User Guide
for the
Design of Hot Mix Asphalt

A support document to the
Interim Guidelines for the
Design of Hot Mix Asphalt
in South Africa (2001)

February 2005

Scope of Document

The **Interim Guidelines for the Design of Hot-Mix Asphalt in South Africa (IGHMA)** was prepared in 2001 as part of the Hot-Mix Asphalt Design Project launched in 1998 by SANRAL (South African National Road Agency Ltd), CSIR Transportek and Sabita (Southern Africa Bitumen Association). The aim of this project was todevelop a new HMA design method for South Africa.

This document has been developed by Sabita to provide a practical guideline for designers of hot mix asphalt. A secondary objective is to simplify and smooth the use of the IGHMA document, which is currently being validated through a series of projects scheduled for completion in 2010. As such, extensive reference is made to the IGHMA, rather than repeating its information, and this document should be considered as a support document and read in conjunction with the IGHMA. The intention of this document is to:

- Highlight important issues and content given in the IGHMA;
- Caution the reader against certain pitfalls or gaps in the IGHMA;
- Provide some guidance on supplementary procedures to achieve a sound and workable mix design; and
- Provide comment and guidance on issues that have arisen since the IGHMA was launched in 2001.

The design of thin layer asphalts (< 25mm) and Ultra Thin Friction Courses (UTFC) is not covered in this document. A separate design guide, now being prepared for asphalt layers of less than 25mm and based on functional requirements and the suitability of generally proprietary brand UTFCs, will be driven through the Agrément system.

The IGHMA document is available from the Asphalt Academy (+27 12 841 2426 or asac@csir.co.za).

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Chapter 1 - Introduction

Hot-mix asphalt has been used in South Africa since the 1920s. In 1978, the Technical Recommendations for Highways (TRH 8) was developed in draft form by the then National Institute for Transport and Road Research (now CSIR, Transportek), This document was approved by the Committee of State Road Authorities (CSRA) to serve as a reference for the design and use of hot-mix asphalt. TRH 8: 1987[1] is the latest edition of the draft document, which is centred on the Marshall Design method but includes additional information and criteria for component evaluation.

Over the years, several changes have taken place in the road building industry which have exposed deficiencies in the scope and depth of the methodology contained in TRH 8:1987. These changes include:

- more aggressive design situations caused by increases in legal axle loading limits and heavy traffic volumes;
- influx of overseas information and of new methods which may lead to fragmentation of methods used in South Africa;
- increased use of mixes such as Stone Mastic Asphalt (SMA), Large Aggregate Mix Bases (LAMBS), Ultra Thin Friction Courses (UTFC) and other thin layer asphalt surfaces (< 25mm) for which no adequate provision is made in the TRH 8:1987[1] document;
- new test methods;
- the introduction and development of modified binders;
- the need to design mixes for high volume roads compared to lower volume roads; and
- the fact that field measurements do not always match the design intentions or laboratory findings.

A joint project was launched in 1998 by SANRAL, CSIR Transportek and Sabita with the aim of developing a new HMA design method for South Africa incorporating state-of-the-art knowledge on materials evaluation, mix design and performance assessment. This new design method was also to take cognisance of climatic and pavement environments, as well as aspects related to construction.

Comment: Stated in Scope

The **Interim Guidelines for the Design of Hot-Mix Asphalt in South Africa (IGHMA)** was prepared as part of the Hot-Mix Asphalt Design Project, and was intended to be read in conjunction with TRH 8:1987[1] until all proposals and criteria contained in the IGHMA could be validated from practice. It was envisaged that the guidelines could then be finalized and specifications developed. Projects related to the validation of the IGHMA are currently being undertaken and should be completed by 2010.

This document has been developed by Sabita to provide a practical guideline for designers of hot mix asphalt. The intention is to simplify and smooth the use of the more philosophical IGHMA document launched in 2001 through a series of regional workshops organised by the Asphalt Academy. It should also be noted that this guideline document should not be used as a substitute for knowledge and expertise. The concepts presented in this document should be applied by sufficiently experienced practitioners in engineering as an additional guide for the design of appropriate mixes.

Comment: Stated in Scope

In short, this user guideline serves purely as a signpost to previous documents, and allows the designer to trace design aspects from simple definitions to detailed research.Comments and guidance on issues that have arisen since the IGHMA was launched are also provided.

The document discusses the design processes under the following headings related to the IGHMA and other document:

Chapter 1: Introduction - (IGHMA Chapter 1)

Chapter 2: Mix Design Procedure - (IGHMA Chapter 2, 3, 4 and 5)

Chapter 3: Discussions on different Mix Types And Specific Design Considerations - (IGHMA Chapters 4, 6, 7 and 8)

Chapter 4: Implementation of Design: Construction and Quality Assurance aspects – (Sabita manual 5[2])

To assist the reader, the issues and points to be noted have been colour-coded as follows:

- ☞ Highlight important issues and content given in the IGHMA;
- ☞ Caution the reader against certain pitfalls or gaps in the IGHMA;
- ☞ Provide some guidance on supplementary procedures to achieve a sound and workable mix design; and
- ☞ Provide comment and guidance on issues that have arisen since the IGHMA was launched in 2001.

1.1 General issues related HMA design

The following general issues related to HMA design have been identified subsequent to the implementation of the IGHMA.

- ☞ In terms of the surfacing layer, it is very important to distinguish between friction courses and surfacing courses, as they may have different functions and hence design requirements.
- ☞ Certain mix types that were used extensively in the past, such as **gap-graded** and **semi gap-graded** mixes, should not be ignored in the mix type selection process. There is a strong feeling in the industry that these mixes have performed well in specific design situations, and should be reintroduced where applicable. However, the previously-used design methods, calculations and specifications for these mixes will have to be brought into line with the IGHMA, which incorporates newer methods and criteria. These mixes are considered in section 4.1 of the IGHMA under densely graded sand skeleton mixes.
- ☞ Certain mixes such as **semi-open graded mixes** with modified binders are very popular, but are not discussed in detail in the IGHMA or TRH8[1]. It is suggested that current good practice should be documented and incorporated in the guidelines at some stage in the future.

☞ Difficulties have been experienced with the use of the IGHMA design process in respect of density measurements related to **thin layer asphalts (< 25mm)**. A more rational design method is therefore being developed, and the aim is to produce separate guidelines for these layers, based on functional requirements under moderate- to light traffic mainly in residential areas. Hence, thin layer asphalts less than 25mm will not be discussed in this document.

☞ The design and evaluation method for generally proprietary brand **ultra thin friction courses (UTFC)** for higher volume roads is being developed through the Agrément system, and will also not be discussed in this document. However, both thin layer asphalt and UTFCs should be considered during the mix type selection process.

☞ Although not commonly used, **sand asphalt** is used from time to time in parking areas and low volume roads where aggregate sources are a problem. Information on the design and application of sand asphalt can be found in SABITA Manual 18[3].

☞ The **mix design process should be fully integrated with the structural design process**. For example, the base stiffness can be increased by *in-situ* stabilisation, and this will reduce strains at the bottom of the asphalt layer and thereby eliminate the need for costly, very flexible asphalt layers.

NB: Designers are urged to read the Overview of the IGHMA to grasp the basics involved in asphalt mix design

Chapter 2 – Mix Design Procedures

As shown in Figure 1, the mix design process can be divided into 5 phases:

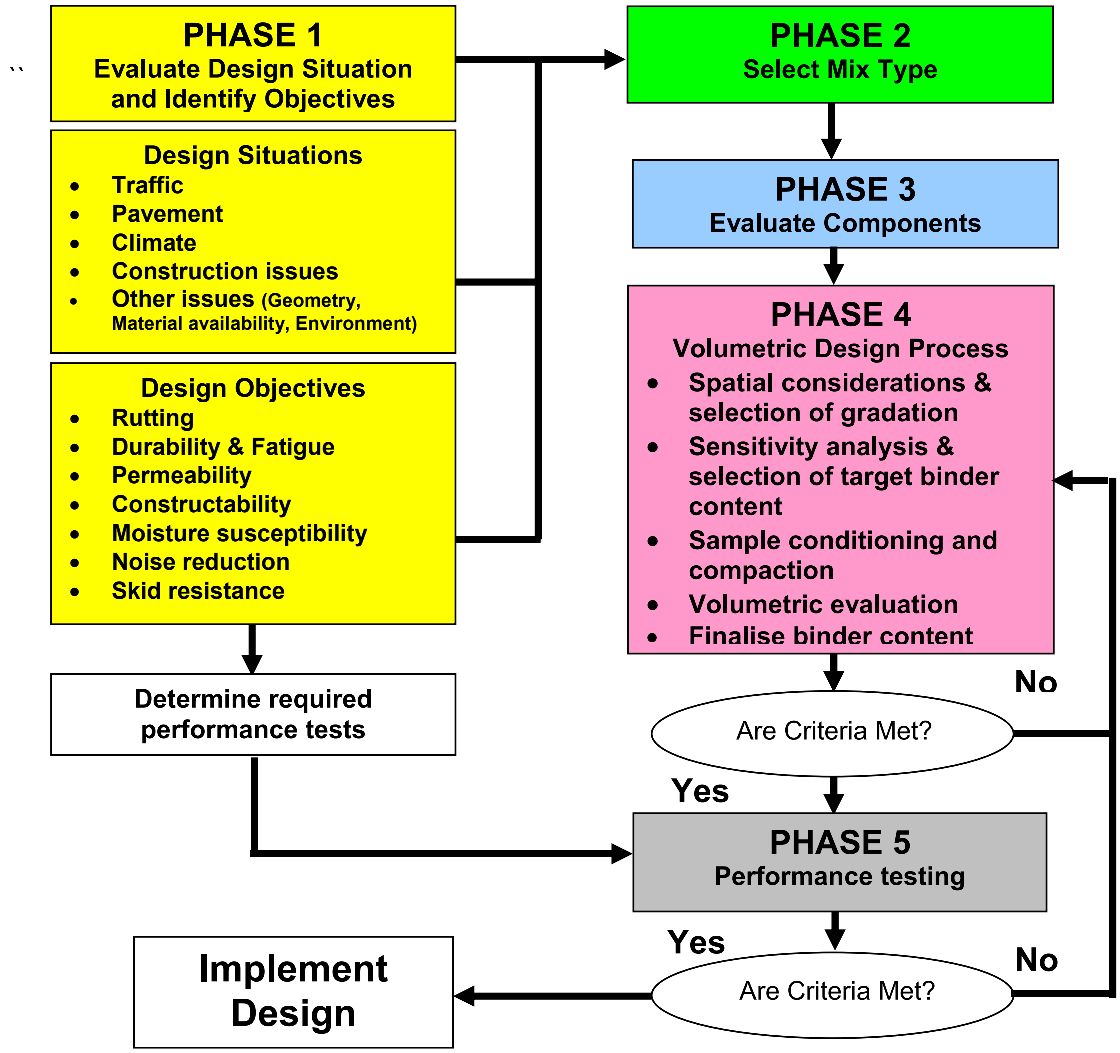

Figure 1
Mix Design Process

Each phase shown in Figure 1 is discussed in more detail in the following sections, and practical suggestions are provided for designers on aspects that should be taken into consideration during the design process.

