BEST PRACTICE GUIDELINE & SPECIFICATION FOR WARM MIX ASPHALT

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DISCLAIMER

PREFACE

This document presents best practice guidelines for the production and construction of Warm Mix Asphalt (WMA) for roads and airfields. WMA, which has environmental, health, economic and engineering benefits, is already being used extensively in the USA, some European countries and China and its use seems set to expand substantially within the next five years.

The main purpose of these guidelines, which utilize knowledge and experience gained from extensive local trials as well as from that gleaned from other countries, is to ensure that WMA is used correctly in South Africa.
Accompanying these best practice guidelines is a stand-alone specification, its purpose being to assist practitioners to implement the production and paving of WMA in South Africa. As with other newly introduced technologies, the specification is bound to require amendment, as practical experience is gained in the manufacture and laying of Warm Mix Asphalt, and should be regarded as interim.

GLOSSARY OF TERMS

ASTM	The latest test method published by the American Society for Testing and Materials
Base bitumen	Penetration grade bitumen of various grades conforming to SANS 307
BS	The latest test method published by the British Standard Institute
COLTO	Committee of Land Transport Officials: Standard Specifications for Road and Bridge Works for State Road Authorities
DIN	The latest test method published by the Deutsches Institut für Normung
Elastomer	A thermoplastic polymer which produces mainly elastic properties at in-service temperatures
Ethylene Vinyl Acetate (EVA)	An ethylene and vinyl acetate co-polymer
G H G	Green house gases
Hot mix asphalt (HMA)	Mixtures of aggregate, bituminous binder and mineral filler produced at an elevated temperature in an asphalt plant
Plastomer	A thermoplastic polymer where the elastic deformation is accompanied by a component of permanent deformation
R A	Reclaimed asphalt
Sabita	South African bitumen Association
SANS	South African National Standard
TG	Technical Guidelines: Asphalt Academy
TMH	Technical Methods for Highways: CSRA

TRH	Technical Recommendations for Highways: Committee of Land Transport Officials
WMA additive	A substance that is blended into the bituminous binder, or introduced into the asphalt plant’s drum or pug mill, that assists in the process of manufacturing and paving asphalt at significantly reduced temperatures
WMA Technologies	Technologies that may include WMA additives as well as other techniques and processes that enable asphalt to be produced at significantly reduced temperatures
Warm Mix Asphalt (WMA)	Mixtures of aggregate, bituminous binder and mineral filler, where a WMA Technology is employed to enable the mix to be manufactured and paved at a significantly lower temperature than HMA, with its quality and performance being equal to or even exceeding that of HMA

1. INTRODUCTION

The purpose of this guideline is to impart best practice in the design, manufacture and placement of Warm Mix Asphalt (WMA), based on local experience, as well as that gained from other countries where this process is used.

This should be regarded as an interim guideline as the WMA process is still under development, with the introduction of further innovations to further enhance its benefits.

It should also be noted that the know-how available at the time of compiling this document was based on continuously graded asphalt mix types, and care should be exercised in extending these guidelines to other mix types. As experience is gained with other mix types it is intended to update and revise these guidelines.

WARM MIX ASPHALT DEFINED

Warm Mix Asphalt is the manufacturing and paving of asphalt mixes at significantly lower temperatures than Hot Mixed Asphalt (HMA), while maintaining or even exceeding the quality of equivalent conventional HMA mixes.

WMA can be conveniently classified by the degree of temperature reduction compared to that of conventional HMA. This is illustrated in Figure 1, which shows the typical ranges in mix temperature, from cold mixes to conventional hot mix asphalt (HMA). It also shows how the consumption of fuel increases in order to produce mixes at higher temperatures.

If the production temperature is less than 100^{o}C (212^{o}F) it is considered as a “half-warm” mix. Generally WMA is regarded to have production temperatures at least 20^{o}C below those of HMA, and above 100^{o}C. While HMA is generally manufactured at temperatures between 140^{o}C and 160^{o}C, WMA is typically produced at temperatures between 100^{o}C and 140^{o}C.

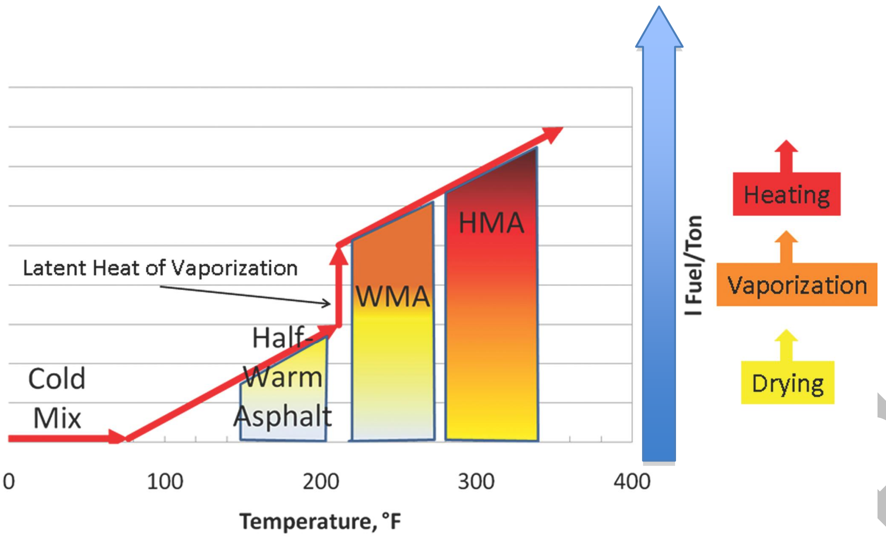


Figure 1 Typical temperature ranges for mixes, from cold mixes to conventional HMA

This guideline concentrates on WMA and does not cover "half-warm" mixes.

CURRENT WORLDWIDE STATUS AND FUTURE TRENDS

The international road construction industry is rapidly adopting the idea of manufacturing and paving asphalt at lower temperatures, among the main drivers being lower overall emissions, improved working environment, reduced energy consumption and engineering benefits. By the end of 2010 an estimated 50 million tons of WMA had been successfully manufactured and paved in the United States. NAPA reports that approximately 10% of asphalt supplied in the USA is WMA and that this proportion is likely to increase to 50% within the next five years. Large quantities are being paved in some countries in the European Union, notably in France, Holland and Germany, as well as the Far East; in China around 3.5 million tons of Warm Mix Asphalt has already been paved.

An idea of how quickly this process is advancing can be gauged by the fact that the very first Warm Mix Asphalt was paved in Germany around 1997.

SOUTH AFRICAN EXPERIENCE

Here in South Africa, a Society for Asphalt Technology (SAT) seminar on WMA was held in Pretoria on 9 July 2008 where it was proposed to form a task team to develop guidelines to conduct trial sections to assess the benefits of the various WMA technologies. Subsequently a meeting was held at the eThekwini Municipality in Durban on 5 September 2008, to plan the construction and evaluation of WMA trials sections.

The first WMA trial in RSA was undertaken on Brackenhill Road, Waterfall, a suburb approximately 30 km inland of Durban, during November 2008, and the second on Leicester Road, located in Durban's industrial area of Mobeni, in May and June 2009.

This work culminated in the completion of the third and most extensive Warm Mix Asphalt trial on Durban's Higginson Highway.

The Higginson Highway trials were carried out over a period of nine months during 2010. Preparation work commenced with the initial laboratory mix designs in April, full-scale plant mix trials in May, June and July, with the main trials on Higginson Highway being undertaken from 25 October to 8 December 2010.

These trials included assessments of mixes containing various proportions of recovered asphalt (RA), up to 40%, combined with the use of conventional and polymer modified binders.

A large amount of practical experience in WMA and the preparation and inclusion of RA in the mixes was gained during these trials.

There is a remarkable degree of synergy between Warm Mix Asphalt and asphalt recycling; WMA processes enhance the use of mixes containing reclaimed asphalt, leading to significant environmental and other cost-saving benefits. This guideline strives to marry WMA and asphalt recycling processes as a means of maximizing these benefits.

This Best Practice Guideline endeavours to assimilate useful practical experience and information gained in the local trials, as well as that from work on WMA from other countries. Information gained from a study tour of WMA Interest Group members to some European Union (EU) countries in 2010 has been utilized in this guideline, as has information gleaned from a comprehensive literature search and discussions with practitioners from other countries.

2. FREQUENTLY ASKED QUESTIONS

WMA has been described as the "darling of the asphalt industry, with its promises of lower emissions, energy savings, improved working conditions due to fewer fumes and lower temperatures at the mixing plant, as well as improved compactibility and an increased capacity to incorporate reclaimed asphalt (RA).

Nevertheless, especially as it is a fairly new technology, a number of questions are asked about WMA. This Best Practice Guideline endeavours to supply answers to these questions; information concerning typical frequently asked questions and the particular chapter in which the topic is covered is shown in Table 2.1.

Table 2.1 Frequently asked questions and relevant chapter

What are the benefits of WMA in terms of the environment, working conditions and costs?	Chapter 3
What technologies are used to reduce the asphalt temperature while still enabling a high level of compaction to be achieved?	Chapter 4
How are WMA Technologies classified?	Chapter 5
Are any additional or less stringent measures required regarding HSE when manufacturing and paving WMA?	Chapter 6
How should the various components that are used to make up the Warm Mix Asphalt handled?	Chapter 7
What quality assurance methods should be applied to the mix components?	Chapter 8
What process is used to approve the mix? What changes are there to the mix design procedures used for HMA?	Chapter 9
How is WMA manufactured; can both batch and continuous drum mixer type plants be used to produce WMA, what modifications are required? How is the plant adjusted to produce the lower temperature mixes?	Chapter 10

What quality assurance measures should be implemented during the manufacture of WMA? Are aspects such as moisture susceptibility and rutting potential addressed?	Chapter 11
Are any special measures required during the transportation and paving of WMA?	Chapter 12
What quality assurance measures should be implement at the paving site?	Chapter 13
When new WMA Technologies become available, what procedure is used to introduce and approve them?	Chapter 14
What changes to the Specification are required?	Annex A

3. BENEFITS OF WARM MIX ASPHALT

Although in Europe the initial drive to use WMA was largely in response to the government policies to reduce green house gas emissions to meet the targets that they agreed to in terms of the Kyoto Protocol, the development of WMA technologies to meet these targets and for other engineering reasons has highlighted further benefits and advantages of WMA technologies over HMA. The main benefits/advantages of using WMA over HMA are discussed below.

Environmental Benefits

Reduced consumption of non renewable fossil fuels and greenhouse gas emissions

The lower mixing temperatures required to manufacture WMA consumes less energy for heating during asphalt production. The reduced consumption of burner fuel conserves non-renewable fossil fuels and reduces greenhouse gas emissions.

Investigations carried out in several countries show significant reductions in emissions of carbon dioxide (CO_2) and nitrous oxide (NO_x), while the emissions of sulphur dioxide (SO_2) and VOC's (volatile organic compounds) varied above and below those of HMA.

Reuse of by-products which would otherwise require disposal

Although most of WMA additives are produced specially for WMA production, some such as Fischer-Tropsch waxes are produced as a by-product of the Fischer-Tropsch process and if not used may become a waste material. Using these products therefore has a direct environmental benefit of reducing waste materials and also pollution from the production of other WMA specific additives.

Increased potential for recycling Recovered Asphalt

The increased potential for recycling RA in WMA over HMA is discussed below as an economic benefit but is listed here also as an environmental benefit as the recycling of RA reduces the volume of waste material that would otherwise have to be disposed of; it extracts the highest value from the RA and reduces the quantity of new (non-renewable resources) aggregate and bitumen required for new asphalt layers.

Health Benefits

Improved conditions for workers and neighbouring communities

The reduced fuel burned at the mixing plant and the lower mix temperatures during production and paving reduce emissions of aerosols, fumes and dust, both at the mixing plant and the paving site, and improve conditions for both the workers and the neighbouring communities.

Investigations into emissions at paving sites in the USA found that where temperatures were reduced by 29°C to 43°C, the average reduction in total particulate matter (TPM) was between 67% and 77%, while the asphalt fumes, measured as benzene-soluble matter (BSM), was reduced by between 72% and 81%, compared to the HMA control.

General worker safety is improved as a direct result of lower asphalt temperatures that reduces the risk of heat related injuries.

At the paving site, a reduction in mix temperature of 30°C in South Africa's hot summer months is very noticeable and welcomed along with the reduced odours produced by the mix.

Siting plants closer to the work

Suitable sites for asphalt plants close to urban road networks, such as those found in major towns and cities are often difficult to find, due to plant emission requirements. Plants have to be situated far from these areas, making for long haulage distances. The lower emissions that can be expected from WMA means that asphalt plants can be located closer to the urban job sites, thus reducing haulage distance. Also the decrease in emissions represents a significant cost saving, considering that 30% to 40% of overhead costs at the asphalt plant can be attributed to emission control. Also, with the vehicles transporting the mix over shorter distances, their fuel consumption and emissions are reduced, further contributing to the savings.

Engineering and Economic Benefits

The engineering and economic benefits of using WMA derive mainly from three aspects.

1. All WMA technologies have to provide better asphalt mix workability than HMA to achieve the required compaction at lower temperatures.

2. WMA's lower mixing and compaction temperatures, compared to HMA, result in flatter thermal gradients between the mix and both ambient and road temperatures. WMA therefore takes longer to cool from mixing to compaction temperature than HMA, thus providing a longer "compaction window" with many engineering advantages over HMA.

