraints 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 C 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 Hotmix 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
- A assessment of the design criteria and methods in the light of the recorded satisfactory performance of thin asphalt layers
- 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:

1. Low permeability, through limited and dispersed voids, to afford protection to underlying layers – often granular bases – from the ingress of water
2. 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
3. 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.
4. 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 low 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 (<80kph) applications.

The four mix design criteria listed above 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 and durability)

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

<table>
<thead>
<tr>
<th>Design objective</th>
<th>Sand skeleton</th>
<th>Softer grade of bitumen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low permeability</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Compactibility</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Low speed skid resistance</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Component materials

1. Aggregates

Layer thicknesses should generally not be less than approximately 3 times the nominal maximum aggregate size, NMAS, to ensure compactibility and low permeability.

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 2.36 mm 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 considered. 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:

<table>
<thead>
<tr>
<th>Layer Thickness</th>
<th>NMAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;20 &lt; 30mm</td>
<td>9.5mm</td>
</tr>
<tr>
<td>&lt;=&lt;20mm</td>
<td>6.7mm</td>
</tr>
</tbody>
</table>

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 0.03 – 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 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 a course of 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 low volume urban roads 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 of critical importance to provide a suitably textured and impermeable layer, it is recommended that the grade of bitumen used in the mix be selected with due care as it 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. 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 compaction.

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

<table>
<thead>
<tr>
<th>Mix type</th>
<th>NMAS (mm)</th>
<th>Bitumen grade</th>
<th>Lay-down temp °C</th>
<th>Min compaction temp °C</th>
<th>Compaction time minutes</th>
<th>% increase relative to COLTO mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLTO</td>
<td>13.2</td>
<td>60/70</td>
<td>140</td>
<td>80</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>SABS</td>
<td>13.2</td>
<td>60/70</td>
<td>140</td>
<td>75</td>
<td>9.5</td>
<td>17</td>
</tr>
</tbody>
</table>
LV Mix* 9.5 80/100 130 65 11.5 41

* LV Mix - Specially designed mix for low volume road applications

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

<table>
<thead>
<tr>
<th>Mix type</th>
<th>NMAS (mm)</th>
<th>Bitumen grade</th>
<th>Lay-down temp °C</th>
<th>Min compaction temp °C</th>
<th>Compaction time minutes</th>
<th>% increase relative to COLTO mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLTO</td>
<td>13.2</td>
<td>60/70</td>
<td>140</td>
<td>80</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>SABS</td>
<td>13.2</td>
<td>60/70</td>
<td>140</td>
<td>75</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>LV Mix</td>
<td>9.5</td>
<td>80/100</td>
<td>130</td>
<td>65</td>
<td>13.5</td>
<td>40</td>
</tr>
</tbody>
</table>

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 sizes, grading cannot be relaxed compared to those applying to thicker asphalt layers.

In addition, the skeletal structure of these mixes consists of 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.

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 low volume roads such further densification by traffic is usually minimal if not negligible. Therefore the designer should provide for a situation of in situ voids in the mix after compaction not to exceed 7%. 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 low volume, 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 for suitability for the specific application.

Alternatively, where the specific circumstances dictate that a new design needs to be performed, 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 low volume,
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 low volume roads 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: <= 9.5 mm
2. “Fine aggregate” i.e. % passing 2.36 mm: 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
Key mix properties of mixes used in the Western Cape, Gauteng and KwaZulu-Natal (KZN) are shown in Table 1 below.

<table>
<thead>
<tr>
<th>Region</th>
<th>Western Cape</th>
<th>KZN</th>
<th>Gauteng</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix ID</td>
<td>CK18</td>
<td>CK2A</td>
<td>ER8</td>
</tr>
<tr>
<td>NMAS</td>
<td>9.5</td>
<td>6.7</td>
<td>9.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grading</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% Passing</td>
<td>13.2</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>9.5</td>
<td>100</td>
<td>100</td>
<td>93</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>6.7</td>
<td>88</td>
<td>97</td>
<td>80</td>
<td>84</td>
<td>78</td>
</tr>
</tbody>
</table>
Table 1

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

Figure 1

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1 HF - Malmesbury Rock (Hornfels)
2 CD - Crusher dust
3 Q,T – Quartzite, Tillite respectively
4 D, Dm Dolerite and Dolomite, respectively
5 75 blow Marshall
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%.
Design method
Where the designer wishes to explore alternative aggregate sources or compositions, it is recommended that methods that examine appropriate spatial composition and volumetrics are 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 investigates 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, to do so 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 will, however be given to assist the designer to examine some of the principles of the method and how these can be met by combining the aggregates in various proportions.