2.1 Phase 1: *Evaluate Design Situation and Identify Objectives*

Figure 2 summarises the issues that need to be evaluated for their impact on the selection of the mix type and subsequent design of the mix. The IGHMA should be consulted for detailed information on each issue.

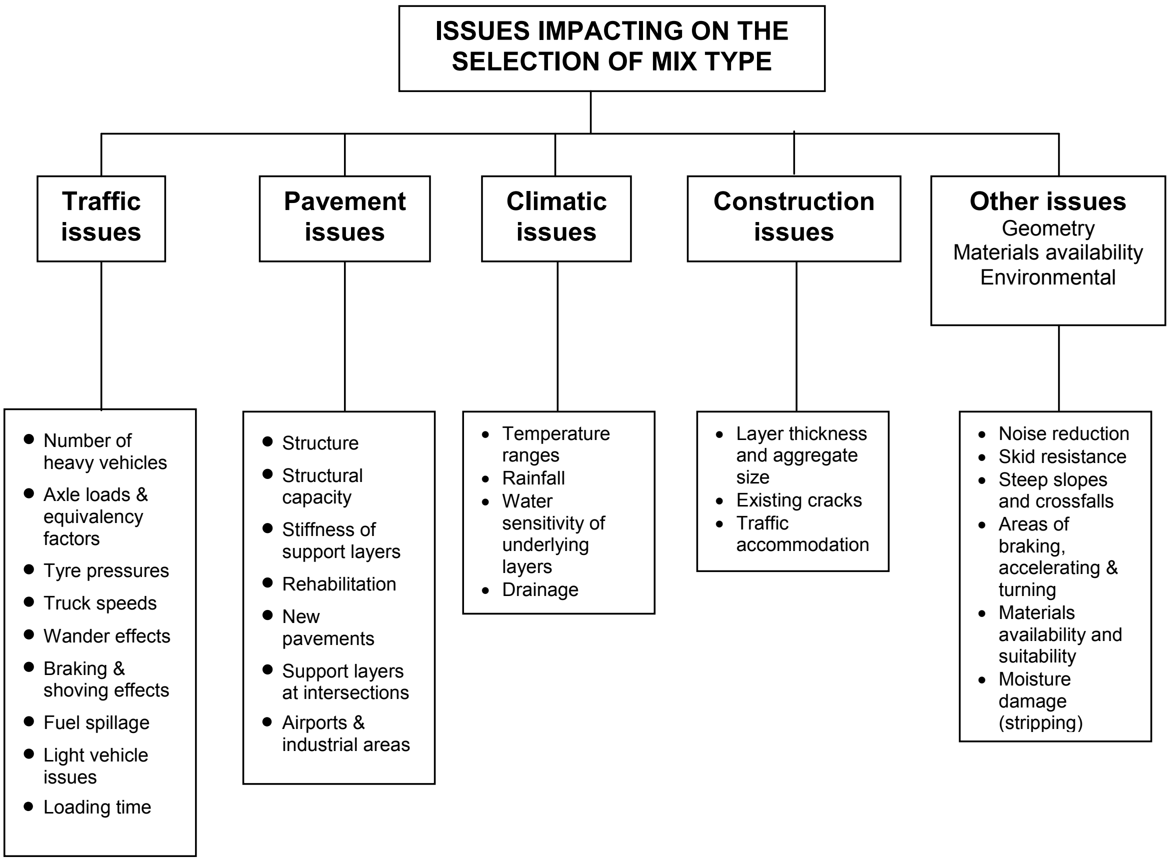

Figure 2
Design Issues having an Impact on Selection of mix Type

Users of the IGHMA should be aware of the following issues that need adequate consideration:

- The IGHMA considers a Pavement Structural Capacity of >10million ESALs to be very heavy traffic. There are many situations in southern Africa at present where significantly higher volumes must be carried, and the asphalt designs for these situations should be assigned to experienced designers.

- Designers should be constantly aware of the conflicting requirements of different design situations on mix parameters as illustrated in Figure 3. The end product must be a balanced solution that provides the optimal result.

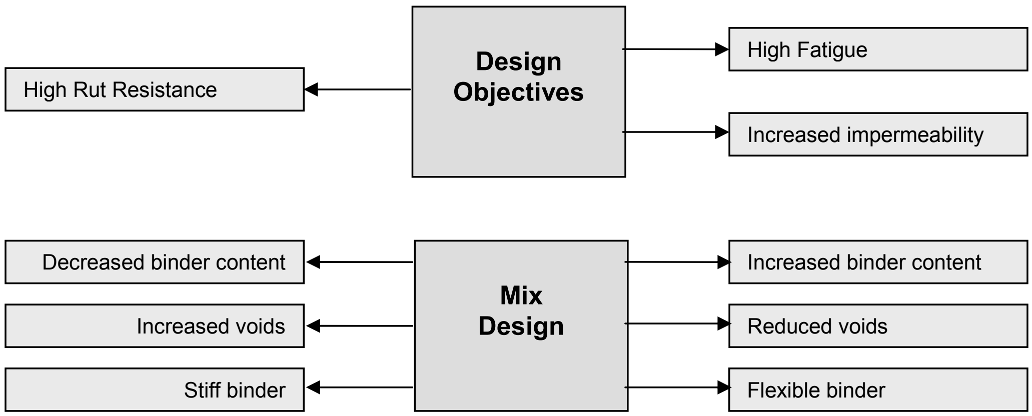

Figure 3
Design Considerations

☞ When undertaking rehabilitation designs, designers should take the flexibility or stiffness of the existing pavement into account. A stiff new asphalt mix can prevent rutting but may crack if placed on a flexible base. The choice of an appropriate HMA mix using a modified binder may be able to address both issues.

☞ In many situations it may not be possible to accommodate all of the design requirements with a single HMA layer of a particular mix, and a combination of layers, mixes or techniques may be required.

☞ Designers should note that partial rehabilitation (in depth and at the surface), which results in the construction of numerous joints, could be more susceptible to water ingress. Consideration should therefore be given to the rehabilitation of larger areas resulting in fewer joints, and appropriate method statements should be specified.

☞ Guidelines for the selection of base materials for different traffic classes can be found in TRH4[4], TRH14[5] and COLTO/COTO Standard Specification for Road and Bridge Works[6]. Table 2.5 of the IGHMA provides a brief summary of suitable base types for different traffic classes.

☞ Designers should note that the temperature maps presented in the IGHMA indicate the extremes in respect of performance of asphalt. This is because one heavily loaded truck tyre can cause as much rutting damage at 60°C as several million at 25°C. Similarly in fatigue performance a single heavily loaded truck at 5°C can cause as much damage as several million trucks at 25°C.

☞ Designers should be aware of the difficulties relating to the mix design processes that are to be followed before a specified mix is actually produced. These processes will include normal tender procedures where tenderers will estimate how to achieve the required properties, as well as the ultimate submission of a mix design by the successful contractor using the lowest cost materials available to meet the requirements. Hence, mix designs must take this into consideration to ensure that both the designer and tenderer are reasonably confident that the desired end product will be realised.

Designers should not specify properties that are unfamiliar to the industry, as this may either lead to undue risk being incurred by the contractor during the tender process with consequent increases in the tendered rates or, alternatively, may lead to tenderers making assumptions that cannot be met when the final mix design is produced.

Designers should be aware of the risks associated with material variability that may occur during construction. Variability in aggregate shape and gradation may result in excess or insufficient voids during construction, even though the end product may still be within specification. This is particularly true for the high stone content mixes that rely on stone-on-stone content and where slight variability produces substantial differences in the VMA. The COMPACT programme[7] is a useful tool that can be used to make predictive estimates of changes in VMA by making slight variations in stone content and overall gradation.

Designers and those responsible for construction should also be aware of the variation that occurs in the mix properties across the width and length of a paver-lane during construction. This variation often occurs due to the mix segregating within the paver box, or because of temperature differences within the loads delivered to the paver. Areas that are coarser or appear visually different from other areas of the completed layer should be marked off and tested separately as discrete uniform sections.

When specifying minimum layer thickness, designers should take into consideration the absolute maximum stone size as well as the quantity of this stone (and not the nominal maximum used in specifying stone, which normally refers to the sieve through which 85% to 100% must pass).

To prevent instability, the maximum layer thickness for stone skeleton mixes should not normally exceed 4 times the nominal maximum stone size.

The practice of rolling pre-coated chips into thin layers of continuously graded asphalt often does more harm to the layer itself compared to the value that is gained from improved skid resistance. Hence, consideration should be given to the use of separate friction courses. However, if single seals are used as friction courses, the underlying asphalt should have a sufficiently high stone content to prevent embedment of the seal into the underlying fresh asphalt. The application of grit (even to SMA mixes) to improve skid resistance in the early life of a wearing course is common practice both locally and overseas.

In situations where emphasis is placed on noise reduction (generally in urban areas) mixes such as Stone Mastic Asphalt (SMA) and porous asphalt should be considered.

☞ The testing of resistance to stripping due to moisture damage cannot be overemphasized and is often neglected. The modified Lottman test is currently the most appropriate test to determine stripping potential. Anti-stripping agents (including lime) should be seriously considered when there is any doubt.

☞ The use of cement to improve resistance to stripping has not been proven and is not recommended.

☞ Drum mixers are more frequently used in South Africa, but the correct plant modification to accommodate additives such as modifiers and anti-stripping agents in the mix is, in general, not consistent, especially on mobile plants at construction sites.

2.2 Phase 2: *Mix Type Selection*

After taking all the design considerations and objectives into account, an appropriate mix or combination of mixes and layers should be selected to suit their intended use.

☞ Table 2.6 of the IGHMA provides a useful tool to rank the design objectives and develop an initial understanding of the precise function of the HMA and its required properties. The steps involved in this rating process are discussed in section 2.8 of the IGHMA.

☞ Designers should use the rating information and Table 2.7 of the IGHMA to make a preliminary mix selection, as the characteristics of the mix components can have an influence in the final mix selection as discussed in the next Phase.

2.3 Phase 3: *Component Selection*

The components of an asphalt mix comprise:

- Aggregate
- filler and
- binder

and are discussed in detail in Section 3 of the IGHMA. Each component is described in terms of physical properties or chemical composition. The test methods for evaluating suitability for use are provided in the IGHMA.