3. WMA's lower mixing temperatures result in comparatively less binder aging during mixing and paving than HMA.

The benefits that derive from these are discussed below.

Compaction aid

The improved workability provided by WMA technologies improves mix cohesion and act as a compaction aid where stiff mixes would be otherwise difficult to compact.

Improved workability for hand work

WMA technologies improve mix cohesion and compactability that is beneficial where hand work is required such as at intersections, widenings, around manholes or for patching.

Paving in cold weather

Climatic conditions in South Africa do not pose the same cold weather paving limitations as countries at higher latitude, nevertheless there are times when low winter temperatures hamper paving operations.

Due to the lower mix and paving temperatures, WMA's slower rate of cooling and longer "compaction window" provide significant advantages over HMA when transporting and paving asphalt in cold weather.

In regions of the country that experience very cold winters, the paving season can be extended using WMA.

Paving at night

The lower WMA compaction temperatures and rate of cooling increase the opportunities for undertaking night work when ambient and road temperatures are lower than during the day and provides great advantages especially for busier roads where traffic can be economically accommodated on fewer lanes only at night when traffic volumes are significantly lower.

Increased haulage time/distance

The slower rate of cooling and longer compaction window allows WMA to be hauled for longer than HMA. This provides the advantage of hauling longer distances, or where in the urban settings traffic congestion is expected, extended haulage times.

In more extreme situations further advantage can be taken by manufacturing mix using WMA technologies but at HMA temperatures to enable substantially longer haulage distances or times.

> NOTE: In order to extend haulage distance, the manufacturing temperature of the WMA mix should be increased to that of a similar HMA mix.

Reduced burner fuel consumption

Lower plant mixing temperatures should result in reduced fuel consumption, the extent of which depends on many factors, some of which include:

- The temperature of the WMA in relation to HMA,
- The moisture content of the aggregates and RA (fuel usage is reported to increase by around 10% for every 1% increase in moisture content)
- The efficiency of the mixing plant's burner, exhaust and emission systems
- Rapid changes between the production of WMA and HMA that required the plant to stabilise at the different operating temperatures

NAPA reports an average 23% fuel saving, with results ranging from 15.4% to 77% reduction in fuel usage.

The WMA trials in South Africa were too short and interspersed with the production of conventional hot mix to measure fuel consumption figures accurately enough to draw conclusions. Nevertheless it can be concluded that there were indeed fuel savings as the plants' burners were turned down in order to produce the mix at the required lower temperatures.

Reduced binder aging

The reduced temperatures of WMA are expected to reduce binder aging during production and paving and result in improved flexibility and resistance to fatigue and thermal cracking in the asphalt layers. It is speculated that this will improve pavement performance and increase the period between maintenance interventions; thus saving money by reducing lifecycle costs and using less non-renewable resources. The extent of the reduced lifecycle costs will have to be verified by long-term pavement performance measurement. Ingredients of some WMA additives have an additional anti aging effect.

Synergy between WMA and asphalt recycling processes

The softer binder resulting from the lower temperatures used in the manufacture of WMA may assist in rejuvenating the aged binder in the RA, thereby improving the mix's fatigue properties. The WMA technology will also improve the compactibility of stiffer mixes that may result from the incorporation of high proportions of RA.

WMA mixes containing up to 40% RA, using both penetration grade bitumen and A-P1 as well as A-E2 binders have been successfully produced and paved in trials in South Africa, while higher percentages of RA, even up to 90% and 100%, with the addition of rejuvenating oil compounds, have been achieved in Germany with manufacturing and paving being carried out at conventional HMA temperatures.

Siting plants closer to the work

Suitable sites for asphalt plants close to urban road networks, such as those found in major towns and cities are often difficult to find, due to plant emission requirements. Plants have to be situated far from these areas, making for long haulage distances. The lower emissions that can be expected from WMA means that asphalt plants can be located closer to the urban jobsites, thus reducing haulage distance. Also the decrease in emissions represents a significant cost saving, considering that 30% to 40% of overhead costs at the asphalt plant can be attributed to emission control. Also, with the vehicles transporting the mix over shorter distances, their fuel consumption and emissions are reduced, further contributing to the savings.

4. OVERVIEW OF WMA TECHNOLOGIES

Several ways to produce WMA have been developed and are briefly discussed below; a more detailed description as well as the application of these technologies is covered in later in this document. The number of WMA technologies is, however, likely to increase as WMA becomes the generally acceptable method of producing pre-mixed asphalt and other technologies will no doubt be introduced.

It should be noted that while an "additive" may be used to reduce the asphalt's temperature, the term "WMA Technology" is used to embrace the full scope of a particular temperature-reducing process.

The aim of WMA Technologies is essentially to enable proper aggregate coating and mix workability at lower temperatures by lowering the viscosity of the binder, (or through another mechanism, for example reduction of surface tension), but there are often other spinoffs, such as improvements to adhesion, resistance to rutting as well as the mix's stiffness and fatigue properties.

Technology suppliers should be expected to make available official blending & handling guidelines concerning the correct and safe usage of their technologies.

WMA technologies may be incorporated as ready-to-use binders or may be added during the mixing process. Two essential quality aspects apply to the ready-to-mix binders; homogeneity and storage stability. In the case of WMA technologies that are added to the binder, homogeneity is most important to ensure consistent quality.

Warm Mix Asphalt Technologies may be conveniently divided into the following broad categories:

- *Water technologies*

In broad terms, three WMA Technologies fall into this category:

- Binder foaming systems where water is injected into the hot binder, causing it to expand significantly into a foam, thereby reducing its viscosity and enhancing its ability to coat aggregate at lower temperatures.
- Water carrying chemical additives, which introduce moisture into the mix, causing it to vaporize and create a foam.
- Systems where moist fines are introduced to the heated coarse aggregate and binder, causing the moisture to vaporize, forming a foam.

- *Chemical additives*

These technologies are based on additives that have little effect on the binder's rheological properties and act mainly by reducing the internal friction of the mix, enabling it to be compacted at the lower temperatures.

- *Rheological modifiers*

This broad category includes products that modify the rheological properties of the binder, reducing its viscosity at mixing and paving temperatures thereby improving aggregate coating and compaction. At road temperatures the binder stiffens, improving resistance to rutting.

5. CLASSIFICATION OF WARM MIX TECHNOLOGIES

This chapter covers currently used Warm Mix Asphalt Technologies in more detail, classifying them into the three main categories mentioned above. It also introduces a sub-class of rheological modifiers termed “polymer-rheological modified hybrids”.

WATER TECHNOLOGIES

In essence, the “water technologies” use water vapour to expand the volume of binder in the mix by causing it to foam. This has the effect of reducing the binder’s viscosity, enabling it to coat aggregate at lower temperatures.

Foamed bitumen has a wide range of applications in the road building industry, and includes its use in “cold” mixes, produced at ambient temperatures, as well as in “half-warm” mixes, which are typically manufactured at less elevated temperatures, between approximately 70^{o}C to 100^{o}C.

The moisture is introduced into the mix in three different ways:

<u>Mechanical binder foam systems</u>
Several mechanical foam systems have been developed, based on the principle of hot bitumen being fed into a chamber or vessel where a relatively small quantity of water (normally between 1% and 3% of the binder mass) is introduced under pressure. The water vaporizes on contact with the hot bitumen causing it to expand many times its original volume into a foam. The foam is discharged directly into the mixing drum or pugmill where it mixes together with the heated aggregate.
The quality of the foam can be described using two parameters; expansion ratio and half-life. Expansion ratio is defined as the ratio between the original volume of the binder and its maximum volume when foamed. The half-life of foamed bitumen is defined as the period (the number of seconds) that the foam takes to settle or break down to half its maximum volume.
The aim is to produce foam with sufficient expansion ratio and half-life to allow satisfactory mixing to be carried out. The properties of foamed bitumen depend upon factors that include:

- Binder properties
- Binder temperature
- System design

Examples of mechanical binder foam manufacturers: Astec “Double Barrel Green”, Gencor, “Ultrafoam GX”, Maxam “Aquablack, Meeker “Aquafoam”, Stansteel “Accu Shear”, Terex/CMI, Shell WAM Foam

<u>Water carrying chemical additives</u>
Natural and synthetic zeolites are mineral additives used to introduce water into the mix thereby reducing binder viscosity. Zeolites are framework silicates with a porous structure that can accommodate and release foreign molecules retaining their own shape and size. Zeolites have ability to lose and absorb water without changing their crystal structure.

Natural zeolites have 6% to 12% of their mass entrapped as water in their crystalline structure and synthetic zeolite up to 25%. This corresponds to 1.5 litres of water of crystallization per ton of asphalt.

Zeolites are added to the mix with the filler during mixing. As the mixing temperature increases the zeolites slowly release their absorbed water into the bitumen, which is dispersed throughout the mixture in the form of very fine droplets. This leads to a marked reduction in the workable viscosity of the bitumen. Asphalt can be paved a lower temperatures. As the asphalt and binder cools, the fine mist condenses. The binder regains its original viscosity and the asphalt mix regains its original properties.

The zeolite releases water as its temperature is increased, expanding the volume of the binder in the form of foam. This allows increased workability and aggregate coating at lower temperatures.

Zeolites are supplied as white (synthetic) or yellowish (natural) coloured powders and can be added in the same way as fillers. They are introduced directly into the mixer with the filler or just after the filler is added, but before the introduction of the binder.

In asphalt mix designs the amount of zeolite added needs to be accounted for as filler. The feed system meters the zeolites from a silo into the plant. Small quantities can be added manually. The required quantity is packaged in paper bags and is then added to the mixer.
Examples of water carrying chemical additives: Aspha-min, Advera WMA.

Moist fine aggregate addition systems

Generally in this process the bitumen is added to the heated coarse aggregate in the mixer. Once the coarse aggregate has been well coated, fine aggregate at ambient temperature with a moisture content of around 3% is introduced. The moisture vaporizes, causing the binder coating the coarse aggregate to foam, which in turn encapsulates the fine aggregate. This technology has been mainly used to produce “half-warm” mixes but can be adapted to manufacture WMA.

Example of this system: LEA, EBE, EBT

CHEMICAL ADDITIVES

These WMA technologies utilize chemical additives that have little effect on binder rheological properties. The products may be supplied in pellet, powder or liquid form, and then mixed into the binder or added direct to the mixer. They work by a surfactant effect that enhances the spreading of the binder film over the aggregate by reducing surface tension, resulting in a lubricating effect on the mix even at lower temperatures. Some of the surfactants used also have an adhesion promoting effect and products can contain additives that have a binder stiffening effect at service temperatures. Other technologies falling into this class are formulated as high residual bitumen content emulsions that contain agents to improve aggregate coating and workability, as well as adhesion promoters. As they are in the form of emulsions these technologies can be stored at much lower temperatures than other binders used in the production as asphalt, at around 80^{o}C. The water in the emulsion vaporizes when it is mixed with the heated aggregate, forming a foamed binder with a significantly increased volume. This enhances aggregate coating at lower temperatures in a similar way to the “water technologies” while the additives modify other mix properties.

Examples of chemical additives: Rediset WMX, Rediset LQ1, Evotherm ET, Evotherm DAT, Evotherm 3G, Cecabase RT, HyperTherm.

RHEOLOGICAL MODIFIERS

These products can be described as viscosity modifying organic additives that reduce binder viscosity at high temperatures and thus allow lower mixing and paving temperatures. At binder temperatures below the additive’s congealing point this reduced viscosity is offset again or the effect is even reversed – the binder regains its original stiffness or even stiffens compared to a comparable conventional bitumen. This means that the binder now contributes more to deformation resistance of the asphalt.

<u>F-T WAXES</u>

Fischer-Tropsch waxes consist of long chain aliphatic hydrocarbons that are produced from syngas under a high-pressure catalytic process. F-T wax molecules have longer chain lengths than paraffins that are naturally found in mineral oil; this explains their different physical properties and the fact that they should not be compared with naturally occurring bituminous waxes. The longer chain length in the F-T wax leads to a higher melting point while the smaller crystalline structure of F-T wax reduces brittleness at low temperatures compared to bitumen paraffin waxes. F-T waxes have been described as "asphalt flow improvers", both during the asphalt manufacturing process as well as during paving operations.

F-T waxes are completely soluble in bitumen at temperatures greater than 115°C. They form homogenous solutions with base bitumen on stirring (high shear mixing is not necessary), and produce a marked reduction in the bitumen's viscosity during its liquid state. Upon cooling the F-T waxes crystallize in the bitumen, increasing asphalt stability and deformation resistance.

<u>FATTY ACID AMIDES</u>

Fatty acid amides are synthesized waxes that consist of a central amide group and two aliphatic hydrocarbon chains. Fatty acid amides are completely soluble in bitumen at temperatures above 140°C. When stirred they mix to form a homogeneous solution with the base bitumen and produce a marked reduction in the bitumen's viscosity during it's liquid state. During cooling the fatty acid amides crystallize thus increasing asphalt's stability and rut resistance.

<u>MONTAN WAXES</u>

Montan waxes and their derivatives are obtained during lignite processing and consist of esters, alcohols acids and high molecular hydrocarbons with a melting range of 70°C to 80°C. The derivatives have melting ranges of 100 to 140°C. Their properties cannot therefore be compared with those of naturally occurring bituminous waxes. Montan waxes are completely soluble in bitumen above their melting range. When stirred they mix to form a homogeneous solution with the base bitumen and produce a marked reduction in the bitumen's viscosity during its liquid state. During cooling the Montan waxes crystallize in the bitumen thus increasing the asphalt's stability and resistance to rutting.