In this method it is assumed that aggregate packing is dependent on six 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:

1. 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;
2. Examination of the packing of the coarse fraction and how this influences the packing of the fine aggregate;
3. Evaluation of the packing of the fine aggregate; and
4. 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.

Initial aggregate categories for NMAS 9.5mm

Figure 2

Coarse fraction

A half size sieve HSS is determined as being the 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 ration 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 0.600 mm 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.

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6 Generally the original PCS would serve as both the maximum and NMAS of the new “blend” being considered. This may require checking, though.
Figure 3 illustrates the various components for a fine graded (sand skeleton) mix with NMAS 9.5mm.

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:

\[
\text{New CA Ratio} = \frac{\% \text{ passing } 1.18 \text{mm} - \% \text{ passing } 0.600 \text{mm}}{\% \text{ passing } 2.36 \text{mm} - \% \text{ passing } 1.18 \text{mm}}
\]
Too high a new CA Ratio may reduce the ability of the sand skeleton to lock-up and therefore result in a tender mix.

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

\( = 0.35 – 0.5, \) preferably \( > 0.4 \)

(As the new \( \text{FA}_C \) 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.

**Existing mixes assessed**

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Western Cape</th>
<th>KZN</th>
<th>Gauteng</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix ID</td>
<td>CK18</td>
<td>CK2A</td>
<td>ER8</td>
</tr>
<tr>
<td>NMAS</td>
<td>9.5</td>
<td>6.7</td>
<td>9.5</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>Medium RZM</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMAS</td>
<td>9.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bailey parameters</th>
<th>Range (fine graded)</th>
<th>77</th>
<th>95</th>
<th>67</th>
<th>63</th>
<th>72</th>
<th>80.5</th>
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<tbody>
<tr>
<td>CUW</td>
<td>70 – 80</td>
<td>F</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td>F</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCS</td>
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<td>1.18</td>
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<tr>
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<tr>
<td>NHS</td>
<td>1.18</td>
<td>0.600</td>
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</tr>
<tr>
<td></td>
<td>1.18</td>
<td>1.18</td>
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<tr>
<td>CA Ratio</td>
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<td>0.600</td>
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<td></td>
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<td>0.564</td>
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<tr>
<td>Range</td>
<td>0.6 – 1.0</td>
<td>0.6 – 1.0</td>
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<td>SCS</td>
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<td>0.150</td>
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<tr>
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<td>0.150</td>
<td>0.150</td>
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</tr>
<tr>
<td>FAc Ratio</td>
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<td>0.421</td>
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<td>0.372</td>
<td>0.446</td>
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<tr>
<td></td>
<td>0.447</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

7 F – fine graded (sand skeleton), C is coarse graded (stone skeleton)
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 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, CA ratios 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.

Table 2

<table>
<thead>
<tr>
<th>% coarse agg. v/v</th>
<th>40.9</th>
<th>50.0</th>
<th>35.2</th>
<th>34.0</th>
<th>37.4</th>
<th>41.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCA&lt;sub&gt;mix&lt;/sub&gt;</td>
<td>55.3</td>
<td>48.0</td>
<td>55.7</td>
<td>54.9</td>
<td>52.4</td>
<td>53.2</td>
</tr>
<tr>
<td>% fine agg. v/v</td>
<td>59.1</td>
<td>47.5</td>
<td>64.8</td>
<td>66.0</td>
<td>62.6</td>
<td>58.7</td>
</tr>
<tr>
<td>Diff vol. fine agg – VCA (%)</td>
<td>3.8</td>
<td>2.5%</td>
<td>8.4</td>
<td>11.1</td>
<td>10.2</td>
<td>5.5</td>
</tr>
</tbody>
</table>

8 Based on the original PCS
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 was not achieved as specified, 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 either 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 very dependent on 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 litres/m² (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 a high quality, dense, sufficiently dry with a high quality finish and sprayed with a tack coat.