Most of the important issues regarding the mix components are discussed in the IGHMA. Some additional aspects are discussed in the following sections.

2.3.1 Aggregates

Aggregates for Hot Mix Asphalt comprise coarse and fine aggregate that are normally obtained from crushing operations.

- Coarse aggregate in an asphalt mix normally consists of crushed stone or other manufactured materials such as blast furnace slag or steel slag that may be selected and processed from waste products obtained from manufacturing processes. If materials manufactured from waste products are used the chemical composition and presence of any deleterious chemicals must be carefully checked and monitored during construction.

- The fine aggregate can consist of a material such as sand, or crushed fines. The particle shape of fine aggregate significantly affects the workability of the asphalt mixture, as well as its resistance to permanent deformation.

- Since improved crushing systems were introduced, the aggregate shape has become more angular and cubical, resulting in easier compaction and a significant influence on other performance characteristics of the mix. Hence comparisons between mixes designed and manufactured with aggregate of a similar grading, but with different particle shape, should be made with caution.

- Current practice is to minimize the use of natural sands due to their more rounded shape and the generally poorer rutting resistance of mixes that include these sands, particularly related to gap and semi-gap graded mixes. However, these mixes provided good performance in certain design situations in the past, and their use should not be disregarded without investigation. The angularity of the sand in these mixes, whether natural or crushed, is critical to their performance and the engineering properties of mixes incorporating higher volumes of the sand fraction should be evaluated accordingly.

- The stability and workability of HMA are greatly affected by the shape of particles, and designers should also be aware that particle packing in a laboratory mould may differ substantially from the packing in a road layer.

- Variability is a significant issue affecting asphalt layers and their properties. In particular, the quality of the rock in aggregate quarries often varies, resulting in the crushing process producing material with different fractions and particle shapes.

Details of the test methods of effective and bulk densities of aggregates are provided in Chapter 5 of IGHMA.

2.3.2 Filler

Filler is defined as the material passing the 0.075 mm (or 75 μ) sieve. There are two types of filler:

- Active filler; and
- Inactive (or inert) filler

Table 3.2 of the IGHMA shows the filler types and characteristics, while section 3.3 contains detailed discussions on the use and application of fillers.

The following paragraphs highlight some particular issues related to the use and application of fillers:

☞ The **filler/binder ratio** has an effect on both the workability and durability of the mix, as well as on its ultimate stiffness and related tensile strength. In the case of continuously graded mixes too much filler may make compaction difficult, while in low stone content mixes such as semi-gap and gap-graded mixes, the filler-binder ratio will have a significant effect on its resistance to deformation. Mixes with ratios of 1.5 have greater resistance to deformation, but are likely to have poorer durability. The effect of this ratio on compactability of the mix, permanent deformation and durability should therefore be carefully understood and controlled during the design process.

☞ It should be noted that **filler/binder ratios cannot be applied to all mix types** as this can restrict certain grading requirements. For example, with a base mix and a target binder content of the order of 4%, the maximum filler that can be included at a maximum specified filler-binder ratio of 1.5 would be 6%. This may be unnecessarily restrictive for this mix.

☞ The **ratio of filler related to the effective binder** content may have more relevance, as this will take the absorption of the binder into account. Typical values of absorption of binder in dense graded mixes are between 0.6 and 1.2 percent.

☞ The **tolerance limit** of ± 1% of filler should be rigorously applied, except for open-graded mixes where the filler content could be as low as 2% filler and the ±1% tolerance may be too high.

2.3.3 Binder

Section 3.4 of the IGHMA provides details in this regard. The following binder types are used in HMA:

- Penetration Grade Binders
- Modified Binders

The Technical Guidelines of October 2001(TG1): ***The Use Of Modified Bituminous Binders In Road Construction***[8] is available from the Asphalt Academy, and should be used in selecting, evaluating and using modified binders.

The most important properties and characteristics of commonly used modifiers are summarised in Table 3.3 of the IGHMA. Designers should be aware that the use of modified binders invariably requires more precise and specialised quality control during construction.

Table 3.4 of IGHMA shows the current SABS 307[9] tests and specifications used for penetration grade bituminous binders.

The following additional comments in respect of binders should be considered:

☞ Regular evaluation and testing of binders should be incorporated into a quality assurance system to continuously confirm the binder quality.

☞ Bitumen is a very complex component of the asphalt mix. Bitumen properties can vary within the specification ranges, which can influence the performance of sensitive mixes.

☞ It should also be noted that binders may change during the course of an HMA contract due to heating and bulk storage over time. A binder's viscosity can be expected to increase by approximately 25% if kept in bulk at elevated temperatures of over 150°C for a month. While this storage practice is not recommended, practicalities on site sometime dictate an occurrence of this nature. In these circumstances changes in properties should be monitored and, where possible, the original design mix should be modified to accommodate changes in raw material properties to achieve the required engineering properties of the mix. Alternatively the stored binder should be rejected.

2.4 Phase 4: Volumetric Mix Design

Following the determination of the design objectives, preliminary selection of the mix type, and evaluation of the various components, the actual volumetric design process can begin.

The basic volumetric design procedure consists of:

- determining the quantity of the various fractions of aggregate that will provide a suitable skeleton that will meet the overall design objectives of the mix; and
- determining the quantity of binder that will fill the voids in the aggregate while still retaining sufficient voids, even after traffic compaction, to prevent the aggregate from "floating" in the binder.

Designers will need to develop an understanding, through experience, of how the different aggregate skeletons will perform. It is important to understand how the voids in the aggregate and the related binder content is determined, to ensure that the binder will not fill all of the available voids and result in the aggregate "floating" in the binder. This can lead to bleeding of the asphalt surface and reduced resistance to permanent deformation.

2.4.1 Spatial Considerations

The concept of spatial composition is discussed in detail in **IHMGA - Appendix B: Basic Principles of Spatial Composition – and** the concept is shown graphically in **Figure B1 and B2** of that Appendix. Basically two opposing packing mechanisms govern the packing of aggregates as illustrated in Figure 4:

- ***Substitution* (or replacement),** in which the space occupied by the fine aggregate fraction is replaced by an increase in the concentration of the coarse aggregate fractions. This mechanism applies to sand skeleton-mixes.
- ***Filling***, in which the spaces between coarse aggregates are filled by an increase in the concentration of fine aggregate without affecting the stone-to-stone contact of the coarse aggregate. This mechanism applies to stone-skeleton mixes.

Typical “replacement” example of asphalt mixes

Typical “filling” example of asphalt mixes

Figure 4
Typical aggregate packing mechanisms

2.4.2 Target Grading

In spite of the extensive experience with asphalt mix designs, there are still many uncertainties about how to determine the aggregate packing to optimize the mix properties, and also how to determine the various proportions of the available aggregates to ensure that the required packing is achieved. The TRB circular on the Bailey Method[10] (***”Transportation Research Circular Number E-C044 – October 2002” of The Transportation Research Board of America- Website: www.TRB.org)*** provides an approach to selecting and adjusting aggregate gradations for HMA design. The following comments are provided related to the method:

☞ The method is a systematic approach to blending aggregates that provides aggregate interlock as the backbone of the structure and a balanced continuous gradation to complete the mixture.

☞ The method provides a set of tools that allows the evaluation of aggregate blends. These tools provide a better understanding in the relationship between aggregate gradation and mixture voids.

☞ Practitioners are also given the tools to develop and adjust aggregate blends to ensure aggregate interlock (if desired) and good aggregate packing, giving resistance to permanent deformation, while maintaining volumetric properties that provide resistance to environmental distress.

☞ The method uses two principles that are the basis of the relationship between aggregate gradation and mixture volumetrics; aggregate packing and definition of the coarse and fine aggregate. With these principles, the primary steps are to combine aggregates by volume and analyse the combined blend.

☞ The principles in the method can be used from the asphalt mix design through to the quality control process, but do not themselves constitute a mix design method. The method does not address the appropriate aggregate properties or asphalt mix properties required to produce a quality asphalt mixture.

The following additional comments are provided related to aggregate grading and packing:

☞ Some of the issues highlighted in the Bailey method[10] are the need for careful consideration of all aggregate fractions to obtain a workable solution, as well as some areas in which variability will create significant problems. Mix designers should study the method to obtain a better understanding of aggregate packing and the effects of small variations in certain fractions on some sensitive mixes.

☞ In most instances the gradation limits provided in current specifications will provide reasonable results for mixes that primarily rely on the sand fraction for stability. Where greater reliance is placed on the coarse aggregate fraction, the mix will be more sensitive to small changes in aggregate fractions, shape and rugosity.

☞ The permeability of coarse, continuously graded mixes and SMA is a significant problem in South Africa, where asphalt layers are required to be impermeable to keep moisture out of water sensitive bases and also to prevent stripping of the binder from siliceous aggregates. The variability in aggregate characteristics, as well as segregation during paving, also contributes to this problem.

☞ Designers should also make use of **software packages** such as **Compact**[7] or **Prado**[11]**,** which are handy in assisting with the calculation and evaluation of volumetric properties and determining the effects of small changes in aggregate fractions on these properties.

The recommended aggregate gradings for different mix types and nominal mix proportions are given in Tables C1 – C5 of Appendix C of the IGHMA. Appendix A from the TRH8 guidelines of 1987[1] describes in detail how to blend various stone size fractions into a given aggregate grading.

2.4.3 Mixing and Conditioning

The recommended procedure for mixing of the aggregate and the binder is as prescribed for the Marshall method (see TMH1[12], Appendix to method C2). No sample conditioning is performed before compaction.

2.4.4 Compaction

Laboratory compaction of mixes essentially entails compacting specimens to try and simulate the volumetric characteristics and performance properties that will occur in the field. Furthermore, while most laboratory compaction methods can produce mixes that reasonably simulate field mixes with respect to the voids that occur, research has shown that none of the laboratory compaction devices are capable of producing mixes with an aggregate packing that closely represents the packing obtained during field compaction. Therefore, performance properties such as resistance to deformation and fatigue should not be determined on specimens compacted in typical laboratory compaction devices. The IGHMA recommends cutting these specimens from slabs that are compacted using rolling wheel compactors. Further comment on the advantages and disadvantages of the various compaction devices are discussed in the subsequent sections.

There are a number of general issues related to the compaction of samples in the laboratory during the design procedure that should be noted:

☞ Although there are practical limits on setting **mixing and compaction temperatures**, more emphasis should be placed on varying temperature control according to bitumen viscosity, especially for modified binders. A change in temperature and viscosity can have a significant impact on the actual densification process of the mix.