Rheological modifiers are either ready-mixed or added at the mixing plant. Ready-mixed blends are produced by stirring the product into the heated bitumen. The blended product can be handled in the same way as penetration grade bitumen but must have adequate storage stability properties. It is possible to store the ready-mixed blends at lower temperatures, to match their lower viscosities. Good storage tank management is vital.

F-T waxes and fatty acid amides can be added into the mixing chamber of a pugmill type plant but this is not generally recommended. The product must be in a liquid state to ensure homogeneous distribution in the mix and the mixing time should be extended. Two methods of in-line blending into the bitumen delivery system is possible, using a <u>melting system or injector</u> to introduce the solids into the bitumen stream.

In the melting system the molten additives are fed directly into the binder weigh bucket. The hot bitumen and liquid wax are blended and then pumped into the weigh hopper at the asphalt mixing plant, thus creating a viscosity modified binder.

The injector system utilizes a tapered section in the binder delivery pipe, through which the bitumen to be modified is pumped. The pressure upstream of the tapered section is reduced, and enables solid and liquid additives to be drawn into the binder stream, thus allowing homogeneous distribution. As the binder temperature is higher than the melting point the additives melt and dissolve in the liquid phase of the binder. The system bypasses the conventional binder feed to the scale. The admixture is added to the mix by volume, which is based on the delivery rate of the binder and the additive. Addition rates may vary from 1% to 2% by mass of binder.

Examples of rheological modifiers: Sasobit ®, Thiopave, Sonne Warmix. Asphaltan-B

POLYMER- RHEOLOGY MODIFIED HYBRIDS

A special sub-class of rheology modifier exists where the principle of co-modified technologies is being used. Such technologies typically employ the combination of an elastomer and a plastomer; some are enhanced with a chemical crosslinking agent to facilitate a more homogenous modified binder with improved elastic recovery characteristics.

These modifiers differ from the others in this class in that they typically increase the viscosity of the binder in the liquid state when compared to virgin bitumen. They do however produce a lower liquid state viscosity when compared to traditional polymer modified bitumen. This is where the benefit of these modifiers is when one is looking to use a lower temperature process while working with polymer modified asphalt. The viscosity of the bitumen is increased upon cooling of the asphalt after construction and therefore increased asphalt stability and rut resistance are delivered.

These modifiers are typically added by way of a solid material hopper feeding system and require intense mixing due to the polymer component(s) and although a high shear mixer is not a must, it is advantageous to quickly produce a homogenously modified binder.

Examples of this sub-class of rheological modifiers: Sasolwax Flex™, Rediset WMX combined with EVA

6. CONSIDERATIONS REGARDING HEALTH, SAFETY & THE ENVIRONMENT

Although Warm Mix Asphalt is manufactured and paved at temperatures that are significantly lower than those of Hot Mix Asphalt, the same HSE standards are applicable to both WMA and HMA.

Safety aspects with regard to binders is covered in Sabita Manual 8: *Safe and responsible handling of bituminous products.*

Procedures for the transportation of bituminous binders is specified in SANS 10228:2006, while safety procedures during the loading and offloading of these products is covered in Sabita Manual 25: *Quality management in the handling and transport of bituminous binders.*

Further safety related information is available in Sabita's Video Series.

The manufacturing of Warm Mix Asphalt involves the addition of some sort of WMA Technology. As already explained in Chapter 5, this is achieved in various ways, either by introducing the technology directly into the mixing drum or pugmill, or by blending it into the bituminous binder. In both cases due cognisance should be taken of safety as part of this operation.

As a result of reduced mixing and paving temperatures the resultant reduction in fumes improves the work environment at both the mixing plant and the paving site.

7. HANDLING OF MIX COMPONENTS

This section covers the handling of all the materials that are normally used in the manufacture of WMA, which include:

- Aggregates
- Filler
- Reclaimed asphalt (RA)
- Binders
- WMA technologies
- Binder modifiers
- Anti-stripping agents

NEW AGGREGATES

In South Africa most of the aggregates used in asphalt consist of crushed stone, although some use is made of natural sand. The procedure for handling, stockpiling and testing of aggregates described in Sabita Manual 5: “*Guidelines for the manufacture and construction of hot mixed asphalt”,* should be followed.
The adverse effect that high moisture contents have on production rates, fuel consumption and emission control costs is covered below under “Reclaiming, preparing and stockpiling RA”, but applies in the same way to the new aggregates used in the mix. The moisture contents of the finer aggregate fractions in particular tend to be high, as they soak up rainwater or arrive saturated from the quarry’s washing process.
It is recommended as best practice to keep the fine aggregate stockpiles under shelter.

FILLERS AS ADHESION PROMOTERS AND ALTERNATIVES

The addition of active fillers, notably hydrated lime, is normally required in “warm” mixes. Typically 1% lime is added to enhance the binder adhesion and resistance to moisture of the mix. Requirement for active fillers are covered in Sabita Manual 5: “*Guidelines for the manufacture and construction of hot mixed asphalt”.* Consideration should also be given to the use of amine-type adhesion promoters (AP’s) as an alternative to hydrated lime. Due to the reduced aggregate drying temperatures there may be residual moisture content in the aggregate during mixing and active amine adhesion promoters can overcome this problem. Note that certain WMA additives contain active AP’s in the formulation.

RECLAIMED ASPHALT (RA)

As mentioned in the Introduction, there is a close match between the asphalt recycling and WMA; a key element in combining these two processes is the reclaiming, handling and storage of the RA. This topic is therefore covered in detail.

Milling RA

Most RA in South Africa is obtained through the use of milling machines rather than by breaking out the asphalt in existing layers in the pavement using excavators or bulldozers and then transporting this material to the crushing plant. An exception to the usual milling method would be the reuse of discarded or surplus asphalt that has been stockpiled at the asphalt mixing plant site.

The main advantages of using milling machines in comparison to the ripping and crushing operation are that they:

- Fragment the asphalt to achieve a fairly uniform grading
- Are able to remove the asphalt without disturbing the edges or underlying materials in the pavement
- Are able to remove the asphalt precisely to the prescribed thickness. This enables selective milling to be carried out where this is found desirable during the design stage, such as when more than one type of asphalt is found in the pavement
- Greatly reduce the risk of contaminating the RA with material from the underlying layer works
- Ability to remove asphalt in separate layers to preserve individual layer material qualities

As RA is generally processed by crushing and screening before it is used in the recycled asphalt mix, there are no special restrictions on the milling process itself, such as milling speed, or milling drum and cutting tool configuration. Practical limitations regarding the milling process should however be taken into account, such as the likelihood of contaminating the RA with the underlying granular base when attempting to mill off asphalt surfacing with a thickness of less than 30 mm. An end-product specification, limiting the maximum size of the milled material to 37.5 mm, is advisable.

It has been found that problems can be anticipated when bitumen rubber “SAM” or “SAMI” layers are milled together with the asphalt layer rather than being selectively milled off and discarded. The bitumen rubber seal tends to remain in large, resilient fragments that hinder the crushing and screening processes. Selective milling is therefore recommended when this material is encountered.

Stockpiling RA

<u>Moisture in RA</u>

An important issue concerning the asphalt recycling process is to limit and if possible reduce the moisture content of the RA before it is recycled. High moisture contents in the RA will result in a decrease in the rate of production and an increase in fuel energy costs, while the increased emissions and steam will tax the mixing plant’s emission control systems. A one-percentage change in moisture content typically results in a ten percent change in the fuel consumption required to heat the RA.

High moisture contents in RA could also result in high moisture being present in the final recycled asphalt mix, which may lead to adhesion problems. Inconsistent moisture contents, that typically result when RA is being loaded from a stockpile that has been partially soaked by a rain shower, tend to cause significant fluctuations in mix temperature. The aim should be for the RA to have a consistent moisture content, not exceeding 4.0%.

Stockpiling techniques

It should be remembered that RA tends to retain moisture to a greater extent than aggregate and the following factors should be considered when stockpiling RA:

- The stockpile areas should be sloped (six degree slopes are ideal) so that they drain freely and ponding does not take place.

- The base of the stockpile area should be hardened so that water does not soak into the material under the stockpile. The hardening of the base will also reduce the chance of groundwater contamination and reduce loss of RA through contamination with the underlying soil.

- Wherever possible RA should be stockpiled in large conical stockpiles with steep sides. A crust will form on the surface of the stockpile, which will tend to shed water and help reduce consolidation of the rest of the stockpile.

- Keep machines off stockpiles to avoid compaction of the RA.

- Covering RA stockpiles with tarpaulins or plastic sheets tends to cause condensation, which increases its moisture content, and should be avoided. An exception to this is when rain is imminent and the stockpiles can be temporarily covered to prevent the material getting wet. However, as soon as the rain has passed, the stockpiles should be uncovered again to reduce the effect of condensation moistening the RA.

- The best method is to stockpile RA in an open sided shed, which will allow moisture to escape while protecting the material from rain.

Processing RA prior to recycling: crushing, screening and fractionating RA

The processing of RA includes crushing, screening, and placing it in separate stockpiles. The aim is to produce a free-flowing material of uniform quality with a defined range of particle sizes in each stockpile. A general rule is that the need to implement these processes becomes increasingly important as the RA content of the recycled mixes is increased. Key factors governing the production of good quality recycled asphalt mixes include consistency and knowing the properties of the stone and bitumen in the RA.

It is generally desirable to fractionate all RA destined for use in recycled asphalt mixes to enhance the level of control at the mixing plant.
When mixes are produced with RA contents above 12%, it becomes necessary to crush and screen the RA into separate fractions to ensure a consistent product that will not impair the quality of the asphalt mix.

Typical RA fractions that would enhance the control of the grading, bitumen content and volumetric properties of recycled mixes consist of a coarse fraction – 16 mm + 8 mm and a fine fraction where the RA passes 8 mm.

As noted previously, the bitumen content of the RA in these fractions varies considerably, with high bitumen contents (typically around 6%) in the minus 8 mm fraction and much lower (approximately 4% bitumen) in the – 16 mm + 8 mm fraction.

The properties of the binder contained in the RA have to be taken into account at mix design stage and the consistency of the recovery binder properties should be checked regularly, particularly if the RA content of the mix exceeds 15%.

Details concerning the scope and frequency of testing are given under "Quality control of mix components". The sampling and testing plan should be coordinated with the stockpiling system discussed below.

Another factor that should be borne in mind when processing and stockpiling RA is that material from each specific site should be stockpiled separately, as its characteristics are likely to be similar. Large quantities of RA from different sources should be kept in other separate stockpiles for the same reason.

The RA should be handled in three distinct stockpiling phases:

- The unprocessed RA is delivered from site and placed in stockpile
- Once the RA has been processed by crushing and screening it is placed in a separate stockpile
- The moisture content, grading, binder content and binder properties of the processed RA in the stockpile is determined and the stockpile is marked as being approved for use in the recycled asphalt mix

BINDERS

Recommendations for the storage of bituminous binders, as well as sampling and testing, are covered in Sabita Manual 5: "*Guidelines for the manufacture and construction of hot mixed asphalt".*

The most commonly used grade of bitumen used in "warm" mixes containing up to 10% RA is 60/70pen. Once higher percentages of RA are used it may be necessary to use a softer grade of bitumen, and 80/100pen or even 150/200pen bitumen may be required to achieve the required mix properties. If 150/200pen binders are not available, 80/100pen binder can be treated with a rejuvenating agent. Well-documented experience had already been gained with such a product, where it was successfully used in two of the national WMA trials. It adds value by allowing the use of high percentages of low recovered penetration binder RA without the need for soft grade bitumen (for example 150/200 pen bitumen). It further allows reduced temperature asphalt manufacturing within the traditional WMA regime, delivers improved workability and compaction as well as a degree of increased deformation resistance. An example of such a rejuvenator would be a waxed based high RA rejuvenator.

In cases where mixes with high RA contents are contemplated, the use of specialized recycling modifying agents should be considered.

The selection of the most appropriate binder for recycled mixes will depend not only on the RA content, but also on the recovered binder properties of the RA. This subject is covered in more detail in this document under Mix Design.

Besides penetration grade bitumen, WMA may be manufactured using polymer modified binders that have the potential of enhancing mix properties such as rut resistance and fatigue. These products are covered in Asphalt Academy's TG 1 *"The use of modified bituminous binders in road construction, 2nd Edition".* Satisfactory experience has been gained in the use of WMA technologies that incorporate modified binders conforming to classes A-P1 and A-E2.

WMA TECHNOLOGIES

As already discussed under Classification of WMA Technologies, a wide range of techniques exist which enable asphalt to be successfully manufactured and paved at much reduced temperatures. The ways in which the various technologies are handled at the asphalt mixing plant are discussed in this section. Technology suppliers should be expected to make available their blending and handling guidelines concerning the correct and safe usage of their technologies [see below].

Mechanical binder foam systems

The foam systems require mechanical modifications and additions to the asphalt plant. Very basically this entails the installation of a foam generator that enables water to be introduced into the hot bitumen in the delivery line. With some designs the foam generator is positioned at, or close to, the discharge point in the delivery line, while in others the foam is generated some distance away and is piped into the mixer. A metering pumping system, coupled to the asphalt plant's control system, supplies a predetermined quantity of water to the generator. The water vaporizes as it comes into contact with the hot binder in the generator, causing the binder to expand as foam. Some systems have a sampling point where the foam can be discharged and its quality assessed. Several suppliers offer foam systems.