Bases on low volume roads often do not comply with these criteria and requires a mindset change to yield adequate returns on the investment of 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°C, helps ensure that the asphalt immediately behind the screed is at a consistent temperature.

**Rollers**
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 window time.

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 to 165°C. Then it will arrive on site at between 155 and 160°C, and come out behind the paver at about 140°C. Should 80/100 pen bitumen be used, these temperatures can all be lowered by approximately 10°C.

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

Tack Coat
Tack coat is very important to ensure good bond and prevent delamination. Depending on how dense or open the underlying surface is, net bitumen application rates of between 0.1 and 0.25 l/m² are recommended.

Weather Conditions
The contents and recommendations of Sabita Manual 22 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 time, 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°C.
- An ideal rolling train would be two breakdown rollers in tandem with a pneumatic immediately behind them.
- In cold conditions, a second pneumatic may be necessary in order to get compaction in the severely restricted compaction window time. (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 rollers are considered necessary.

Hand work
Where handwork has to 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 in 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 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 and Appendix B)
- 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 D). 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 such as applying a mineral-filled anionic stable mix emulsion, diluted for the correct consistency, by hand squeegee should be considered. 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 texture surfaces.
REFERENCES


9. **A Gaved (1996)** “Surface Attention” INTERNATIONAL HIGHWAYS


13. **ME Baines (1985)** TRRL “Cooling of bituminous layers and time available for their compaction” TRRL Research report 4
# APPENDIX A: PAVEMENT CONDITION SUMMARY

<table>
<thead>
<tr>
<th>SURFACE FINISH</th>
<th>Even</th>
<th>Uneven</th>
<th>Rough</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAVEMENT STRUCTURE</td>
<td>Stiff</td>
<td>Flexible</td>
<td>Very Flexible</td>
</tr>
<tr>
<td>UNDERLYING LAYERS – Soundness/Sensitivity to Water</td>
<td>Base or existing Asphalt</td>
<td>Good</td>
<td>Moderate</td>
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<tr>
<td>PAVEMENT DISTRESS</td>
<td>Cracks – Crocodile</td>
<td>None</td>
<td>Localised</td>
</tr>
<tr>
<td></td>
<td>Cracks - Random</td>
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<td>Localised</td>
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<tr>
<td></td>
<td>Potholes</td>
<td>None</td>
<td>Localised</td>
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<tr>
<td></td>
<td>Failures</td>
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<td>Localised</td>
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<td></td>
<td>Surface</td>
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<td>Unevenness</td>
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<td></td>
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<td></td>
<td>Patches</td>
<td>Little</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

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 B: RISK EVALUATION

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

<table>
<thead>
<tr>
<th>Sensitivity to Water</th>
<th>High (3)</th>
<th>Moderate (2)</th>
<th>Low (1)</th>
<th>Points</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Climate or Local Experience</td>
<td>Wet or High</td>
<td>Moderate</td>
<td>Dry or Low</td>
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<tr>
<td>Underlying Layer Sensitivity</td>
<td>Poor</td>
<td>Moderate</td>
<td>Good</td>
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<td></td>
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<tr>
<td>Total</td>
<td>Risk</td>
<td>Comments</td>
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<tr>
<td>1 to 2</td>
<td>Low</td>
<td>No special measures.</td>
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<tr>
<td>3 to 4</td>
<td>Moderate</td>
<td>Treatment needed to reduce permeability.</td>
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<td>5 to 6</td>
<td>High</td>
<td>Consider special measures to protect layers from water ingress.</td>
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## Structural Performance

<table>
<thead>
<tr>
<th>Pavement structure</th>
<th>Very Flexible</th>
<th>Flexible</th>
<th>Stiff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distress</td>
<td>Extensive</td>
<td>Moderate</td>
<td>Little</td>
</tr>
<tr>
<td>Total</td>
<td>Risk</td>
<td>Comments</td>
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</tr>
<tr>
<td>1 to 2</td>
<td>Low</td>
<td>Pre-treat.</td>
<td></td>
</tr>
<tr>
<td>3 to 4</td>
<td>Moderate</td>
<td>Pre-treat but expect some limited failures.</td>
<td></td>
</tr>
<tr>
<td>5 to 6</td>
<td>High</td>
<td>Even with pre-treatment there may be several failures. Consider rehabilitation.</td>
<td></td>
</tr>
</tbody>
</table>