☞ The current Marshall procedure in TMH 1[12] specifies a **compaction temperature** that provides a binder viscosity of 134 ± 14 seconds (Saybolt Furol method) or $280 \pm 30 \times 10^{-6}$ m^2/sec (Kinematic viscosity). In theory, mixes with **modified binders** should be compacted at the same viscosity. However, some modified binders have different compaction characteristics, and consistently higher densities can be obtained at the same or lower temperatures. Whatever the temperature selected for laboratory compaction, practitioners should be aware that for the same binder content, mixes exhibiting significantly different densities at different temperatures may have a risk of closing up more than expected under traffic.

☞ It is desirable to **first compact all mixes that will be manufactured with modified binders using conventional binders** and to subsequently assess whether compaction with the modified binder results in opening or closing of the mix relative to the conventional binder. This approach is not recommended for non-homogenous binders (bitumen-rubber), which requires specific gradings.

☞ Current **guidelines for compaction of some SBS modified binders** recommend that the mix must be compacted at a temperature 2°C higher than the equivalent unmodified binder for every 1% modifier added to the bitumen. It is proposed that compaction temperatures for modified mixes are obtained from the modified binder manufacturers, and that the densities achieved within a range of temperatures close to those recommended are checked to assess consistency.

☞ It should be noted that the sequence of adding and mixing different components to a laboratory could have an influence on the actual properties of the mix. Care should be taken to monitor the amount of binder sticking to the mixing bowl to ensure that this is not significant.

☞ The **IGHMA differs an approach from the Superpave procedure**[13] , in that while the Superpave procedure uses a different compaction effort (N Design) depending on the design situation, and specifies a uniform minimum void content at that effort, the IGHMA proposes that the compaction of all continuously graded mixes proceed using a uniform compaction procedure, and that the void content be assessed at different levels of compaction. For example, according to the IGHMA, a mix in a light traffic situation should have voids of between 3% and 4.5% after 90 total blows of the Marshall hammer. However, the Marshall compaction test should proceed to 150 blows and the designer should also assess the voids at this effort. If the mix has very low voids of below 2% at 150 Marshall blows, and the designer is concerned about early heavy traffic loads that may cause the mix to close up and rut, then a slightly lower binder content or different grading may be selected. In this way, the designer should have increased confidence regarding both the voids in the mix immediately after construction (approximated by the voids after 75 blows) as well as after typical trafficking (approximated by the voids after 75 + 15 blows), as well as the ultimate minimum voids that may occur in the mix if it were subjected to isolated heavy traffic (approximated by the voids after 150 blows).

The end result of this approach is that if the designer does not have a Marshall compaction device with a specimen height monitor available to assess the full compaction curve of the mix, then the design void content at 150 blows can be varied depending on the traffic situation and can be 2 to 3% for light traffic, 3 to 4% for medium traffic and 4 to 5% for heavy traffic. In any event it would be this latter void content at 150 Marshall blows that would be used in the specification, as site mixes should be monitored using 150 blow Marshall compaction.

☞ In heavy traffic situations the designer should take care to ensure that the mix does not have excessive voids immediately after construction which could result in moisture ingress and stripping. For this reason the IGHMA method suggests a maximum void content after construction (approximated by 75 Marshall blows in the laboratory) of 8%. Indications are that the 8% limit may be too high for certain mixes and may result in excessive permeability, particularly where significant density variations occur. Hence a maximum value of 7% voids is preferred and is normally specified.

In the case of heavily trafficked roads the ultimate void content after 300 gyrations in the Gyratory Shear Compactor is also assessed and can be varied depending on the severity of traffic loading with respect to rutting. The void content should however, never be less than 2%.

There are basically 5 different methods of compacting asphalt mixes from which volumetric properties can be determined:

Marshall compaction

The Marshall compaction is the conventional static, impact compaction method (refer to TMH 1[12], Appendix to method C2) applicable to all the mix types, which requires a certain number of blows on each side of the sample briquette to determine the optimum binder content. The device is relatively inexpensive and is readily available in South Africa. However designers should note the following:

- ☞ The aggregate packing produced by this device is not representative of field packing, particularly in densely graded mixes. Hence, specimens compacted with this device should not be used to determine any performance properties that will be influenced by this characteristic.

- ☞ The device may underestimate the density of mixes that are difficult to compact, and should be used with caution. Alternatively the results from this method should be checked using the gyratory shear compaction as recommended in the IGHMA.

- ☞ The number of blows required to compact the asphalt briquettes to refusal density may differ for different mixes due to the composition of the mix and its workability. For example, a stone skeleton mix should require fewer blows to achieve maximum densification than a continuous mix, and additional compaction may lead to crushing of the aggregate. However, tests with, say, 35, 50 and 75 blows per side should be carried out to assess the differences in density at different blow counts, and also whether any crushing occurs. A reduced number of blows should only be used for design purposes when the designer is satisfied that the additional blows will not produce a significantly different density result, or cause aggregate crushing that is not likely to occur in the field.

Modified Marshall compaction

This is described in section 8.9 of IGHMA, and determines the void content a cylindrical briquette after each blow of the Marshall hammer. This allows the designer to better assess the mix behaviour during compaction and traffic densification. The method also differs from the conventional Marshall method in that, instead of using five different binder contents, three binder contents are used. This process and the rationale for its use are discussed in detail in the IGHMA section 4.1. Essentially, this procedure provides some additional information during compaction to evaluate the mix densification process and whether this has progressed to its limit during the test.

Table 4.1 of the IGHMA provides interim guideline criteria for voids of densely graded mixes, subject to different traffic situations when using this method.

Gyratory Compaction

This compaction effort was developed for the US Strategic Highways Research Programme (SHRP) Superpave mix design method. Similar to the modified Marshall method, this method of compaction can also monitor the increase in sample density (expressed as a percentage of its theoretical maximum specific density) with increasing compactive effort.

☞ The aggregate packing produced by this method more closely resembles field compaction, but the edge effects produced by the mould are still significant.

☞ The method can compact the material to more closely resemble the maximum density likely to be achieved in the field, although aggregate crushing could occur at a high number of revolutions with weaker aggregates, and will influence the densities achieved.

☞ While in the Superpave method the density is evaluated at 3 points along the densification curve depending on the expected traffic, in the IGHMA method a maximum of 300 gyrations is applied to sand skeleton mixes carrying heavy and very heavy traffic, and 100 gyrations for SMA. In the Superpave method, the voids and density achieved at different gyrations, as well as the ultimate density and voids, are evaluated to assess the likely performance of the mix in different design situations, and to determine the design binder content.

(See also appendix B section B4 of the IGHMA)

Hugo Hammer compaction

This compaction method is mainly applicable to large aggregate mixes for bases (LAMBS), as it consists of larger compaction moulds to accommodate larger stone sizes. The compaction hammer, with its unique moulded face, is turned 30° after each blow to simulate a kneading action in an attempt to ensure aggregate packing that more closely resembles field packing.

☞ While this method is capable of producing higher densities than the Marshall method with mixes that are difficult to compact, the specimens produced by this method should also not be used for performance testing.

The method of compaction and the compaction process is described in SABITA Manual 13 of 1997 *"The design, construction and use of large aggregate mixes for bases"*[14].

Kango Hammer compaction

The Kango (vibratory) hammer compaction to refusal density is commonly used overseas to compact asphalt samples both in the laboratory and on site, and is considered to provide a better simulation of field compaction. In addition, the void structure of the samples obtained from this method better represents that achieved in the field.

☞ Use of this method by over enthusiastic operators could result in the crushing of aggregate and the production of very high densities that are unlikely to be obtained in the field. Therefore, this method should not be used without undertaking some initial control testing using other compaction devices.

☞ Further investigation of this method for use in South Africa is recommended. Designer should note that the results from current laboratory compaction methods used in South Africa (eg 150 blow Marshall compaction) cannot be directly related to those obtained from the Kango compaction method.

2.4.5 Density

There are a number of issues related to design and construction density that need to be considered when specifying HMA densities.

☞ Experience has shown that most continuously graded mixes or stone skeleton mixes compacted to less than 93% of MTRD (Maximum Theoretical Relative Density) are permeable. Therefore, current practice is to rather specify a **minimum relative compaction** of at least **93% of MTRD** instead of the 97% minus the design air voids that was used previously. The current SABS specification of 95% of Marshall density is also too low and should be changed to 93% of MTRD.

☞ It should be noted that using a minimum of 93% MTRD could lead to **compaction difficulties** on certain mixes where the design air voids exceed 4%. In these cases, the field compaction will have to approach 98% of Marshall density.

☞ In **specific situations** (such as with low stress areas with low traffic loads and volumes) where design voids of less than 4% are specified, the 97% minus design air voids specification can be applied, as the resulting mix will still be compacted to at least 93% of MTRD.

☞ The **IGHMA design process does not include different compaction levels** for different traffic situations, but rather advocates the development of an understanding of the void content of the mix throughout the compaction process in the laboratory and in the field. Laboratory compaction procedures should be consistent and the specified void content of the mix must be varied depending on the traffic situation.

2.4.6 Volumetric evaluation

In order to understand the volumetric properties of a mix design, it is important to first understand the various parameters and how to calculate them.

The volumetric mix design procedure described in Chapter 4 of the IGHMA is based primarily on the determination of density, voids in the mineral aggregate (VMA), voids in the total mix (VIM) and voids filled with binder (VFB), with voids in coarse aggregate (VCA), specifically applicable to SMA mixes. These values are obtained once the samples have been compacted by the selected method.

To facilitate volumetric design and evaluation in its totality, the following quantities need to be measured:

- BRD (Bulk Relative density) of the individual and combined aggregate fractions.
- MTRD (Maximum Theoretical Relative Density-Rice's method).
- BRD of the compacted mix.
- ERD (Effective Relative Density) of the combined aggregate.
- Effective binder content.
- RD (Relative Density) of the binder.
- Absorption of binder by the aggregate.

Chapter 5 of the IGHMA deals with all the calculations related to the volumetrics. The basic calculations for determination of component properties and volumetric quantities are listed in Table 5.1 of the IGHMA.

Issues related to volumetrics are:

☞ It is very important that **volumetric properties** should be checked for consistency and reasonableness when evaluating the various parameters.

☞ Small **errors in the BRD** of the fines and the total BRD of the mix, as well as **absorption properties of the aggregates,** can result in significant errors in the calculation of the voids in the mix and hence the design binder content.

☞ Designers should also be aware of **porous aggregate that can continue to absorb quantities of binder** long after construction, which could lead to apparent binder hardening. Ideally, an alternative, less absorbent aggregate source should be found. However, should an alternative source not be available, binder contents on the higher side should be selected, and the consequences of increasing the binder content critically evaluated.

☞ **Accurate density measurements** are critical to the confident calculation of volumetric parameters.

☞ The need for **different void specifications** for slow and fast lanes on heavily trafficked roads should not be underestimated, as the densification under traffic will differ.