A general requirement of foam systems where either penetration grade or polymer modified bitumen is used is that the binder temperature should be at least 160^{o}C in order to produce foam of satisfactory quality. However, the determination of a more precise binder temperature range, which is dependent upon the particular binder to be used, is covered under Mix Design. As a rule of thumb the optimum binder temperature for foam production increases with increased binder viscosities, for instance a significantly high binder temperature is required for polymer modified binder compared to say 80/100 pen bitumen.

Water carrying chemical additives

Synthetic or natural Zeolites are supplied in white (synthetic) of yellowish (natural) powdered form, with 100% passing the 0.5 mm sieve. They are introduced directly into the mixer similarly to fillers before the required quantity of binder is added.
In asphalt mix designs the amount of zeolite added needs to be accounted for as filler. The feed system meters the zeolites from a silo into the plant. In the case of batch mixing plants small quantities can be added manually; the required amount comes in paper bags and is then added to the mixer. Zeolites are introduced with, or after, the filler is added. The mix has to be stirred at least 5 seconds before adding the binder. Zeolites must be kept in a dry, weather-proof storage area.

Moist fine aggregate addition systems

This system can be used on both batch and continuous type asphalt mixing plants. Fairly extensive modifications are required to batch plants where a separate conveyor or auger is used to transfer the moist fines into the pugmill. In a continuous drum mixer type plant the moist fine fraction can be introduced using the recycling collar.

Blending of powdered, pelletized or liquid WMA additives

The blending process may be carried out on-site by the asphalt supplier with the necessary equipment and storage facilities, or off-site by a company that specializes in blending bituminous binders.

The blending of WMA additives that are supplied in a powdered, prill, pellet or liquid form, is basically carried out by heating the bitumen to the required temperature before adding the quantity of additive necessary to achieve the prescribed dosage rate, the main goal being to obtain a homogeneous binder. The bitumen tanks should be equipped with mechanical stirrers as well as a pumping system to circulate the binder to ensure homogeneity.

Some solid particulate additives can be effective when added directly to the asphalt mixer and suppliers should be consulted on this option.

Information to be supplied by the WMA Technology supplier

The information that the WMA Technology supplier is required to provide depends upon the specific technology proposed. In the case of powdered, pelletized, or liquid WMA additives, the following information, obtained from the WMA Technology supplier, should be implemented before the binder blending is carried out:

- HSE documentation (MSDS) and safe handling procedures
- Bitumen temperature range at time of blending
- Additive dosage rate
- Blending temperature range
- Blending period
- Storage temperature range
- Maximum storage period at relevant storage temperature

The information to be provided by the WMA Technology supplier when foamed bitumen technologies are used should include:

- HSE documentation (MSDS) and safe handling procedures
- Bitumen temperature limits during storage as well as during mix manufacture
- Quantity of water per ton of mix used to produce the foam
- The pressure of water in the foam system

Blending of polymers

In some instances a polymer modifier may also be required, and this is blended into the binder at the same time as the WMA additive. Similar information on the particular polymer as that given above for WMA additives should be obtained and implemented.

Addition of anti-stripping agents

As with HMA some aggregates may necessitate the addition of anti-stripping agents in the binder, to improve the mix's moisture susceptibility. This aspect is dealt with during the laboratory mix design stage. Here again, the supplier of the anti-stripping agent should be requested to provide the information listed above with regard to their product, and this should be implemented during the blending stage.

8. QUALITY ASSURANCE OF MIX COMPONENTS

The extent and level of quality control of Warm Mix Asphalt is the same as that of HMA with regard to the sampling and testing of the mix components. However when the WMA mixes include reclaimed asphalt (RA), additional testing is required.

Quality systems for asphalt are covered in Section C of Sabita Manual 5 *"Guidelines for the manufacture and construction of hot mix asphalt"*, while in the case of recycled mixes, additional information on this subject is available in TRH 21:2009 *"Hot mix recycled asphalt".*

The most pertinent aspects of quality control directly related to the various components that are typically used in the manufacture of Warm Mix Asphalt mixes are covered in this section.

SAMPLING & TESTING OF AGGREGATES AND FILLERS

A full set of tests that are carried out on aggregates is presented in the table below. Most of these tests are incorporated in quality control plans, but some, such as Polished Stone Value, the Ethylene Glycol Test are normally carried out only as part of the initial laboratory mix design work.

One notable addition to the usual list of tests is moisture content testing; this test is of particular importance in the case of the fine aggregate fractions, but should also be routinely carried out on all the aggregate fractions used in the mix.

Sampling of the aggregate stockpiles should be undertaken in accordance with TMH 5: *"Sampling methods for road construction materials".*

Component	Test description	Test Method
Aggregate	Grading	SANS 3001-AG1
	Flakiness	SANS 3001-AG4
	Polished Stone Value	SANS 5848
	Sand Equivalent	TMH1 B19
	Water Absorption	TMH1 B14 & B15
	Bitumen Adhesion	TMH1 B11
	Bitumen Absorption	TMH1 C4
	ACV	TMH1 B1 (SANS 3001-AG10)
	10% FACT	TMH1 B2 (SANS 3001-AG10
	Clay lumps and friable particles	ASTM C142 – 97(2004)
	Ethylene Glycol	HMA (2001)
	Determination of moisture content by oven drying	SANS 3001-GR20
Inert and active fillers	Grading (% passing 75 µm)	SANS 3001-AG1
	Bulk density in toluene	BS 812
	Voids in compacted filler	BS 812
	Methylene Blue test	SANS 1243

Tests on aggregates used in WMA

<u>Notes</u>:
Tests given in brackets are with SABS awaiting publication as part of the 3001 series.
There may be equivalent tests listed generally under SANS (SABS).
The new SANS 3001 series supersedes equivalent TMH1 and other SANS methods.

A practical frequency for testing aggregates is to carry out the following tests on each fraction on a daily basis during the production of WMA:

- Grading
- Flakiness (coarse fractions)
- Sand Equivalent (fine fractions)
- Moisture Content

The other tests on aggregates should be carried out as part of the initial assessment of the material sources and as part of the laboratory mix design. Thereafter the frequency of these tests is very dependent upon their quality in relation to the required limits; if their quality falls well within specified limits, a lower frequency is required compared to instances where quality is more marginal.

The tests on the fillers are included in the laboratory mix design and are usually only repeated if the source or brand of filler changes.

SAMPLING AND TESTING OF RA

Some important aspects to ensure the uniformity and quality of RA are covered in this guideline under “Handling of mix components”, while further information on this topic can be found in TRH 21:2009 *“Hot mix recycled asphalt”.*

The various tests carried out on RA are included in the table below. It is usually accepted that the quality of the aggregate in the RA is sound in terms of its strength, shape, binder adhesion and absorption properties, and it is only in rare cases that these tests are required.

Tests on RA

Component	Test description	Test Method
Reclaimed asphalt (RA)	Grading	SANS 3001-AG1
	Flakiness	SANS 3001-AG4
	Bitumen Adhesion	TMH1 B11
	Bitumen Absorption	TMH1 C4
	ACV	TMH1 B1 (SANS 3001-AG10)
	10% FACT	TMH1 B2 (SANS 3001-AG10)
	Determination of moisture content by oven drying	SANS 3001-GR20
	Binder content	SANS3001-AS20
	Recovered binder properties:	DIN 1996
	- Penetration	ASTM D5
	- Ring & Ball Softening Point	ASTM D36

Notes:
Tests given in brackets are with SABS awaiting publication as part of the 3001 series.
There may be equivalent tests listed generally under SANS (SABS).
The new SANS 3001 series supersedes equivalent TMH1 and other SANS methods.

As mentioned under “Handling of mix components”, the properties of the binder contained in the RA have to be taken into account at mix design stage and the consistency of the recovered binder properties should be checked regularly, particularly if the RA content of the mix exceeds 12%.

Typically the moisture content, grading and binder content of each RA fraction should be checked prior to the start of the day’s mix production.

A lower testing frequency can be used for recovered binder testing, with R&B Softening Point and Penetration testing at intervals of 1000 tons of RA used, taking into account the need for additional testing when there are obvious changes in the source or quality of the RA. As mentioned under “Handling of mix components”, the sampling and testing plan should be coordinated with the stockpiling management system discussed under that item.

SAMPLING & TESTING OF BINDERS

SANS specifications require that sampling of bitumen be carried out in accordance with ASTM D140 and any additional requirements of TMH5 to determine whether a “lot” complies with the appropriate requirements of the specification.

Useful information on the sampling and testing of bituminous binders is contained in Sections A and C of Sabita Manual 5 *“Guidelines for the manufacture and construction of* *hot mix asphalt"*, while the procedures for sampling at various operational situations are comprehensively covered in Sabita Manual 25 (2005).

All modified binders should be sampled and tested in accordance with the procedures set out in TG1 Method MB-1: *Sampling of modified binders and MB-2: Sample preparation.*

Tests on Bituminous Binders

Binder Type	Property Tested	Test Standard
Penetration grade bitumen	Penetration	ASTM D5
	Softening Point	ASTM D36
	Dynamic Viscosity (at 60°C and 135°C)	ASTM D4402
	Rolling Thin Film Oven Test (RTFOT)	ASTM D2872
	n-Heptane/Xylene Spot test	AASHTO T102
Modified binders	Flash Point	ASTM D93
	Modified Rolling Thin Film Oven test	MB-3[1]
	Elastic recovery of polymer modified binders by ductilometer	MB-4
	Torsional recovery of polymer modified binders	MB-5
	Storage stability of polymer modified binders	MB-6
	Modified Vialit Adhesion test	MB-7
	Softening point of modified binders by ring and ball method	MB-17
	Dynamic (apparent) viscosity of polymer modified binders	MB-18

Notes:
1. Test methods designated "MB" are included in TG1.

Penetration and Ring & Ball Softening Point tests are normally carried out in the mixing plant site laboratory while the other tests listed in the table above are typically undertaken in a specialist binder testing facility.

Modified binders should be tested before the WMA Technology is added to check that they comply with TG 1 requirements as some WMA Technologies may alter the properties of polymer modified binders. The testing should be repeated after the WMA Technology has been added to assess its effect on the binder.

QUALITY ASSURANCE OF WMA TECHNOLOGIES

As covered previously in this guideline, WMA technologies may be very broadly divided into ***Water technologies***, ***Chemical additives***, and ***Rheological modifiers.***

While two of the water technologies (foamed bitumen and moist fines) use mechanical techniques to reduce mix temperatures, other WMA technologies utilize liquid, powdered, or pelletized products. WMA additives are normally sold against a chemical quality specification that should be referred to. No performance specification is normally given.

Some foamed bitumen systems offer the opportunity to visually examine the foam properties but in most instances this is not possible. Foam systems should be fitted with flow and pressure gauges so that flow rate and pressure of the water used to produce the foam can be monitored. The final quality of the mix can be assessed in terms of its performance at a reduced temperature.

Likewise, when using the other technologies, the quality control is focused on the WMA mix, except that dosage rates of the respective additives can be physically checked against those prescribed.

9. THE MIX APPROVAL PROCESS

The mix approval process for WMA is much the same as that for HMA; as illustrated in Figure 6.1, this is done in several steps to ensure that the finally approved mix will perform adequately. Guidance on each of these steps that lead to final approval of the mix is given in this section.

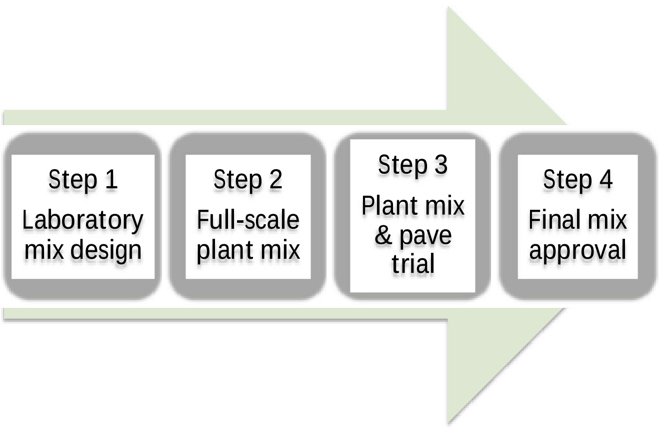


Figure 6.1
Process for mix approval

Step 1 Laboratory mix design

The *Interim Guidelines for the Design of Hot Mix Asphalt in South Africa (IGHMA*), published in 2001, can be used as a basic guideline for WMA designs. This document is supplemented by Sabita's Manual 24 *User Guide for the Design of Hot Mix Asphalt*, published in 2005, which is intended to simplify and smoothen the use of IGHMA, and makes extensive reference to original interim guideline.

It should be noted that Manual 24 includes mix types that are outside the present scope of this interim guideline for WMA, which only caters for continuously graded mix types.