## Visual Performance

<table>
<thead>
<tr>
<th>Surface finish</th>
<th>Rough</th>
<th>Uneven</th>
<th>Even</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>Extensive</td>
<td>Moderate</td>
<td>Little</td>
</tr>
<tr>
<td>Total</td>
<td>Risk</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>1 to 2</td>
<td>Low</td>
<td>No special measures.</td>
<td></td>
</tr>
<tr>
<td>3 to 4</td>
<td>Moderate</td>
<td>Pre-treatment. NB Some blemishes will show through, especially random cracks.</td>
<td></td>
</tr>
<tr>
<td>5 to 6</td>
<td>High</td>
<td>Rough ride unless scratch coat or levelling course constructed.</td>
<td></td>
</tr>
</tbody>
</table>

## Construction

<table>
<thead>
<tr>
<th>Air Temperature</th>
<th>&lt; 18°</th>
<th>18° - 24°</th>
<th>&gt; 24°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Velocity</td>
<td>&gt; 15 km/h</td>
<td>&lt; 15 km/h</td>
<td>None</td>
</tr>
<tr>
<td>Base Soundness</td>
<td>Poor</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Total</td>
<td>Risk</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>1 to 3</td>
<td>Low</td>
<td>Optimum paving conditions</td>
<td></td>
</tr>
<tr>
<td>4 to 6</td>
<td>Moderate</td>
<td>May experience problems with compaction and hence permeability.</td>
<td></td>
</tr>
<tr>
<td>7 to 9</td>
<td>High</td>
<td>Paving under these conditions is strongly not recommended.</td>
<td></td>
</tr>
</tbody>
</table>
### APPENDIX C: PAVEMENT CONDITION - WORKED EXAMPLE

<table>
<thead>
<tr>
<th>SURFACE EVENNESS</th>
<th>Even</th>
<th>Uneven</th>
<th>Rough</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAVEMENT STRUCTURE</td>
<td>Stiff</td>
<td>Flexible</td>
<td>Very Flexible</td>
</tr>
<tr>
<td>BASE – Soundness/Sensitivity to Water</td>
<td>Good</td>
<td>Moderate</td>
<td>Poor</td>
</tr>
<tr>
<td>PAVEMENT DISTRESS</td>
<td>Cracks - Crocodile: None, Localised, Widespread</td>
<td>Cracks - Single Random: None, Localised, Widespread</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Potholes: None, Localised, Widespread</td>
<td>Surface: Lean/Dry, Moderate, Fatty/Rich</td>
<td></td>
</tr>
<tr>
<td>PRE-TREATMENT</td>
<td>Unevenness: Little, Moderate, Extensive</td>
<td>Cracks - crocodile: Little, Moderate, Extensive</td>
<td>Cracks - single: Little, Moderate, Extensive</td>
</tr>
<tr>
<td></td>
<td>Patches: Little, Moderate, Extensive</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 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. |

For several roads or a long length of road subdivide into uniform sections and provide a summary sheet for each.
APPENDIX C/continued: RISK EVALUATION – WORKED EXAMPLE