☞ In order to ensure that sufficient binder is available to produce a durable mixture, it is advisable to calculate the average **film thickness** of the binder in the mix (using the method in TRH 8 1987: Appendix B[1]), although there is a belief that surface areas cannot be accurately calculated and should only be used as an indicator. However, each mix type will have its own unique film thickness requirement. Furthermore there is a difference between loose and compacted mixtures. Film thickness calculations assume that each aggregate particle, including the filler, is separate, each with its own coating of bitumen. In a compacted mixture the spaces between the coarse aggregate are filled with mastic of bitumen and fine aggregate. Bitumen surrounding the aggregate is in fact not a thin film as portrayed by the thickness calculations, but is a volume of bitumen shared by adjacent aggregate particles.

In addition to the volumetric parameters described in the IGHMA, the **effective volume of binder** should also be reported as a percentage of total volume. This is because the binder content, reported as a percentage by mass, differs when the aggregate BRDs differ. In this way users will become familiar with the volume of effective binder and the extent to which it fills the available voids. Theoretically, this value should be similar for the same type of mix.

2.4.7 Optimum binder content

An initial estimate of the optimum binder content should be made after evaluation and consideration of all the volumetric criteria and related issues described in the previous sections.

2.5 Phase 5: Performance testing

In order to evaluate the performance properties of a mix, the required tests are selected based on the rated design objectives discussed in **Chapter 2**.

The three major performance properties to be tested and evaluated are:

- Permanent deformation
- Fatigue
- Moisture damage (stripping)

Other performance tests for specific types of mixes that will also be discussed include:

- Indirect Tensile Strength tests (ITS)
- Resilient Modulus
- Dynamic Creep
- Cantabro Abrasion test
- Shellenbergh drainage test
- Water permeability tests
- Axial Loading Slab test
- Modified Marshall test

Details and references for the test methods are given in Chapters 6, 7 and 8 of the IGHMA document. The following general key points related to performance testing have relevance:

☞ It is important for designers to understand that **no clear qualitative relationships between the different performance tests and actual field performance** have been derived to date. Therefore, the evaluation of some performance test results are based on recommended ranges of test values associated with different situations, rather than on fixed criteria.

It should be noted that thin layer asphalt < 25mm and ultra thin friction courses are not included in the discussion and recommendations in this document.

☞ Pavement and HMA designers should be familiar with the **typical ranges of test results** that are obtained from the various performance tests. The typical ranges of test values allow designers to have some freedom to assess the suitability of the mix for a given situation and also to assess the risk associated with a specific mix or design situation.

☞ For most design situations, the **evaluation of rutting and fatigue** poses the greatest challenge as far as mix performance evaluation is concerned. The procedures for rutting and fatigue evaluation are discussed in detail in Chapters 6 and 7 of the IGHMA respectively.

☞ In addition to rutting and fatigue, **mix durability and permeability** also need to be evaluated. Permeability is assessed by means of the test procedure described in Chapter 8 of IGHMA. Mix durability (resistance to stripping) is assessed by means of the Modified Lottman Test described in Section 8.3 of IGHMA. It should be noted that while the aggregate and volumetric properties (including density) of the mix are major factors influencing its durability, the properties of the binder also have a significant influence on durability. A proper evaluation of binder properties as discussed in Section 3.4 of IGHMA is therefore essential to counteract potential durability problems.

Valuable tests have been developed in recent years to evaluate and determine the behaviour of HMA mixes. Chapters 6, 7 and 8 of the interim Guidelines discuss these tests, interpretations and the failure mechanisms in detail. The validation of recommended test methods, and the establishment of performance-related specification limits, are ongoing and scheduled for completion in 2010.

2.5.1 Permanent Deformation

(See also Chapter 6 IGHMA for more details on the evaluation of permanent deformation)

Permanent deformation, or rutting, is a complex phenomenon influenced by packing of aggregate, stiffness and quality of the binder and underlying support, and is compounded by high surface temperatures and high traffic volumes. Hence, resistance to rutting poses significant challenges as far as performance evaluation is concerned.

Rutting is a relatively common type of distress in hot-mix asphalt layers, and can lead to ponding of water in wheel tracks, which can be a serious road hazard in wet weather. Rutting can also lead to poor riding quality, which in turn results in increased vehicle operating costs

It is widely acknowledged that rutting is a two-phase process consisting of:

- **densification** accompanied by a decrease in volume; and
- **shear** deformation at constant volume.

Factors influencing the resistance to permanent deformation are:

- Temperature
- Loading rate or vehicle speed
- Stress state
- Viscosity of the binder
- Packaging characteristics
- Volumetric aspects
- Aggregate characteristics

The following evaluation methods are available

- Expert system approach for sand skeleton mixes (refer to IGHMA Appendix D)
- Wheel tracking devices
  - Transportek wheel tracking device
  - Soillab wheel tracking device (based on the erosion tester)
  - Mini Mobile Loading Simulator (MMLS)

Of the methods available, wheel tracking devices are the most commonly used and the values shown in Table 6.1 of the IGHMA may be used as tentative guidelines to evaluate the performance of a mix using these devices. However, when interpreting the results the following aspects should be kept in mind:

☞ A **number of rut measurement devices** are used in South Africa and cognisance should be taken of their differences and the variation in interpretation of results.

☞ To date no South African testing protocols make provision for **shear testing,** as the testing requires sophisticated and expensive equipment. Research on the suitability of shear testing is continuing and is included in the ongoing validation process of the design method. Shear testing is however highly recommended as an important indicator during the evaluation process.

☞ To date, there is **no direct correlation** between the different **wheel tracking devices**. However, despite the differences it is important to obtain a relative indication of the actual performance of the mix. Factors that can influence the actual test results are:

- Origin and type of samples obtained. (Lab mix or field mix)
- Reheating of samples
- Correct field simulation in terms of manufacture, construction and service conditions

☞ In the absence of further **investigation and calibration** between different methods, interpretation of results should be undertaken with due care and transparency.

☞ The **temperatures at which rut measurements are carried out** are crucial, and will lead to significant differences in rutting behaviour depending on the temperature/stiffness relationship of the binder.

☞ The **MMLS (Mini Mobile Load simulator)** device is a very useful tool for simulating field conditions and assessing mixes, both in the laboratory and in the field.

2.5.2 Fatigue

(See Chapter 7 IGHMA for the evaluation of fatigue performance)

Factors influencing the fatigue cracking in asphalt are:

- Layer support
- Temperature
- Aging of binder
- Type of binder
- Wander
- Mix gradation

The following evaluation methods are available:

- Indirect Tensile Strength tests (ITS)
- Four-point Bending Beam tests

The most appropriate test result is the four-point bending beam test, but practitioners must appreciate the testing difficulties associated with fatigue testing and the prediction of fatigue under real traffic at in-service temperatures. The following issues should be considered when interpreting fatigue testing results:

☞ It is virtually impossible to use small differences in fatigue lives, as determined from laboratory testing, in predictive models and transfer functions in mechanistic design, and expect to establish reasonable predictors. It is far better to understand the order of magnitude of the fatigue capability of a mix, understand the operating conditions of the mix and layer, and then make nominal estimates of fatigue life.

☞ Because of the problem highlighted in the previous bullet, very little fatigue testing is carried out on project mixes, and this field remains in the domain of research or product manufacturers.

☞ The ITS test is considered a poor indicator of fatigue for thin layer asphalts (constant strain). Although not providing a direct relationship, it does give a better indication of resilient modulus or stiffness in that high ITS values seem to correlate with high resilient moduli and vice versa. For example, open-graded bitumen rubber asphalts have ITS values as low as 300 – 400 kPa, with resilient moduli of between 900 and 1300 MPa. On the other hand, densely graded asphalt with high viscosity binder and a binder content on the dry side of the VMA curve could have ITS values in excess of 1500 kPa, and resilient moduli in excess of 5000 MPa.

☞ Typically, thin wearing courses, particularly those placed on fairly flexible supports, should have relatively low stiffnesses (within limits) to be able to resist the repeated tensile strains induced in the layer by traffic action. Hence, by assuming the relationship discussed previously between ITS and resilient modulus, the ITS of the asphalt should not be excessive. However, thick layer asphalts (eg basecourse mixes) should have high stiffnesses to be able to resist the repeated tensile stresses induced in the layer. Consequently, mixes with high ITS values should be preferred.

Guidelines for the interpretation of ITS results for Fatigue Performance are shown in Table 7.1 of the IGHMA. Guidelines for the interpretation of Bending Beam Fatigue data (constant strain) are shown in Table 7.2 of the IGHMA. (Refer also to step 1-3 in Chapter 7.4 of the IGHMA).

2.5.3 Moisture Sensitivity (Modified Lottman Test)

The Modified Lottman test is used for the determination of moisture sensitivity. This is one of the most important aspects to be controlled during a mix design. ITS measurements are taken before and after a sample is subjected to an environmental stress regime (submerging the specimens in water and then freeze-thawing the wet specimen). The readings obtained are expressed as a tensile strength ratio (TSR) and represent the mix's ability to prevent moisture penetration, and also its ability to withstand the expansive effects of the ice which forms internally when it freezes.

Typical TSR values based on permeability and climate are listed in Table 8.2 of the IGHMA.

☞ It is suggested that the TSR tests to determine the moisture sensitivity should be conducted at 7% voids at a minimum compaction of 93 % of TMRD in the field to determine the values based on a worst-case scenario.

☞ TSR tests can also be carried out on cores extracted from the road to simulate field conditions as close as possible.

2.5.4 Other Design and Performance Tests

(see chapter 8 of the IGHMA 2001)

The following other tests are also used to evaluate additional performance properties of a HMA mix:

Indirect Tensile Strength (ITS) test

In addition to being an indicator of fatigue performance of thick layers and resilient modulus as discussed in section 2.5.2 of this document, the ITS also gives an indication of the cohesive strength of a mix, and typical guidelines in this regard are summarised in Table 8.1 of the IGHMA 2001

☞ The ITS values as referred to in Table 8.1 should be used in conjunction with the other performance tests discussed above. Considered on its own, the result can mislead the designer in the interpretation of rut resistance or fatigue.

Resilient Modulus

The Indirect Tensile Test (ITT) is also used to determine the resilient modulus (MR) or stiffness of a mix by incorporating repeated loads as well as vertical and horizontal strain measurements.

☞ No specific guidelines are available but higher MRs will probably have lower fatigue lives in constant strain mode (thin asphalt surfacings), while asphalts with lower MRs are preferred on more flexible pavements as they could possibly absorb the deflection better without fatigue cracking.

☞ MR values can vary significantly as they depend on small strain measurements and hence should not be included in project specifications. MRshould rather be used as an indicator of potential fatigue performance during designs.

Dynamic Creep

This involves repeated loading of cylindrical test specimens in the axial direction normally at 40°C. The accumulated permanent deformation is monitored as a function of the number of load repetitions.