The same phasing of the mix design procedure proposed in Sabita Manual 24, presented in Figure 6.2, is used in the design of WMA mixes

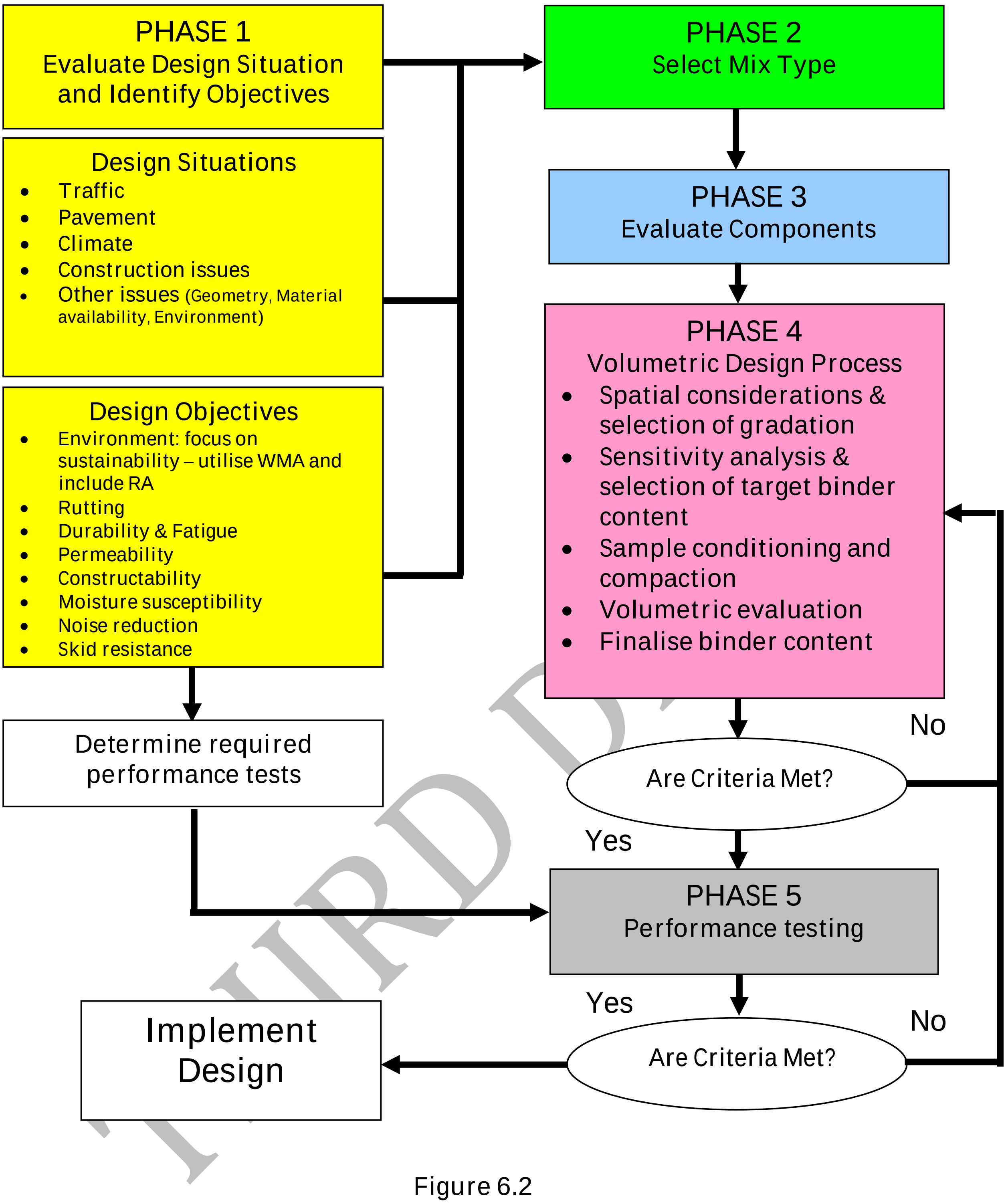


Figure 6.2
Mix Design Process

Various issues that require consideration during the mix selection process are shown in Figure 6.2. It should be borne in mind that only continuously graded mixes are covered in this guideline, nevertheless this figure is useful in illustrating issues that impact upon the selection of the most appropriate mix type.

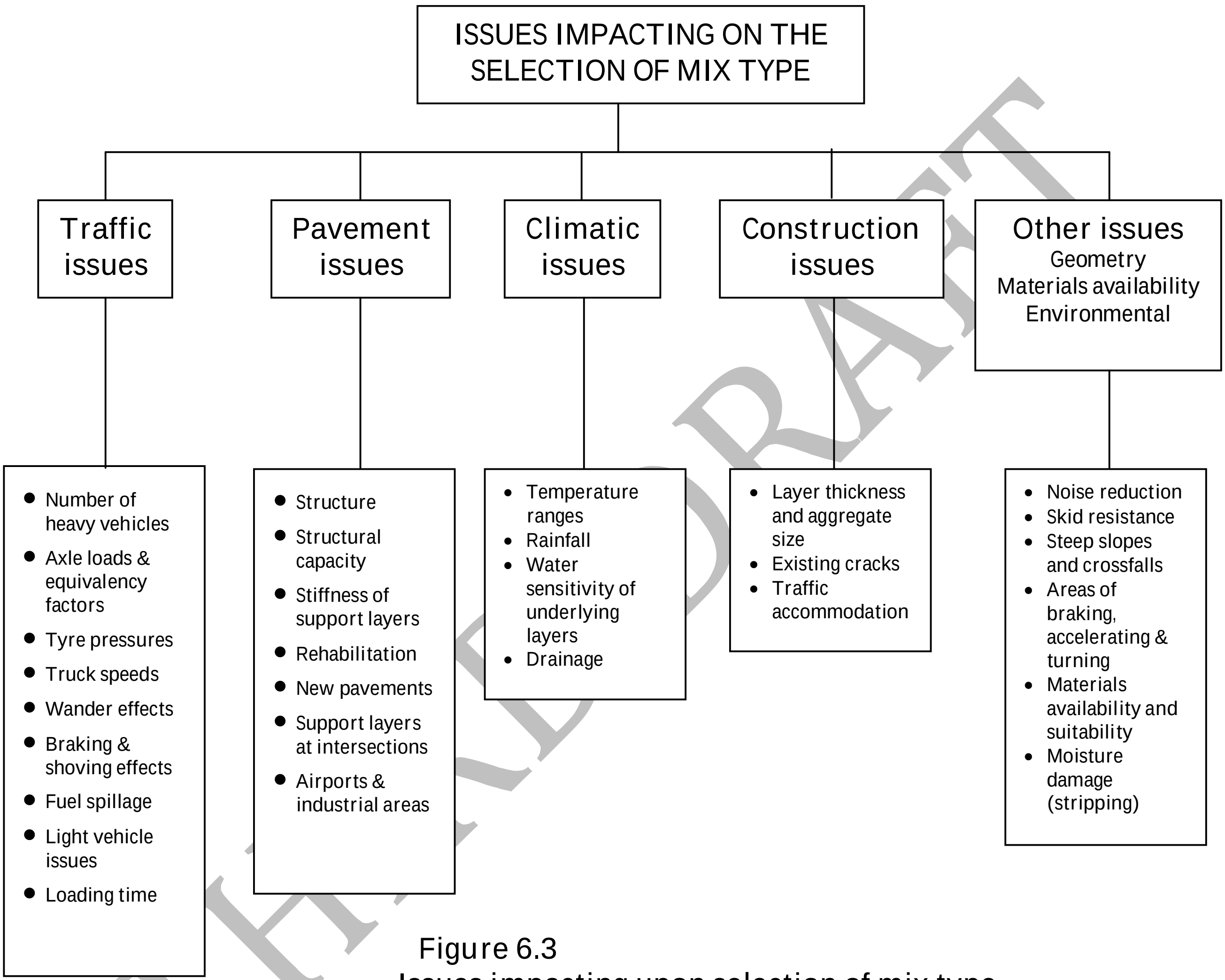


Figure 6.3
Issues impacting upon selection of mix type

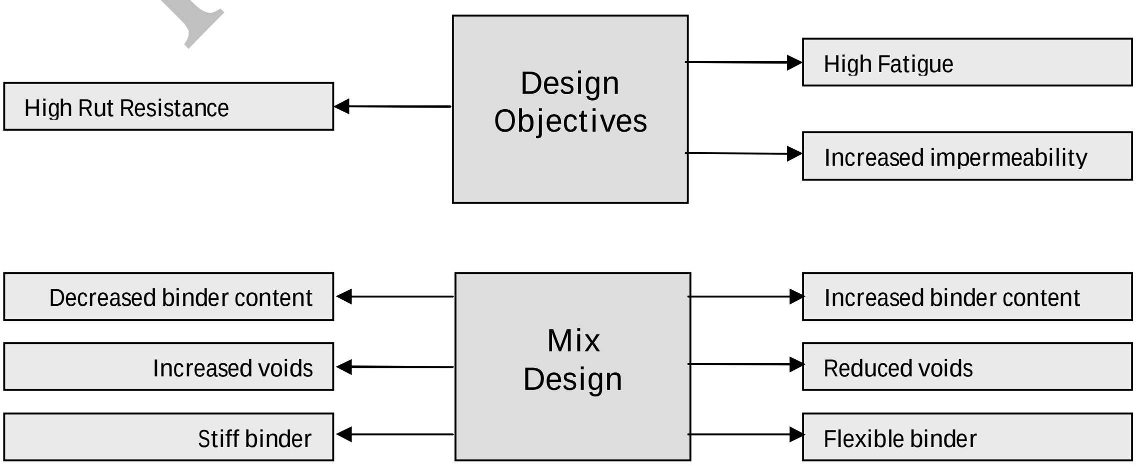


Figure 6.4
Design Considerations

Sabita Manual 24 emphasizes the need to balance the conflicting requirements of different design situations in order to provide the best solution. These are illustrated in Figure 6.4.

Besides the selection of the usual components that make up asphalt, aggregate, filler and bitumen, an appropriate Warm Mix Asphalt Technology and RA content should be decided upon. As a wide range of WMA Technologies are available the following should be considered when selecting one:

- Some technologies, such as chemical and rheological additives, may be supplied to the asphalt manufacturer as a ready mixed blended binder, or

- The asphalt producer may opt to blend the binder in-house

- Water-based WMA Technologies require the installation of some type of foam generator, with an integrated control system

- The level of temperature reduction required. Some technologies may permit larger temperature reductions than others

- Whether other mix properties, such as those obtained using polymer modified binders are required

- The availability, back-up service and cost (additive price v dosage) of the WMA Technology

In selecting mix components consideration should be given to the tendency for WMA to be more sensitive to moisture than HMA. In some instances anti-stripping agents may already be incorporated into the WMA Technology but it is mostly necessary to include hydrated lime as an active filler or amine AP's. An additional anti-stripping agent may have to be blended into the binder as a precaution when aggregates exhibit distinct bitumen adhesion problems.

An important consideration at an early stage in the design process is the addition of reclaimed asphalt (RA) in the mix. Reference is made to Draft TRH 21:2009 *Hot Mixed Recycled Asphalt,* regarding the selection, preparation and use of RA. The incorporation of RA into asphalt mixes makes common sense, as it reduces the quantity of virgin aggregate as well as the required quantity of new binder in the mix.

Decisions regarding the use of RA at the component selection stage initially focus on:

- The feasibility of using RA in the mix; the quantity available and the haulage distance, also the cost of RA versus the cost of virgin aggregate
- Crushing and screening facilities,
- Asphalt mixing plant capabilities for producing recycled asphalt mixes

Sampling and testing of RA is dealt with under "Handling of mix components" and is also covered under "Quality control of mix components". During the mix design stage every effort should be made to obtain samples of the RA that are fully representative of those that are to be used in full-scale asphalt production as changes in the grading, binder content and recovered binder properties will inevitably affect the characteristics of the mix.

For mixes containing more than 15% RA, it is essential that the RA used in the mix designs must be representative samples obtained from pre-crushed, screened and fractionated stockpiles dedicated for the full-scale production of the mix. It is extremely difficult to obtain representative samples of RA that has not been prepared in this way. Crushing and screening small quantities of RA in the laboratory that may not simulate the RA produced in full-scale stockpiles closely enough and may lead to significant differences between the results of mix designs carried out in the laboratory compared to those undertaken full-scale through the plant.

The RA should be tested to determine its aggregate grading. For mix design purposes the grading should be determined after the binder has been extracted. The binder content and recovered binder properties (Penetration and Softening Point) should also be determined at this stage.

Once the RA content of the WMA exceeds 15% the properties of the binder to the used in the mix are likely to become important. This is particularly relevant where the binder in the RA is very age hardened, which is mostly the case with RA in South Africa. The use of softer grades of new binder, and even rejuvenators, have to be considered as the RA content is increased above 15%. Further guidance in this respect is given in to Draft TRH 21:2009 *Hot Mixed Recycled Asphalt.*

The essential steps to be taken in the mix design procedure using WMA Technologies with liquid, powdered, or pelletized additives are illustrated in Figure 6.5.

With WMA being produced at lower temperatures, there is less chance for the aggregates and RA to be fully dried out and particular attention should be given to the mix's moisture susceptibility. It is usual to include 1% hydrated lime or amine adhesion promoter in the mix, and in addition, depending upon the bitumen adhesion properties of the aggregate, it may be necessary to add an anti-stripping agent.