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

<table>
<thead>
<tr>
<th>Sensitivity to Water</th>
<th>High (3)</th>
<th>Moderate (2)</th>
<th>Low (1)</th>
<th>Points</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate or Local Experience</td>
<td>Wet or High</td>
<td>Moderate</td>
<td>X</td>
<td>Dry or Low</td>
<td>2</td>
</tr>
<tr>
<td>Base Sensitivity</td>
<td>Poor</td>
<td>X</td>
<td>Moderate</td>
<td>Good</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>Risk</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>Low</td>
<td>No special measures.</td>
</tr>
<tr>
<td>3 to 4</td>
<td>Moderate</td>
<td>Low permeability treatment needed.</td>
</tr>
<tr>
<td>5 to 6</td>
<td>High</td>
<td>Consider special measures to protect layers from water ingress.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural Performance</th>
<th>Pavement Structure</th>
<th>Very Flexible</th>
<th>Flexible</th>
<th>X</th>
<th>Stiff</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distress</td>
<td>Extensive</td>
<td>Moderate</td>
<td>X</td>
<td>Little</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>Risk</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>Low</td>
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</tr>
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<td>Even with pre-treatment there may be several failures. Consider rehabilitation.</td>
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<table>
<thead>
<tr>
<th>Visual Performance</th>
<th>Surface evenness</th>
<th>Rough</th>
<th>Uneven</th>
<th>X</th>
<th>Even</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>Extensive</td>
<td>Moderate</td>
<td>X</td>
<td>Little</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
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<th>Comments</th>
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</thead>
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</tr>
<tr>
<td>5 to 6</td>
<td>High</td>
<td>Rough ride unless scratch coat or levelling course constructed.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction</th>
<th>Air Temperature</th>
<th>&lt; 18°</th>
<th>18° to 24°</th>
<th>&gt; 24°</th>
<th>X</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Velocity</td>
<td>&gt; 15 km/h</td>
<td>None</td>
<td>X</td>
<td>None</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Base Soundness</td>
<td>Poor</td>
<td>X</td>
<td>Moderate</td>
<td>Good</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
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<th>Comments</th>
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<tbody>
<tr>
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<td>Optimum paving conditions</td>
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<tr>
<td>4 to 6</td>
<td>Moderate</td>
<td>May experience problems with compaction and hence permeability.</td>
</tr>
<tr>
<td>7 to 9</td>
<td>High</td>
<td>Paving under these conditions is strongly not recommended.</td>
</tr>
</tbody>
</table>
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 of a mat is low.

On a well designed and properly compacted continuously graded mat laid at a thickness of at least 3 times NMAS, the Marvil test will invariably 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 lit/hr.

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

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

The following is a recommended amendment 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.

**(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 0 ml mark and maintain the water level at this mark for 5 minutes.

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

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

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

(c) If the water reaches the 150 ml 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 < 1 l/hour.

(b) Calculate the permeability for the 50 ml and 100 ml levels for both tests. Take the 50 ml permeability from the second test and report this. Check this value against the first 50 ml 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 150 ml 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 50 ml mark (or the next lowest) as large differences in the effective head can alter the results.

WORKED EXAMPLES

\[ P = \frac{V_w}{T} \] in litres per hour

Where \( V_w = \) volume of water in ml and \( T = \) time in seconds.

Case I - Highly Permeable

<table>
<thead>
<tr>
<th>Test</th>
<th>Time</th>
<th>Volume</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 secs</td>
<td>150 ml</td>
<td>54 l/hour</td>
</tr>
<tr>
<td>2</td>
<td>12 secs</td>
<td>150 ml</td>
<td>45 l/hour</td>
</tr>
<tr>
<td>3</td>
<td>12 secs</td>
<td>150 ml</td>
<td>45 l/hour</td>
</tr>
</tbody>
</table>

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

Case II - Moderately Permeable

<table>
<thead>
<tr>
<th>Test</th>
<th>Time</th>
<th>Volume</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50 secs</td>
<td>50 ml</td>
<td>6,0 l/hour</td>
</tr>
<tr>
<td></td>
<td>80 secs</td>
<td>100 ml</td>
<td>4,5 l/hour</td>
</tr>
<tr>
<td></td>
<td>155 secs</td>
<td>150 ml</td>
<td>3,5 l/hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test stopped at 155 secs</td>
</tr>
<tr>
<td>2</td>
<td>35 secs</td>
<td>50 ml</td>
<td>5,1 l/hour</td>
</tr>
<tr>
<td></td>
<td>90 secs</td>
<td>100 ml</td>
<td>4,0 l/hour</td>
</tr>
<tr>
<td></td>
<td>170 secs</td>
<td>150 ml</td>
<td>3,2 l/hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test stopped at 170 secs</td>
</tr>
</tbody>
</table>

Value Reported :- 5,1 l/hour (50 ml 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 secs

Value Reported :-  1,0 l/hour (50 ml 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
LIFTING APPARATUS AND SPACER

PLACING APPARATUS
APPLYING GREASE TO OUTER EDGE

HAMMER TO PREVENT SLIDING