☞ This test can be used to evaluate the likely rut resistance of mixes with a low to moderate rut potential. However, the testusually gives very high values for dense continuous mixes with modified binder, and may overestimate the rutting performance of the mix. Unstable mixes have been known to disintegrate in the test.

☞ Experience has shown that some modified binders reduce the dynamic creep modulus of mixes, but have performed well in service.

☞ In general, dynamic creep tests should only be used on sand skeleton mixes, and preferably on those containing unmodified binders. Stone skeleton mixes (eg SMA, semi-open graded and porous asphalt) are known to be rut-resistant mixes, but will fail the test as the test is carried out in an unconfined mode.

Comment: Rephrase??

Typical values are listed in Table 8.3 of the IGHMA.

Cantabro Abrasion test

This test is used to evaluate the abrasion of open-graded mixes using the LA Abrasion test (ASTM C131-81) without the steel balls.

☞ The recommended maximum abrasion loss is 20%.

Shellenbergh Drainage test

This test is used to evaluate binder run-off in open-graded and SMA mixes. Typical values with regard to binder run-off are:

% Weight Loss	Performance
<0.2%	Good
0.2% – 0.3%	Acceptable
>0.3%	Poor

Water Permeability test

This property can be tested using a number of test methods. The ones commonly used in South Africa are:

- Constant head water permeability test (carried out on laboratory specimen)
- Marvil water permeability test (carried out on site)

Both tests have shortcomings primarily related to the location and direction of paths that are available for water to flow through. As can be imagined, the test results vary considerably due to the myriad possible flow paths, but repeated results with values in the higher range, as indicated in the IGHMA, will be indicative of definite problems.

The **constant head permeability** must be regarded as the most appropriate test method to evaluate permeability, provided the test is carried out in a manner that prevents water from flowing around the specimen and along the sides instead of through the specimen.

The following issues will assist in developing a better understanding of asphalt permeability:

☞ Due to the inherently variable nature of the permeability testing, it is suggested that practitioners should not rely solely on the results of the test, but should also make visual observations during specific tests for seepage of water adjacent to sealed edges of cores and moulded specimens. Thisalso applies to the *in situ* apparatus related to the Marvil test. **Visual assessment of the amount of voids that are present, and their inter-connectivity,** is also recommended when making a judgement on the permeability of a mix.

☞ Testing for permeability properties is not recommended on Marshall briquettes (even at 7% voids). This property should be measured on cores taken from constructed pavements, especially at new longitudinal joints.

☞ It should be noted that **traffic compaction has the greatest effect on the surface of the asphalt,** and may make the surface less permeable than the rest of the layer. This will result in increasing the variability of Marvil test results of the layer as permeability may only be detected where the surface allows moisture into the underlying more permeable part of the layer.

☞ Marvil tests have been carried out with some success on specimens extracted from the road as well as on manufactured slabs. One of the criticisms of the test is that water flows under the sealed edge of the apparatus, although this problem has been solved to some extent by the use of a neoprene ring to seal the apparatus to the test surface.

☞ There is a need to identify and verify a definitive permeability test (or tests) related to performance criteria for different mixes. The tests are currently used to test sections and mixes relative to one another.

☞ High sand content mixes such as gap-graded and semi-gap-graded asphalt are far less permeable, and easier to construct to a greater degree of consistency, than continuously graded mixes.

☞ Moisture sensitivity, and the resultant **stripping,** is regarded as one of the **major causes of failure,** and should be evaluated with care at all stages of mix design, trial section construction, and final construction.

☞ Permeable areas are often easier to identify after rain, as these areas retain moisture for much longer than the impermeable areas. The visual observations not only provide an indication of the degree of permeability, but also the extent and location, such as whether the areas adjacent to joints are more permeable than the rest of the layer.

☞ The **more permeable areas will generally be less dense** and additional testing as well as significantly greater attention needs to be paid to these areas of asphalt construction than has been the case in the past. Problems of this nature may have increased in recent times with the change from gap and semi-gap-graded mixes to continuously graded mixes.

2.5.5 Field trials and final adjustments

In order to evaluate the performance properties indicated from the laboratory mix design process, and to improve the confidence levels in the design mix, it is essential to carry out field trials where practicable, especially for roads designed to carry heavier classes of traffic. The following comments relate to field trials and Appendix A of this document provides additional information:

☞ It is suggested that where practicable, all the tests discussed in this section, including the performance tests, are repeated on the field trial mix and preferably at three different binder contents to increase the reliability in the recommended design mix. The length of such a trial section should be at least 150m.

☞ The trial section provides an opportunity to do some final adjustments to the mix, and to determine a final production mix (job mix) formula. The job mix formula is the mix that will finally be approved after the necessary adjustments have been made. This mix will therefore be used for production.

- ☞ Another important objective of a trial section is to determine the compactive efforts of different types of equipment, minimum compaction temperatures and final paver screed settings.

- ☞ It is also highly recommended that the **MMLS** (Mini Mobile Loading Simulator) be used to test the performance properties of critical mixes.

- ☞ It is suggested that in the absence of a rainstorm, the layer in the field trial be thoroughly wetted with a water cart to assess the variability and degree of permeability over the full extent of the layer, including the joints. When the techniques of constructing the mix without any significant variability and with effective impermeable joints have been developed, the construction of the trafficked layer should commence.

- ☞ When assessing the degree of permeability, it may also be necessary to wash the surface of the layer with Teepol or similar to promote moisture penetration and eliminate surface tension effects.

Chapter 3 - Discussions on different mix types and specific design considerations

This chapter briefly discusses the most frequently used mix types and highlights specific design considerations. Reference to detailed information is also provided.

The mixes to be discussed are:

- Sand skeleton mixes (Including gap and semi gap mixes);
- Stone mastic asphalt;
- Open-graded mixes;
- Large aggregate mixes for bases; and
- Semi-open graded mixes.

3.1 Sand-Skeleton mixes

(Refer to Section 4.1 of the IGHMA for detailed discussions and TRH8 1987[1] section 3.2 and 5.2.1)

In the context of these design guidelines, sand-skeleton mixes refer to **continuously graded, semi-gap graded and gap-graded mixes**.

☞ Sand-skeleton mixes are the most commonly used mix types in South Africa,although gap-graded mixes have fallen out of favour because of the need to obtain and use a “sharp”, angular sand that will provide adequate resistance to rutting.

☞ In a continuously graded mix the spaces between the coarse aggregate particles are overfilled with the well-graded portions of finer aggregate, primarily coarse sand.

☞ Sand skeleton mixes derive their stability from a sand-skeleton (unlike stone mastic asphalt and open-graded mixes, which rely on a stone-skeleton).

3.1.1 Component selection

The selection of aggregate, filler and binder is discussed in Chapter 2.

3.1.2 Selection of a design gradation

Typical gradation envelopes for densely graded mixes with various nominal maximum stone sizes are shown in Appendix C of IGHMA.

In the selection of the nominal maximum stone size, layer thickness considerations need to be taken into account (see, Table 2.8 IGHMA).

☞ It should also be noted that coarser mixes will generally have greater stability, but may also exhibit high permeability immediately after construction, particularly if target densities are not met in isolated areas due to segregation.

☞ The maximum density line theory, as described in TRH 8 - 5.2.1.3, as well as the comments provided in the Bailey method, are useful tools to adjust gradings for volumetric and stability considerations.

☞ The use of TRH 8 1987[1] Table 3 is suggested when continuous coarse mixes are designed, and not Appendix C of the IGHMA. The coarse grading mix specified in Appendix C and in the COLTO/COTO specifications[6] is too close to a grading used for designing asphalt bases, and the maximum stone size specified can influence the actual performance as a surfacing layer.

3.1.3 Binder content selection and evaluation of compactability

(See also section 4.1 IGHMA for detail discussions)

The procedure requires a thorough understanding of the compaction and volumetric characteristics of the mix at different binder contents, and for different compactive efforts.

The process for the design of sand skeleton mixes requires that the designer should balance and evaluate several aspects that will influence performance, such as:

- Traffic;
- Compactability;
- Initial Voids Content after Construction;
- Final Void Content after Trafficking;
- Laboratory Compaction versus Construction and Traffic Compaction.

The following additional comments should be noted:

☞ The use of the gyratory shear compactor is proposed for coarser mixes in critical design situations, as opposed to the Marshall compaction, as it provides a better indication of the likely ultimate density that could be achieved.

☞ Table 4.1 of the IGHMA shows the guidelines for void criteria in order to select the optimum binder content. These criteria ensure that the permeability and density requirements after construction are met, as well as the stability requirements based on minimum void content after trafficking.

☞ **Minimum VMA Criteria** for continuously graded mixes are shown in Table B2 Appendix B - IGHMA

3.1.4 Performance testing

The performance tests are selected on the basis of the rated design objectives (Chapter 2 Phase 1).

3.2 Stone mastic asphalt

Stone mastic asphalt (SMA) is a premium mix type with a complex grading for use as a surfacing and friction course under heavy traffic conditions. The primary characteristics of a properly designed SMA are:

- good resistance to permanent deformation and reasonable fatigue properties because of its stone skeleton structure and high film thickness;
- improved durability and generally better wet weather skid resistance and noise reduction characteristics compared with continuously graded mixes; and
- improved stability from the stone skeleton. Fibres are normally added to the mix to prevent drain-down of the binder during transportation and placing of the mix.

3.2.1 Design considerations

SMA mixes are best utilised as thin surfacing on heavily trafficked roads and at intersections. To achieve the required properties from the mix, the following should be considered at the design stage:

- high quality aggregates are required;
- a consistent gradation and binder content is required to maintain stability throughout the life of the mix; and
- it is not economical that SMA mixes be used in a structural layer and therefore, in practice, this means that the thickness of an SMA layer is generally limited to 40mm or less.

3.2.2 Design procedure

The design method is based on experience in the South African environment. The method is based on volumetric considerations, with the criteria for voids being derived from experience and volumetric principles. SMA mixes are normally relatively easy to compact.

Figure 4.7 of the IGHMA shows the steps to follow in the design process.

3.2.3 Component selection

The component selection process, as outlined in section 2.3 of this document, should be followed to finalize the grading and selection of the design binder content. In addition, the following specific consideration applies to the selection of components for SMA mixes:

☞ Fibres are normally added to SMA mixes to stabilise the mastic to prevent drain-down during construction. Cellulose fibres or mineral fibres in loose or palletised form can be used. However, care should be taken to avoid overheating the fibres in the production stage of the SMA, and compaction temperatures should not be too high as this will result in binder run off and subsequent bleeding.