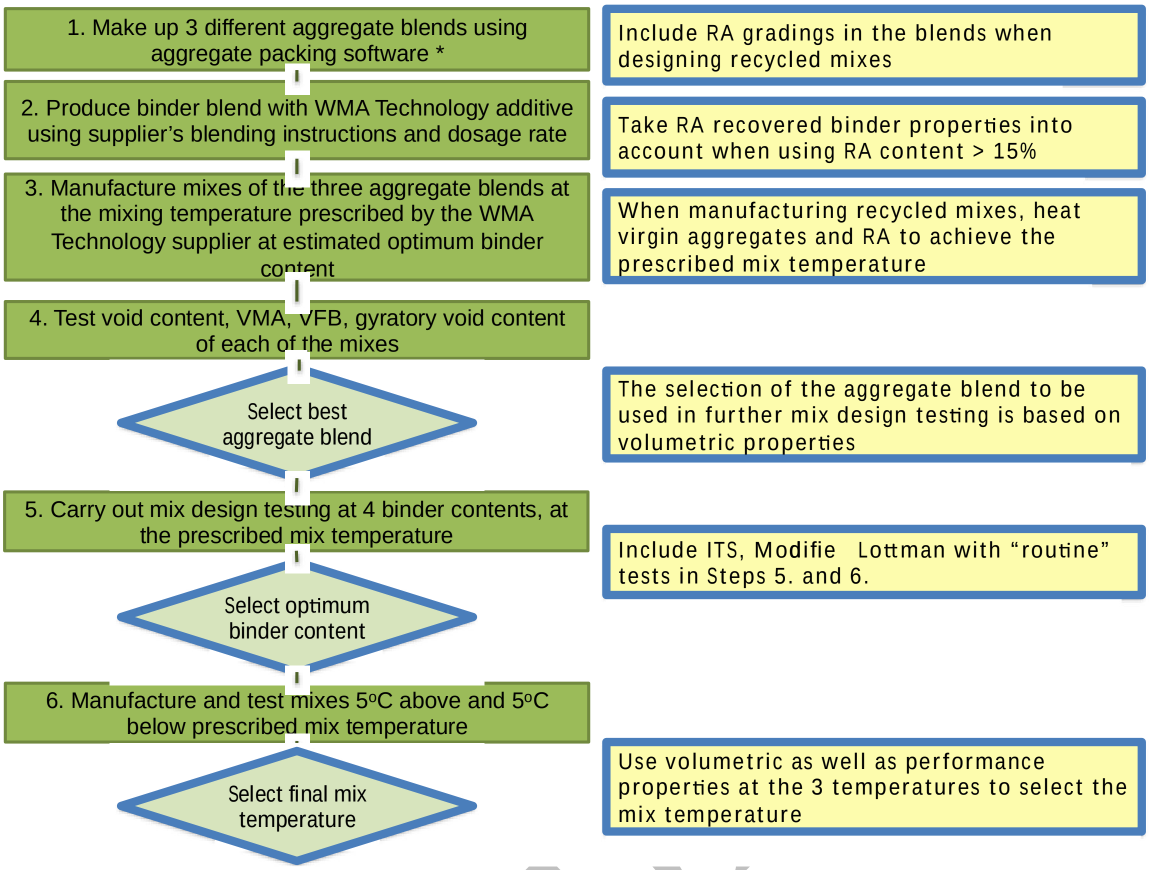


Figure 6.5
Mix Design Procedure for WMA Technologies with liquid, powdered or pelletized additives

When laboratory mix design work is carried out using emulsified WMA technologies, a slightly revised procedure should be adopted. The emulsified additive is normally added to the heated aggregate/RA at a relatively low temperature (normally around 80°C), while a further drop in temperature occurs as the moisture from the emulsion vaporizes as it is mixed with the heated aggregate/RA. To counteract this, the aggregate/RA should be preheated to a temperature between 5°C and 10°C above that normally required for non-emulsified WMA additives. More detailed information should be sought from the specific WMA Technology supplier in this respect.

At the time of writing these guidelines, it was not possible to carry out laboratory mixes using foamed bitumen WMA Technologies, as suitable specialized laboratory equipment to produce foamed bitumen was not available. Although plants are available that are able to produce foamed bitumen on a laboratory scale, these are specifically designed for use in Bitumen Stabilized Materials (BSMs), where the foamed bitumen is injected into the cold aggregates as they are being mixed. For WMA, where mixing is carried out at an elevated temperature, a properly heated mixer is required. With the rapid development of WMA, this current challenge will undoubtedly be overcome.

The procedure currently used is illustrated in Figure 6.6. It can be seen that full-scale mixing through the asphalt plant is required to optimize mixing temperature and binder content.

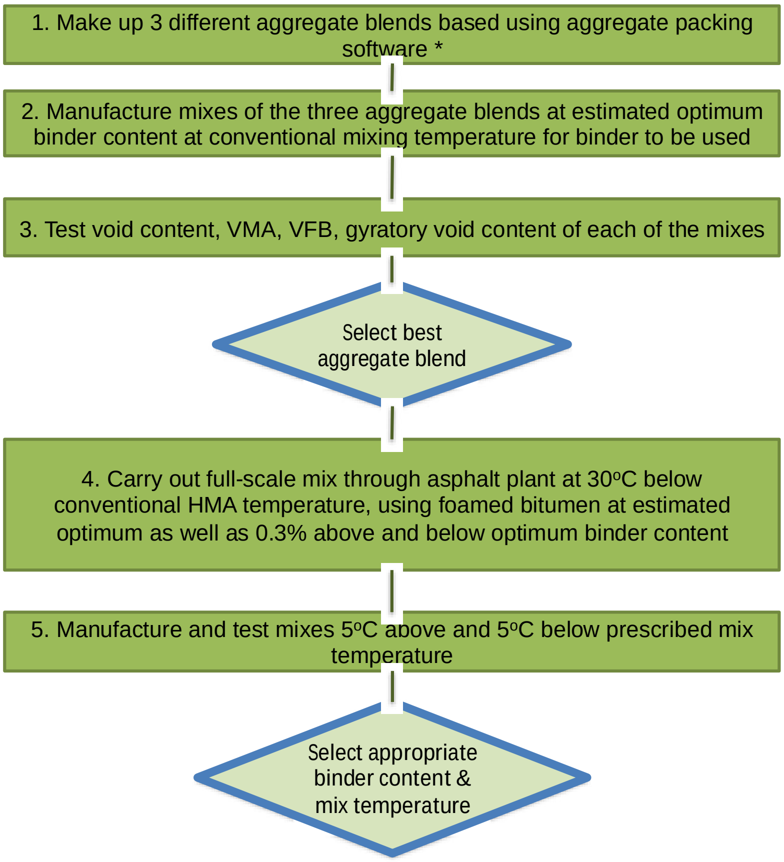


Figure 6.6
Mix Design Procedure for WMA Technologies using foamed bitumen

NOTE * Software such as Prado, Compact, or the Bailey Method can be used to optimise aggregate packing, however the results can be misleading in the case of finer graded mixes and engineering judgement is required to decide on the most appropriate grading to be used.

Step 2 Full-scale asphalt plant mix

Once the laboratory mix design has been completed, a full-scale mix is manufactured through the asphalt plant and is sampled and tested.

Besides eliminating the inevitable "shift" between the results of laboratory-scale and full-scale mixes, this step in the mix approval procedure provides an opportunity to check:

- Plant capabilities in producing the mix at the reduced temperature. As covered in more detail under "Manufacture", this will entail adjustments to the plant's burner fuel flow and in some cases to the plant's production rate.

- Full-scale binder blending in the case of WMA Technologies that include liquid, powdered, or pelletized additives. This process includes having the bitumen temperature at the blending temperature prescribed by the WMA Technology supplier. If polymer modifiers are also to be added, the elevated temperature required to blend these products will also have to be taken into account. Where indicated in the laboratory mix design, anti-stripping agents are also added at this stage. Usually it is necessary for the binder storage tank to be fitted with mechanical stirrers as well as pumping systems that enable the binder to be circulated; this is carried out as a means of ensuring that additives are uniformly dispersed in the binder. Cognisance should be taken of any storage time and temperature limitations that may be stipulated by WMA Technology and additive suppliers.

- Systems for heating and adding RA, and the effect that the RA has on mix properties, especially recovered binder properties. This is difficult to simulate in the laboratory and will depend on plant type (whether a continuous drum mixer or batch plant), as well, as where the RA is added in the mixing system, for instance through a centre ring in a drum mixer or to the pugmill in the case of a batch type plant.

- Moisture content of the mix. This will show whether sufficient drying has taken place to reduce the moisture content of the mix to below 0.5%.

- Pneumatic or mechanical auger type systems for adding powdered WMA Technologies, such as zeolites into the mixing drum or the pugmill.

- Mechanical water based WMA Technology systems. The quantity of water added to the binder affects foam properties. Some systems allow sampling of the foam to assess its properties and make adjustments to optimize the quality of the foam.

The mix should be manufactured at the prescribed temperature, ± 5^{o}C, with the mixes being produced at three different binder contents, one at the optimum binder content established in the laboratory mix design and the others with binder contents of 0.3% above and below the laboratory design's optimum.

The quantity of mix produced at each point depends upon factors such as:

- Plant type (batch or continuous type mixing plant)
- Minimum binder blending and storage facilities

In practice, the minimum quantity of mix produced at each of the three points is between 20 tons and 50 tons depending upon the mixing plant's type and capacity.

The temperature of the mix is determined and representative samples are taken for testing. Insulated hotboxes may be used to maintain temperature for the manufacture of Marshall briquettes and gyratory compaction testing. Table 6.1 lists the various tests that should be carried out on these samples.

Table 6.1 Tests carried out on samples from plant mixes

Test description	**Test Method**
Carry out these tests on samples from each point	
Grading Binder content Marshall Stability & Flow Bulk density and voids content Indirect tensile strength (ITS) Immersion Index Gyratory voids content	SANS 3001-AG1 SANS 3001-AS20 SANS 3001 –AS2 SANS 3001 – AS10 ASTM D6931-07 TMH1 C5
Carry out these tests on optimum point only	
Modified Lottman (TSR) Recovered binder properties: - Penetration - Ring & Ball Softening Point	AASHTO T 283 DIN 1996 ASTM D5 ASTM D36

A clearer picture of the optimum binder content as well as the properties of the mix should emerge from the second step.

This step provides the opportunity to optimize manufacturing temperatures further and the full-scale plant mixes can be extended to produce mixes at 5°C higher and 5°C lower than the optimum manufacturing temperature established in the laboratory mix design. The large quantity that can be sampled at the plant mix stage also enables accelerated trafficking rut depth testing, such as the Hamburg Rut Test or MMLS Rut Test.

In short, although expensive in terms of having to utilize the asphalt mixing plant and necessitating the production of relatively large quantities of asphalt for the purposes of testing, the plant mix stage provides a very valuable chance to evaluate the mix and to rectify problems before a much larger scale of work is carried out in the plant mix and paving trials.

Step 3 Plant mix and paving trial

The third step is to utilize the results of the plant mixes in manufacturing sufficient quantities of WMA for it to be paved in a trial section. This, the final step in the mix approval process, is intended to provide confidence that:

- Mix components that will be used in project are resourced and prepared

- The asphalt mixing plant is set up to introduce the required quantity of RA, if recycled mixes are to be manufactured
- Adjustments have been made to the asphalt mixing plant to enable the mix to be produced at the prescribed reduced temperature
- Ancillary asphalt plant equipment, such as foamed bitumen generators, are installed and calibrated
- Binder blending and storage facilities are fully prepared
- Arrangements have been made to transport the mix to the paving site
- Paving and compaction equipment has been arranged and is in a satisfactory condition to successfully pave and compact the WMA

A useful checklist for asphalt trial sections is given in Appendix A of Sabita Manual 24 “User guide for the design of hot mix asphalt”.

An assessment of the plant mix results will enable binder contents and mix temperatures to be optimized. Typical manufacturing and paving temperatures are given in Table 6.2. It should be noted that WMA mixes that contain polymer modified binders require higher manufacturing and paving temperatures than those where penetration grade bitumen is used in the mix.

Other checks that should precede the trial are similar to those required for Step 2 “Full-scale plant mix”.

Table 6.2 Typical manufacturing and paving temperatures

BINDER TYPE	Manufacturing (^{o}C)	Upon arrival at paver (^{o}C)
40/50 pen	130 - 140	120 - 130
60/70 pen	120 - 130	110 - 120
A–P1	140 - 150	130 - 140
A-E2	140 - 150	130 - 140

Wherever possible the underlying structure of the section on which the trial is to be undertaken should be similar to that of the main project. This will enable a suitable compaction pattern to be established on the trial that can be repeated on the full-scale project.

By this stage the mix properties should be largely established, and the trial should concentrate on:

- Manufacturing a consistent mix at the predetermined temperature
- Paving it within the prescribed thickness and riding quality tolerances
- Achieving the specified level of compaction

The quantity of mix required for the trial will depend upon a number of factors, including asphalt plant type and the minimum quantities of binder that can be prepared and stored. The plant also needs time to warm up and for mix temperatures to stabilize. At the paving site it is important that sufficient mix is available to assess the mix’s workability under the compaction equipment. Specifications typically call for trial sections between 300m^2 and 600m^2, but this quantity of asphalt is considered to be on the low side to assess the mix properly, and a minimum quantity of 100 tons of WMA is generally recommended.

Sabita Manual 5 “Guidelines for the manufacture and construction of hot mix asphalt” provides valuable information on paving and compaction.

As sampling and testing of the asphalt is similar to that for the main project, these topics are covered under “Construction”. It should however be borne in mind that the paving trial offers the first opportunity to closely monitor the temperature of the newly manufactured mix, as well as the temperature of the mix as it arrives at the paver. In the same way, the trial section enabled the compactibility of the mix to be properly monitored and assessed.