3.2.4 Selection of design gradation

Typical gradations for SMA mixes with various nominal maximum stone sizes are shown in Appendix C of IGHMA. Designers should be aware that in certain circumstances slight differences, outside the envelopes specified, might occur. The limits should therefore be seen as a guideline. In the selection of a nominal maximum stone size, the considerations with respect to layer thickness should be taken into account (see Table 2.7 of IGHMA). The following comments should also be noted:

☞ The successful performance of SMA mixes is highly dependent on the particle composition and spatial arrangement of particles (refer also to Bailey Method).

☞ Specific steps should be taken to ensure that the stone skeleton of the SMA mix is not overfilled with mastic. To evaluate whether this is the case, the voids in the coarse aggregate (VCA) of the compacted mix have to be less than the VCA of the coarse aggregate without mastic. (see calculations in section 4.2 of IGHMA)

3.2.5 Binder content selection

Reference should be made to notes 1 to 5 in sections 4.2 of the IGHMA for binder content selection, and Table 4.2 of that document for volumetric design criteria for SMA Mixes.

3.2.6 Performance testing

The performance tests are selected on the basis of the rated design objectives (Chapter 2).

3.2.7 Mix deficiencies

A useful table to address mix deficiencies is shown in Table 4.3 of the IGHMA. The following additional references are provided:

☞ Problems and Potential Solutions for SMA Mixes are addressed in NCHRP Report 9-8/4[15].

☞ Although not documented and distributed, valuable research has been carried out on the Wilhelmi test[16] to evaluate the stiffness of the mastic in a SMA mixture. It is suggested that this test be incorporated as part of the mix design process.

3.3 Open-graded mixes

(Reference should be made to Sabita Manual 17[17] for detailed discussions on open-grade (porous) asphalt mixes).

Open-graded asphalt (porous asphalt) is used primarily as a surfacing layer to:

- improve skid resistance in wet weather;
- reduce spray and improve visibility in wet weather; and
- reduce noise pollution.

To achieve this, open-graded mixes rely on a stone skeleton for stability and have void contents typically in the order of 20 per cent. Because of their high permeability, open-graded mixes have to be laid over an impermeable layer.

The stiffness of open-graded mixes is generally significantly less (typically 50%) than that of more densely graded mixes, while their resistance to rutting is high in thin layers.

☞ The tendency of porous asphalt to clog with dust and detritus has caused a rethink of its use on South African roads. Overseas apparatus has been introduced to "deep cleanse" the layer periodically, maintaining its efficacy, but this equipment is currently not available in South Africa.

☞ Other new innovations include a so-called sacrificial layer, with a smaller stone size, as an overlay on top of the existing open graded layer, resulting in a surfacing somewhat similar to a porous double seal

☞ Because of the open structure and the need for higher than usual binder content, open-graded mixes are prone to exhibit binder drain-down during construction.

3.3.1 Design considerations

The following aspects should be considered when designing open-graded mixes:

☞ The binder content should be as high as possible for the given voids content and stability requirement to prevent stripping and ravelling.

☞ If the underlying layer consists of water sensitive materials or has widely spaced cracks, it is recommended that a stress-absorbing membrane interlayer (SAMI) be constructed to avoid water ingress and retard crack reflection.

☞ Provision should be made for the water to pass through the porous layer and to exit laterally into collecting drains or onto the shoulder.

☞ An adequate crossfall is needed to prevent water from being trapped in the open-graded asphalt layer.

☞ A lateral transition zone or cut-off drain should be constructed between an open-graded asphalt layer and other sections consisting of impermeable material.

☞ Never cut joints with edge blades as this will seal the void structures and prevent water escaping from the mix through the interconnecting voids.

☞ Open-Graded Asphalt should preferably not be used:

- at intersections;
- in industrial areas where there is extensive wear from abrasion, spillage of fuels or any other contamination from deleterious material which may tend to clog up the void structure of the mix;
- in areas with permeable or soft supporting layers; and
- on roads that are frequently soiled by waste or windblown dust and sand.

3.3.2 Component selection

The first step in the design procedure is the component selection. Apart from the general guidelines for component selection given in Chapter 2 of this document, the following apply specifically to open-graded mixes:

☞ Since open-graded mixes derive their stability from the stone skeleton, it is vital to ensure that hard and durable aggregates are selected.

☞ Reduction in binder drain-down is usually achieved by using modified binders or paving at cooler temperatures.

☞ A mineral filler content of between 1 and 2 per cent is recommended to enhance the adhesion properties of the binder.

3.3.3 Selection of design gradation

Typical gradations for open-graded mixes with various nominal maximum stone sizes are given in Appendix C of IGHMA.

3.3.4 Binder content selection

A detailed description of the selection of optimum binder content can be found in Sabita Manual 17[17]. See also as a summary Table 4.4 for gradation and binder content selection in the IGHMA, and the notes that follow Table 4.4 of that document.

3.3.5 Performance testing

The performance tests are selected on the basis of the rated design objectives (Chapter 2).

☞ For high to very high traffic levels, it is recommended that performance testing be conducted on open-graded mixes to evaluate durability and moisture susceptibility.

- Durability - evaluated using aged specimens in the **Cantabro** test procedure (see SABITA Manual 17[17])
- Moisture Susceptibility - evaluated using the **Modified Lottman** procedure (AASHTO T283) as described in Section 8.3 of the IGHMA

3.4 Large aggregate mixes for bases (LAMBS)

(Reference should be made to Sabita Manual 13 1997[14] for detail discussions on LAMBS mixes)

LAMBS are used primarily for asphalt bases as the structural support layer in heavy-duty pavements. Heavy-duty pavements are those expected to carry traffic volumes in excess of 30 million E80s during their design period. The runways of high-volume airports and certain loading facilities could also fall into this category.

☞ Drainage is of the utmost importance and should be carefully designed when utilising these mixes to minimize the risk of stripping

3.4.1 Design considerations

Consideration must be given to structural and environmental aspects, which must be taken into account prior to the mix design stage. Other considerations include layer thickness.

3.4.2 Component selection

See section 4.4 of the IGHMA for detailed calculations and discussion of the Fuller maximum density equation.

There is limited information available on the gradation design of LAMBS, which promote stone-skeleton type mixes. The design principles of SMA type mixes should be applied.

3.4.3 Design process

Refer to Sabita manual 13[14] as well as section 4.4 and figure 4.10 of the IGHMA for the various steps entailed in the design process.

3.4.4 Design criteria

Design criteria for LAMBS as outlined in Sabita Manual 13[14] are shown in Table 4.5.of the IGHMA 2001.

3.4.5 Performance testing

The following aspects relate to the testing of LAMBS:

- ☞ Indirect tensile testing is used to determine the indirect tensile strength (ITS), the strain at maximum stress, and the resilient modulus (stiffness) of LAMBS.
- ☞ The dynamic creep test is used to assess the deformation characteristics of LAMBS. Sabita Manual 13[14] details the specifications for the tests.
- ☞ The design criteria are outlined in Table 4.5 of the IGHMA. To assess the susceptibility of the mix to moisture damage, it is recommended that the Modified Lottman test method be used.
- ☞ Procedures for the conditioning of LAMBS specimens for moisture susceptibility tests are outlined in Sabita Manual 13[14].

3.5 Semi open-graded mixes

Semi open-graded mixes with modified binders are very popular for use on heavily to very heavily trafficked roads, especially in areas with reduced ultra-violet radiation. Typical gradations for semi open-graded mixes are shown in Appendix C of the IGHMA.

- ☞ Design methods and aspects are not discussed in detail in the IGHMA, but it is suggested that the current available data be officially documented and incorporated in the IGHMA guidelines at a later stage. Further information on semi-open graded mixes is provided by Balmaceda *et al*[18] and Potgieter *et al*[19].

Chapter 4 – Design Implementation: Construction and Quality Assurance aspects

As part of the design process, it is important to minimize problems related to mixing, construction (paving operations) and quality assurance of the recommended mix design. Some of the issues related to implementing the design are highlighted in this section.

Reference is made to SABITA Manual 5[2]: *Guidelines for the Manufacture and Construction of Hot-mix Asphalt*, which discusses some of the issues discussed in this section.

4.1 Segregation

☞ Segregation is a common problem that occurs during manufacturing and paving of a HMA layer. Certain mixes, such as LAMBS and coarse graded mixes, are more prone to segregation than others. It is therefore very important to adjust the paving operation to accommodate these mixes.

☞ Many problems can originate in the aggregate stockpiling and handling processes at the plant, while others may occur during mixing and transporting. Hence these processes should be carefully monitored to ensure early detection of segregation, and to take appropriate action to eliminate the problem.

☞ Segregation may also occur due to improper loading of the paver, and the site staff should ensure that the loading box is properly filled and that a uniform and adequately thick mat of asphalt is fed into the paver screed.

☞ Information and informative illustrations related to segregation can be found in the Technical brochure: T-117 *SEGREGATION: Causes and Cures* published by Astec[20]. This document also discusses different gradings and gives guidance on avoiding tender mixes.

4.2 Compaction and layer thickness

While adequate compaction of HMA layers is a function of an appropriate HMA design, good construction practices and controls are also essential to ensure a uniformly dense layer. While the purpose of this document is not to provide a manual for asphalt layer construction, the following critical areas which have caused problems in the past are highlighted for information:

☞ The timing of the entire process from batching through to paving and compacting is crucial to achieving the required compaction.

☞ The **type** and **sequence** of use of compaction equipment must be adjusted for each type of mix to ensure uniform densification and the required riding quality.

☞ The **rolling speed** is also critical on certain mixes and should be controlled accordingly.

☞ The transverse distribution of rollers and how the mix is compacted both longitudinally and transversely are important factors that should be established early in the construction process, and strictly controlled.

☞ Correct roller operation is essential.

4.3 Temperature control

☞ Temperature control is of utmost importance when manufacturing and paving a HMA mix, as the temperature is directly related to the viscosity of the mix. Differences in mix temperatures can cause differences in compaction, resulting in segregation, permeable surfacings, subsequent ingress of water, and stripping.

☞ Recent work in the Western Cape, reported at CAPSA 04[21], also highlights the limited time available, in certain situations, from the time of placing the mix until it is fully compacted.Very useful guidelines are also provided on compaction windows, especially for thinner layers.

☞ The technical brochure: T-134 *Temperature Differential Damage,* published by Astec[20], is recommended to assist and inform users regarding temperature difficulties.

4.4 Binder variation

Although the specification allows for a certain amount of binder variation, the variances must be controlled. Variations that are too large, either too low or too high, or varying from high to low, commonly occur in the industry. A diagnostic flow chart for binder variability is provided by Astec[20] as part of their Technical paper T-114, and provides a useful tool to assist in identifying and avoiding some of the problems and their causes.

Binder variation also commonly occurs as a result of variances in the mix composition, e.g. too much fine or coarse aggregate resulting in too high or too low binder respectively.