With the completion of the plant and paving trial sufficient information should be available for the mix to be approved for full-scale use on the main project.

10. MANUFACTURE

MIXING PLANT REQUIREMENTS

The essence of asphalt mixing plant design is obviously to produce homogeneous asphalt with the prescribed mix proportions at the required temperature. The plant’s design production rate must also be achieved. In addition to their cold feed and binder systems, primary considerations in the design of all types of asphalt mixing plant hinge around their heating, exhaust extraction and emission control systems; these are finely balanced to work in unison.

WMA requires mix temperatures to be significantly reduced. This entails some design rethinking and in the longer term, when WMA is used routinely, asphalt plants will no doubt be designed for normal operation at “warm” mix manufacturing temperatures.

Asphalt mixing plant design has undergone significant development over the past ten years, particularly in the use of microprocessor systems that automate the cold feed and mixing operations. The two basic types of asphalt mixing plant most commonly used are the batch type mixing plant and the continuous drum mixer type plant, both of which types can be adapted to manufacture WMA. These are the two mixing plant types discussed below. However it should be mentioned that other mixing plant configurations are also in use, such as double barrel and double drum mixers.

One of the main themes running through these guidelines is the synergy between WMA and recycling; mixing plant design should therefore in most cases include features that enable them to produce “warm” mixes that also contain reclaimed asphalt (RA).

Of primary concern, when any of the various types of mixing plants are used, is that the RA and the virgin aggregates are properly blended together; the blending process facilitates good heat transfer and prevents both mechanical and thermal segregation.

It should be borne in mind that mixing plants must be designed to comply with the same gas and particulate emissions standards when producing WMA (including those that also contain RA), as they are for conventional asphalt mixes; they should comply with National Environment Management Air Quality Act (Act No 39 of 2004). Guidelines regarding the various types of mixing plants can be found in SABITA Manual 5[15], as well as in NAPA Information Series 123[10].

In this section the use of batch type plants is considered, firstly for “warm” mixes per se and secondly for “warm” mixes that contain RA. Continuous type mixing plants are then discussed in a similar manner.

Batch type mixing plants

In batch type mixing plants almost all the heating and drying of the aggregate is carried out in the drier drum; only a small amount of additional heat is provided by hot gases in the elevator. When "warm" mixes are produced there are two ways that the mix temperature can be reduced:

- Reduce the heat energy produced by the burner
- Increase the production rate

It is necessary to achieve a balance between heating and production rate for a particular mixing plant. Normally producers choose to reduce the fuel flow to the burner whilst maintaining the same production rate. However it is vital that sufficient drying takes place to ensure that the moisture content of the mix is reduced to less than 0,5%. In some cases, if the moisture content of the mix is found to be too high, it may be necessary to reduce the production rate by reducing the feed rate of material into the drier drum. This will increase the ability of the burner to dry out the aggregate, reducing its moisture content further. This highlights benefits of keeping fine aggregate and RA under shelter to reduce high and varying moisture contents, a topic which is discussed in Chapter 7 of these guidelines.

Modifications to existing batch type mixing plants to manufacture "warm" mixes normally involve the burner system; its capability to run efficiently at lower fuel flow settings. Burner systems are a specialized field and it may be necessary to seek advice as to whether the existing system can be adjusted sufficiently to suit the lower temperature regime or whether replacement is necessary.

The emission system, which usually includes a bag-house, also requires consideration, as it has to cope with the lower temperature of the exhaust gases. If the temperature of the moisture-laden gases falls below dew point, the bags in the bag-house may clog. As this normally takes place during low ambient temperatures, portions of the bag-house may have to be insulated. Bags that are specifically designed for use in the manufacture of WMA, where clogging may be more prevalent, are currently under development.

<u>WMA mixes containing RA</u>

Two broad options exist to introduce the RA into the asphalt mix:

<u>Option 1</u> **Pugmill recycling using a separate RA weigh hopper**

The RA is fed directly into the pugmill via a weigh hopper. The virgin aggregate has to be superheated to transfer sufficient heat to the "cold" RA; The dry mix cycle may require slight adjustments to facilitate better heat transfer. A mini explosion occurs as the moisture in the RA makes contact with the superheated aggregate. After this initial burst, the steam is released at a slower rate (typically within a period of 30 seconds) by the vigorous mixing process in the pugmill. Adjustments/modifications may be required to ensure that the steam that is generated during the first few seconds after the RA is fed into the pugmill is adequately vented into the dust extraction system.

High RA content mixes can be produced using this process if the RA is dried prior to being introduced into the pugmill, and various drying systems exist to facilitate this.

<u>Option 2</u> **Introducing RA into the bucket elevator**

RA is fed via a cold feed bin directly into the hot elevator at the point at which the heated virgin aggregate is discharged from the drying drum. The RA mixes with the hot virgin aggregate in the bucket elevator, releasing steam more gradually as the material is lifted in the elevator to the screening deck. Thereafter the blend of RA and virgin aggregate is weighed off and falls into the pugmill where it is thoroughly mixed together with the binder. This process facilitates good heat transfer from the virgin aggregate to the RA as the RA remains in contact with virgin aggregate for a relatively long period. This eliminates the violent release of steam associated with the direct pugmill heat transfer method.

Continuous type drum mixing plants

In continuous drum mixer type plants all the heating and drying takes place in the mixer/drier drum. The hot exhaust gases assist in this process. As with batch type mixing plants, the reduction in temperature required in the manufacture of “warm” mixes can be achieved in two ways, by reducing the heat energy produced by the burner, or by increasing the production rate. Similar to batch type mixers, the temperature reduction is usually achieved by lowering the burner’s heat output rather than by increasing material throughput.

The same level of importance applies to continuous drum type mixing plants as batch type plants regarding the need to store aggregate and RA so that their moisture contents are kept as low as possible.

Other factors that come into play when reducing mix temperatures, such as modifications to burner and emission control systems, including bag-house management, apply in the same way for continuous drum mix type plants as for batch type plants.

When it comes to continuous drum-type mixing plants, two basic configurations are available, parallel flow and counter flow. Feeding RA into a drum type plant is easier as the generation and venting of steam can be managed more easily through the drum, which has a larger area. However, the possible risk of generating “blue smoke” is greater, as in some instances the burner flame makes direct contact with the RA as it is being fed into the drum.

The most basic parallel flow drum mixer utilises a cold feed bin for the metering of RA and then feeding it into the drum via an inclined belt, in the same way that virgin aggregate is fed into the drier drum. Due to the fact that the flame is in direct contact with the RA material, so-called “blue smoke” may occur, and the proportion of RA that can be used in the mix is therefore limited to a maximum of 10%.

Parallel-flow drum mixers can be equipped with a centre RA ring. This mid-entry design system enables the RA to be kept away from the high temperatures at the burner end of the drum, thus reducing damage to the binder in the RA and reducing “blue smoke” emissions. The percentage of RA that can be used with this type of mixer is still limited by the level of emissions caused by the effect of high temperatures on the binder that is added during the recycling process. A maximum of 25% RA is usually achievable with this type of plant.

The use of a separate rotating mixing drum or continuous pugmill, known as an “after mixer” or “coater”, where the heated mixture of virgin aggregate and RA is mixed together with the binder, reduces emissions, as the hot gasses from the mixing drum do not come into direct contact with the binder and the RA content can consequently be increased to at least 30%.

The design of counter-flow drum mixers, where the burner is located at the opposite end of the drum to that into which the virgin aggregate is fed, enables excessively high process gas temperatures to be reduced by the cooler, moisture laden aggregate as the gasses evacuate the dryer. Steam is typically exhausted at the burner end of the dryer while the high temperatures that prevail in this part of the drum destroy hydrocarbons carried in the air stream.

Various different types of counter-flow drum mixers exist:

- Counter-flow drum with a RA ring. Mixing takes place in the drum on the burner side of the RA ring

- Counter-flow drum with an after-mixer (or coater) where mixing takes place.

Two other continuous drum mixer types are in operation:

<u>Twin drum</u>
In the twin drum system, two drums are set up so that the aggregate is heated in the first drum using a counter-flow configuration. Once the aggregate has passed through the first drum it falls into the second drum. The RA, as well as the binder, is introduced into the second drum where further heating by the exhaust gases takes place. This configuration ensures that neither the RA nor the binder is in direct contact with the burner flame. RA contents of at least 30% are possible using the twin drum system.

<u>Double barrel</u>
The double-barrelled continuous mixer system consists basically of a double-shelled drum. New aggregate is introduced into the inner drum where it is direct contact with the burner flame, while RA and binder is fed into the drum's outer shell. The advantage here is that the RA is heated by conduction and the mix is not exposed to excessively high temperatures, thus reducing the effects of aging. Mixes with RA contents of at least 30% are possible using double-barrelled mixing plants.

The table below shows the maximum capabilities of the various types of mixing plants in terms of the percentage RA that they are typically able to handle.

Type of mixing plant	**Maximum % RA**
Batch mix • Pugmill only • Pugmill and hot elevator	 10 25
Drum mix • Parallel flow feed with aggregate • Parallel flow with centre ring • Counter flow with RA ring • Counter flow with after-mixer	 10 30 40 40
Twin dryer drum	50
Double barrel drum	70

COLD FEED REQUIREMENTS

It is necessary to provide a separate cold feed bin for each RA fraction. To enable the RA to be added smoothly, without the risk of blockages, the following points should be taken into account:

- The sides of the cold feed bins should be built steeper than those used for new aggregates
- Lengthen the openings of the cold feed bins onto the feed belts
- Longer feed belts are required
- Dribble the RA into cold feed bin to prevent packing
- Avoid use of vibrators
- Do not leave RA with a high binder in the cold feed bins overnight

BINDER STORAGE FACILITIES

Recommendations for the storage of bituminous binders, as well as sampling and testing, can be found in Sabita Manual 5: "*Guidelines for the manufacture and construction of hot mixed asphalt".*

The complexity of the binder storage facilities will depend to a large extent on whether it is intended to carry out the necessary blending on-site, or if a ready-blended binder is to be used in the "warm" mixes.
In the former case the on-site blending requires at least heated binder tank equipped with mechanical stirrers, as well as a recirculation pumping system.

WMA TECHNOLOGY ADDITION SYSTEMS

Both rheological modifier and chemical additive types of WMA Technologies that are blended into the binder are added through the mixing plant's normal binder addition system. In the case of batch plants the binder is usually pumped into a weigh pot before being introduced through a spraybar into the pugmill. In most continuous type drum mixing plants, the binder is introduced into the mixing drum by means of a volumetrically calibrated pumping system.

Water carrying chemical additives, which are in powdered form, can be added manually into the pugmill of batch type mixers. In the case of continuous drum mix type plants, the powder, which is normally added at a rate of around 0.3% by mass of the mix, can be added through the filler system, or by intruding it through the RA collar. It can also be introduced into the mixing drum using the pneumatic system used for feeding the cellulose fibre used in some asphalt mixtures.

Equipment to produce foamed bitumen may be installed on both batch and continuous drum mixing plant types. The systems obviously operate differently, with separate generations of foamed bitumen for each batch in the former type of plant and a continuous production of foam in the latter plant type's case.

MONITORING AND CONTROL SYSTEMS

Both basic type of asphalt mixing plant should have the following monitoring and control systems:

- Binder storage tank heating temperature
- Integrated individual cold feed hopper (new aggregate and RA) and burner fuel flow
- Burner fuel flow meter
- Infrared skip temperature monitor
- Infrared silo discharge temperature monitor

Foaming systems should include integrated flow metering and pressure sensing systems for both the binder and the water used to produce the foam.

11. QUALITY ASSURANCE IN THE MANUFACTURING PROCESS

Quality assurance of WMA in the manufacturing process is the same as that for HMA and can be divided into process control and acceptance control.

The reader is referred to information on process control in Sabita Manual 5. Aspects of process control that fall within the manufacturing process include the testing of virgin aggregates and RA, binders, as well as the asphalt mix. The former three materials are covered in some detail under Section 8 "Quality assurance of mix components".

In the initial stages of WMA production, special attention should be given to mix temperature, with frequent temperature measuring being taken as the plant settles down and produces mix with consistent temperatures within the reduced WMA temperature range.

Testing should be carried out using the parameters given in Table 6.1.

There is some debate as to whether the mix should be sampled at the asphalt mixing plant or at the paver for acceptance control testing of parameters such as binder content, voids content, ITS, and Marshall properties.

From a practical viewpoint it is best to sample the mix from the silo discharge point or from the delivery truck before it leaves the asphalt mixing plant and to use this sample to carry out gyratory voids content testing as well as to manufacture briquettes for:

- Marshall properties,
- Bulk density and voids content,
- Immersion Index, and
- ITS testing

Process control testing of binder content and grading is also undertaken on this sample.

While some road authorities require samples for acceptance control testing of aggregate grading and binder content of the newly paved mix to be taken behind the paver's screed, this method has practical disadvantages. It is difficult to take representative plate samples at random positions across the full width of the screed, especially in cases where the asphalt layer thickness exceeds around 40 mm. It is therefore recommended that all sampling be carried out at the mixing plant, where the sample can be accurately split and the required process as well as acceptance control testing can be undertaken on replicate samples.