☞ Practitioners should note that while binder variation in certain finer mixes may not be very critical, binder variations in coarser mixes or stone skeleton mixes may be super-critical, and can cause significant problems. This should be determined and known prior to the commencement of paving, and the use of tools such as Compact[7] and Prado[11] are useful in this regard.

4.5 Joints

Inadequate compaction of joints often occurs, resulting in porous areas that experience early distress. Although more difficult to construct, it is important to avoid any ingress of water. The most common problems appear to be either transverse segregation in the paver or slightly thicker, adjacent paved areas that support the edges of rigid steel rollers, thus preventing adequate compaction.

☞ Technical brochure **T-130 *LONGITUDINAL JOINTS: Problems and Solutions*** published by Astec[20] provides guidelines with informative illustrations.

4.6 Trial sections

The value of trial sections should not be underestimated, as they provide an important step in the HMA design process as highlighted in section 2.6 of this document. Hence, where practical, it is essential to carry out trial sections before a mix can be approved. Trial mixes provide a process for the validation of the laboratory mix design and the final production mixes will rely heavily on the outcome of the trial section.

☞ Appendix A of this document contains a **checklist** for use during trial sections.

☞ Small quantities of urban work or mixes for low level designs are not recommended for trial sections due to practical considerations.

4.7 Sampling and testing

☞ The importance of correct sampling procedures and subsequent testing cannot be over emphasized. The whole design process described above is based on information obtained from testing in the laboratory. However, if samples of the components of the mix design or the mix itself are incorrectly taken it will render the results obsolete.

☞ Sampling and testing is critical, and should be carried out by accredited laboratories with experienced and proficient personnel.

4.8 Statistical judgement plans

Statistical judgement plans are normally specified for each contract for use in accepting or rejecting completed work.

☞ It is important to have an agreed quality assurance (QA) plan in place before commencement of a contract. However, the plan should include, but not preclude or replace, sound engineering judgement. Sections should not be rejected (or in some cases accepted) based on extremely minor deviations from acceptance limits without serious consideration of all the engineering implications. Similarly, areas that are visually different within a section should not be regarded as a uniform section, and should be tested and evaluated separately. This does not mean that the judgement plans should be abused, but logical evaluation and adequate investigation must precede final decisions in this regard.

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Appendix A

Field Trial Check List

ASPHALT TRIAL SECTION

A) **Pre-Trial Procedures**	YES	NO

Choose a site for the trial. This should have a similar surface, strength and gradient to that on which the mix on trial is to be laid.

Details of Site.

....

....

....

....

B) Aggregates

		YES	NO
i)	Are there sufficient stockpile areas?		
ii)	Are the stockpiles constructed correctly and is the material uniform ?		

Size of aggregate :

37.5 mm		
26.5 mm		
19.0 mm		
13.2 mm		
9.5 mm		
6.7 mm		
Crusher dust		
Fine sand		
Coarse sand		

C) **Hot Storage for Binder**	YES	NO
i) Is capacity sufficient for the programmed rate of production?		
Capacity .... t		
Required daily capacity ....t/day		
ii) Are tanks fitted with automatic temperature recording systems?		
iii) If a modified binder is to be used, are the blending facilities and methods appropriate to ensure a uniform product having the required properties?		
iv) Is heating thermostatically controlled?		
v) Is there a warning system for variation in temperatures?		
vi) Is binder circulated in tank and between tank and mixer?		
vii) Are supply pipes lagged?		
viii) Is there a level indicator?		
ix) Are sampling points to specification?		

D) **Check Cold Feed Bins**		
i) Are methods of controlling rate of feed operating smoothly?		
ii) Are these controls accurate?		
iii) Are there precautions to prevent spill over?		
iv) Is there adequate warning system if rate of feed alters?		

	YES	NO
v) Is there an efficient interlock between cold feed and binder feed?		
vi) Are fine aggregate feeds susceptible to arching?		
vii) Is there a method of detecting and compensating for variations of moisture in the aggregates?		
vii) Has contractor cold feeds against RPM of belt pulley? Attach calibration curves to report. Report must indicate gate setting.		

E) <u>Mixing Plant</u>

	YES	NO
i) Is rated capacity sufficient for the programmed rate of laying? **Rate Capacity .... t/h** **Required Capacity .... t/h**		
ii) Are the proposed heating fuel and burners compatible?		
iii) Is the method of control of the fuel/air mixture adequate?		
iv) Are burners clean and nozzles to specification?		
v) Are drum rollers correctly set and in good conditions?		
vi) Are drum flights in good conditio ?		
vii) Are binder spray bar and nozzles clean and in accordance with specification?		

		YES	NO
viii)	Can position of spray bar be altered so as to control filler in mix and can adjustments be easily made?		
ix)	Method of determining temperatures of binder at plant. Is this adequate and are the results visible to the operator?		
x)	Temperature controls of aggregate and final mix. Are these adequate and are the results available to the operator?		
xi)	Is the plant fitted with appropriate filler feed to allow accurate proportioning?		

F) <u>Emission Control</u>

i) Type

....
....
....
....

		YES	NO
ii)	Is dust collector matched to capacity of mixer?		

iii) What method is used to return a portion of the recovered fines to the mix?

....

iv) What method is used for the disposal of unwanted fines?

....

		YES	NO
v)	Do emissions from the stack comply with Act 45 of 1965? (As amended)		

		YES	NO
G) Buffer Storage			
i)	Is this of adequate capacity?		
ii)	Is this properly lagged?		
iii)	Do discharge gates operate smoothly?		
H) Elevator between Mixer and Buffer Store			
i)	Are buckets in good condition?		
ii)	Are chains and cables in good condition?		
I) Paver			
a)	Truck pushing rollers: are these:		
i)	Clean?		
ii)	Free running?		
b)	Hopper		
i)	Are sides reasonably smooth?		
ii)	Does side tilt mechanism work properly?		
iii)	Are rubber skirts in good condition?		
iv)	Do feed control gates work smoothly?		
v)	Are feed conveyors in good condition?		
	- Flights?		
	- Bed (no holes)?		
	- Chains, conditions and tension, OK?		

		YES	NO
1)	Screed Unit		
i)	Are pivots free running?		
ii)	Are screed plates smooth and flat?		
iii)	Is bevel on tamper bars to specification?		
iv)	**Are tamper bars straight and correctly set?**		
v)	Is clearance between tamper bars and screed correct?		

Note clearance .... mm

Specified clearance .... 0.05 .... mm

		YES	NO
vii)	Is gap between tamper bars and screed clean?		
viii)	Are crown controls for screed working smoothly?		
ix)	Is locking system for crown control adequate?		
x) xi)	**Is screed inclination set correctly ?** **Oscillator bar frequency? (tearing of mix?**		

Note:

Turn buckle gauge reading ....

Actual : ....

Specified : ....

		YES	NO
xi)	Are augers in good condition and tight to shaft?		
xii)	Are the centre auger flights reversed?		

			YES	NO
xiii)	Are augers set at correct height?			
	Actual height			
	Specified height			
xiv)	If telescope screed is fitted :			
	a)	Do parts move smoothly?		
	b)	Do wings form a smooth continuation of main screed without steps?		
	c)	Are spreader screw extensions in good condition?		
	d)	Are tamper bar extensions to specification and is clearance between tamper and screed correct?		
	e)	Do tamper bar extensions protrude the correct distance below the screed?		
xv)	If screed is not telescopic :			
	a)	Are there sufficient extension boxes?		
	b)	Are screed, tamper bars, spreader screws in good condition?		
	c)	Does extension form a continuation of main screed unit without steps?		
	d)	Are tamper bar and screed correctly set relative to each other?		

		YES	NO
	e) Do extensions to spreader screws attach tightly to main section?		
xvi)	Are screed heater burners working properly?		
xvii)	Does screed control at working platform work correctly?		
xviii)	Attachments:		
	a) Are side cut off plates free to move?		
	b) Is joint matcher securely attached to chassis?		
	c) Is joint matcher in good condition?		
	d) Is mounting for travelling straight edge securely attached to chassis?		
	e) Is travelling straight edge free to slide on it's mounting?		
	f) Is travelling straight edge correct length?		
	g) Are shoes on straight edge free to move?		
	h) Is tensioning winch in good condition?		
	i) Is sensor unit working?		
	j) Are tyre pressures and ballast correct?		

- Note pressure .... KPa, and ballast ....
- Specified ....

	YES	NO
k) Are solid tyres on small wheels clean and intact?		
l) Check for fuel, oil and hydraulic leaks. Is paver free of leaks?		
m) Is guide chain arm free to move in chassis?		

J) Chip Spreader

	YES	NO
i) Is spreader correct width? Width .... m		
ii) Do gates move freely when hopper is loaded?		
iii) Does charging hopper move easily across spreader when loaded and on an adverse camber?		
iv) Are agitator prongs in good condition?		
v) Are planks available to allow wheels to travel on hot mix?		
vi) Is 1m^2 test screed available?		
vii) Is 15 or 20 kg spring balance available?		
viii) Check for fuel and oil leaks. Is spreader free of leaks?		

K) Steel Wheel Rollers

	YES	NO
i) Are edges of rollers in good condition?		
ii) Is change of direction smooth (no backlash)?		

		YES	NO
iii)	Is roller properly ballasted? (Record mass and position) Mass .... t Position		
iv)	Do wheel spray bars give a uniform cover on wheels?		
v)	Are wheel clearing mats in good condition?		
vi)	Are scrapers in good condition and set?		
vii)	Check for oil, fuel and hydraulic leaks. Are rollers free of leaks?		
viii)	Do brakes work?		
ix)	Is reversing smooth?		

L) Pneumatic Rollers

		YES	NO
i)	Are tyres in good condition?		
ii)	a) Is there a variable pressure system for tyre pressure?		
	If so, is it working and is pressure gauge working and visible to driver?		
	b) Are all tyre pressures uniform? Note tyre pressures .... KPa		
iii)	Is roller properly ballasted? (Record mass and position) Mass .... t Position		

		YES	NO
iv)	Are spray bars working uniformly?		
v)	Are cleaning pads in good condition?		
vi)	Check for fuel, oil and hydraulic leaks. Is roller free of leaks?		

M) <u>Hand Tools, Etc</u>

		YES	NO
i)	Straight edge, is it clean and straight?		
ii)	Rakes and shovels, are they clean and in good condition?		
iii)	Are thermometers available? No. .... Size		

H) <u>Transport Vehicles</u>

		YES	NO
i)	Are the basins clean?		
ii)	Do tailgates open and close properly?		
iii)	Are load covers fitted?		
iv)	Are vehicles free from fuel, oil and hydraulic leaks?		
v)	Does tipping gear work?		
vi)	Registration numbers of vehicles.		