The properties of mixes using some WMA Technologies may change slightly during the period between manufacture and paving, the significance of these changes being dependant upon which WMA Technology is used. It is recommended that a blanket two hour “curing period” be adopted for all WMA mixes, where samples taken at the mixing plant for the tests listed above are kept in the oven set at the mid-range compaction temperature for the respective WMA mix.

It is recommended that the applicable statistical judgement scheme in COLTO clause 8206 or clause 8305 be used for acceptance control of binder content, voids in mix.

12. CONSTRUCTION

In almost every respect, the same methods of construction are used for Warm Mix Asphalt as for HMA. Sabita Manual 5 *"Guidelines for the manufacture and construction of hot mix asphalt"* provides useful information in this regard. A previously mentioned characteristic of WMA is that the "compaction window" of this product is larger that that of conventional hot mix asphalt. This means that more time is available to compact the asphalt layer. Also the level of effort required to compact WMA is less than that required for HMA, even at its reduced temperature, i.e. WMA is more compactible than a similar HMA mix at conventional HMA temperatures.

Advantage can be taken of this characteristic in cases where long haulage distances are unavoidable. A solution is to manufacture the asphalt with the addition of the WMA Technology at conventional HMA temperatures. This will enable the mix to be transported over much longer distances, dependent upon the prevailing ambient temperatures and wind speeds.

PREPARATORY WORK

The preparation work that should be undertaken before paving the WMA is as described for HMA in Sabita Manual 5.

In instances where a new pavement is constructed, the pavement layer on top of which the asphalt is to be paved will normally consist of unbound crushed stone or cementitiously bound gravel or crushed stone. The application of a prime, to penetrate and condition the surface of this layer, is necessary. More detailed information on the use and application of primes is given in Sabita Manual 26 *"Interim Guidelines for Primes and Stone Pre-coating Fluids".*

As covered in Sabita Manual 5, it is always necessary to apply a tack coat on top of the prime, once it has dried; to ensure that there is a good bond between the granular and asphalt layers.

When the WMA is paved as an overlay on top of an existing asphalt layer, a tack coat should likewise always be applied. It is also necessary to apply a tack coat between newly paved asphalt layers, for instance between asphalt base and surfacing layers.

PAVING & COMPACTION

The paving and compaction techniques used for WMA are the same as for HMA. The reader is again referred to Sabita Manual 5. As the temperature of the WMA mix that arrives at the paving site is typically 30^{o}C below that of conventional HMA the paving crew usually immediately notice the lower temperature and lack of fumes and odour.

The temperature ranges for breakdown, intermediate and finish rolling will likewise be lower than for HMA and depend on factors such as binder and WMA Technology type, layer thickness and ambient weather conditions.

OPENING TO TRAFFIC

The decision on how soon after paving to open the newly paved WMA to traffic is influenced by:

- Ambient weather conditions, including temperature and wind speed
- Traffic loadings, speed

- Asphalt layer thickness
- Mix temperature
- Binder properties

As a guide, the section can generally be opened to traffic once the surface temperature falls below 50^{o}C.

WEATHER CONDITIONS

WMA is subject to certain weather conditions, in a similar way to HMA. Precipitation in the way of rain or drizzle, the ambient temperature, and well as the wind speed, all need to be taken into account as they do with HMA.

Useful guidance on this subject is covered in Sabita Manual 22 *“Hot Mix Paving in Adverse Weather”* and the reader is urged to study this document.

This manual provided valuable information on:

- Good paving practices
- Risks involved
- Limiting conditions for paving
- Precautions required

The two major areas covered in the manual that are directly related to weather are:

- Wind. The wind speed and temperature affects the rate of cooling of the mat, with higher wind speeds, and cold temperatures causing the most rapid decrease in mat temperatures. The mat thickness will also influence the rate of cooling, with thin layer thicknesses in cool, windy conditions being influenced most strongly.

- Water. Rain will obviously cause the asphalt layer to cool rapidly and the water may also enter the mat before the asphalt is fully compacted. The manual covers the rapid cooling effect of water sprayed by the sprinkler systems onto the roller drums and tyres. This effect can be greatly remedied by the use of release agents mentioned elsewhere in this document, as this enables the volume of spray water to be significantly reduced.

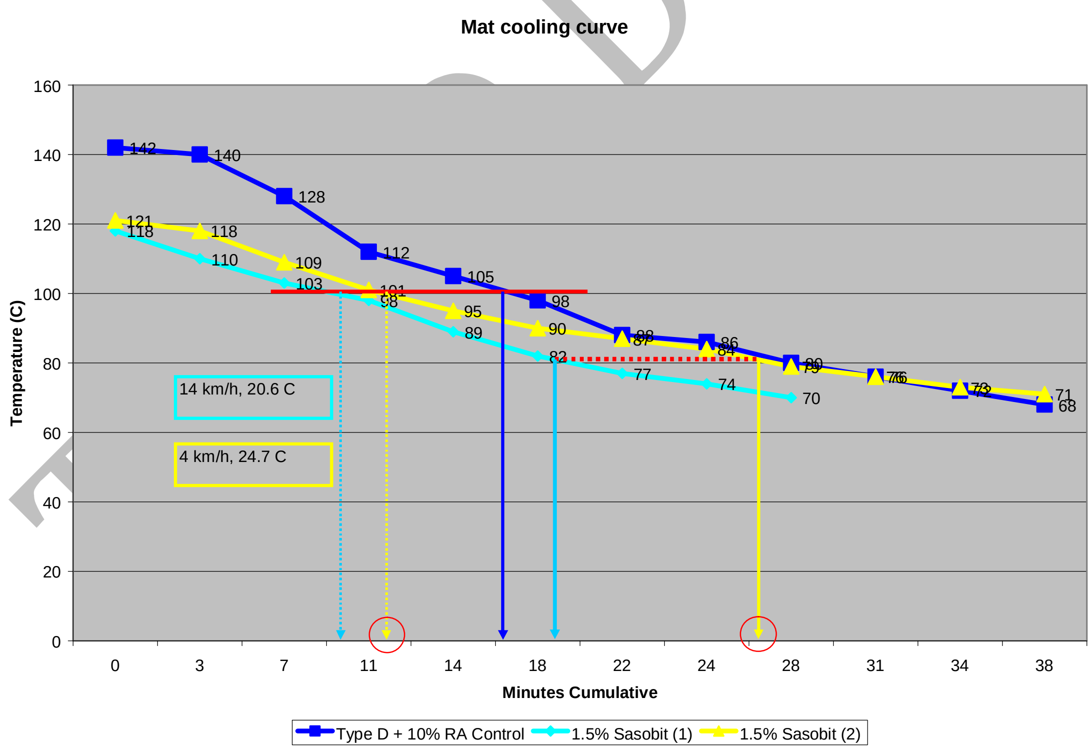
As already mentioned in Chapter 3 of this guideline, the slower rate of cooling and longer compaction window allows WMA to be hauled for longer than HMA, which is important when long haul distances are necessary. WMA also has advantages in situations where traffic congestion results in it taking significantly longer to haul the mix from the asphalt plant to the paving site.

Due to WMA’s lower compaction window compared to HMA (see Table 6.2), paving can be carried out at slightly lower air temperatures, as shown in Table 12.1.

Table 12.1 Minimum air temperature versus base temperature and wind speed

Layer thickness		25 mm	40 – 60 mm	> 60 mm
Base temperature		18°C	10°C	4°C
Binder type	Wind speed (km/h)	Minimum air temperatures		
60/70 pen	0 - 10	10°C	5°C	2°C
A-E2, AP1		15°C	10°C	4°C
60/70 pen	> 10	15°C	10°C	5°C
A-E2, A-P1		18°C	13°C	10°C

In the example given in Figure 12.1, the benefit of a widened compaction window is evident when one compares the WMA cooling curves against that of the control mix and the temperature predicted by PaveCool. The curves in this example were produced by placing a TelTru thermometer in the mat and taking readings to a minimum of 70 °C. It is clear that an additional 8-16 minutes (depending on air temperature and wind speed) are afforded to the paving team to reach density when using the WMA mix.



13. QUALITY ASSURANCE AT THE PAVING SITE

Quality assurance of WMA at the paving site is the same as that required for HMA, with monitoring of:

- the temperature of the mix on arrival at the paver. This entails measuring and recording the temperature of each truckload of WMA as the mix is tipped into the paver hopper.
- compaction of the asphalt layer. Process control is normally carried out using a nuclear gauge during the final stages of compaction, while acceptance control is undertaken on core samples taken the next day. The cores are also utilized in checking layer thickness.

Other measurements to ascertain whether the layer conforms to the specified construction tolerances and finish requirements, such as level and grade, cross section, and surface regularity are also taken on the completed asphalt layer.

As mentioned under Section11 “Quality assurance in the mixing process”, there is some debate as to whether the mix should be sampled at the asphalt mixing plant or at the paver for acceptance control testing of parameters such as binder content, void content, ITS, and Marshall properties.

From a practical viewpoint it is best to sample the mix from the silo discharge point or from the delivery truck before it leaves the asphalt mixing plant and to use this sample to carry out gyratory void content testing as well as to manufacture briquettes for:

- Marshall property,
- Bulk density and void content,
- Immersion Index, and
- ITS testing

Process control testing of binder content and grading is also undertaken on this sample.

At the paving site, samples of the mix taken behind the paver’s screed are utilized for acceptance control testing of aggregate grading and binder content. A stratified random sampling pattern across the width of the paved strip should be implemented.

It is recommended that the applicable statistical judgement scheme in COLTO clause 8206 or clause 8305 be used for acceptance control of binder content, voids in mix, and compaction.

14. PROTOCOL FOR INTRODUCING A NEW WMA TECHNOLOGY

During the past five years many WMA Technologies have been marketed and used successfully; at the time of writing this guideline 23 WMA Technologies were available in the USA!
In South Africa, the following WMA Technologies have been thoroughly assessed by the Warm Mix Asphalt Interest Group:

- Sasobit ®
- Rediset^{TM} WMX

- Sasolwax Flex™,
- NA Foamtec™
- Rediset™ WMX in combination with standard EVA

These WMA Technologies were subjected to the full mix approval procedure covered in Chapter 9, including extensive full-scale trials.

The protocol should cater for WMA that is produced by one or a combination of several technologies involving:

- The asphalt mixing plant (such as a foamed bitumen system or introduction of wet sand)
- Adding mineral or chemical additives (including emulsified additives) into the plant's mixing drum or pugmill
- Blending additives into the binder

Additionally the protocol should allow the incorporation of reclaimed asphalt (RA) into the mix.

The protocol for introducing a new WMA Technology is completed in three phases, the first phase being to provide documentation around the WMA Technology to be used. The second phase includes the laboratory mix design, followed by the plant mix and finally the full-scale mixing and paving trial. In the third phase, the information obtained in the preceding phases is assessed and approval is given for the WMA to be used.

Phase 1

Provide the following information:

a) WMA Technology and/or WMA additives information
b) WMA Technology supplier's established recommendations for usage
c) WMA Technology manufacturer's established target rate for water and additives, the accepted variation for production, and documentation showing the effect of excessive variability with either water or additives.
d) WMA Technology supplier's materials safety data sheets (MSDS)
e) Documentation of past WMA Technology field applications including date paved, tonnage, road owner, road details and location, mix design, field density, and performance to date under traffic. State whether RA was used in the mix, and if so, the proportion used.
f) Temperature range for mixing
g) Temperature range for compaction

Phase 2

Carry out the mix design approval process described in Chapter 9, which includes the laboratory mix design, followed by the plant mix and finally the full-scale mixing and paving trial.
During this process, it is essential to check:

The moisture susceptibility of the mix using the Modified Lottman test should comply with the minimum TSR given in Table 14.1.

Table 14.1 Minimum Modified Lottman TSR for mixes in different climatic conditions

CLIMATE	MODIFIED LOTTMAN TSR (Minimum)
Dry	0.70
Medium	0.75
Wet	0.80

- Moisture contents of the newly manufactured mix. Moisture contents should not exceed 0.5%.

- Rutting potential. This is carried out using the MMLS to test cores from the trial section. This testing may also be undertaken earlier in the phase but if this is done it should be repeated on the paved layer. MMLS rut depths after 100 000 load repetitions, carried out on core samples, should comply with the maximum rut depths in Table 14.2.

Table 14.2 Maximum rut depths on core samples after 100 k load repetitions of MMLS

ROAD & TRAFFIC CLASS	ASPHALT LAYER THICKNESS			
	40 mm	60 mm	75 – 90 mm	>90 mm
Free flowing highway speed	2.5	2.5	2.6	3
Rolling gradients with trucks	2.3	2.5	2.5	3
Fast free flowing	2.1	2.0	2.3	2.5
Steep gradients, intersections	2.1	2.0	2.3	2.5

- Mix temperatures should be checked at the mixing plant and each load of mix should be checked as it is tipped into the paver hopper. Any deviations from the range specified by the WMA Technology supplier should be highlighted.

- Compaction of the layer, using core samples extracted from the completed layer. The minimum compaction should be 97% minus the design voids of the voidless mix.

Phase 3

The final phase in approving the WMA Technology is based on an assessment of the documentation, and the results obtained in the laboratory, plant mix, and full-scale paving trials.

ANNEXURE A

INTERIM SPECIFICATION FOR WARM MIX ASPHALT BASE & SURFACING

CONTENTS

1 DEFINITIONS

ASPHALT

A mixture of predetermined proportions of aggregates, reclaimed asphalt, filler, bitumen and other agents which are heated and mixed together in a specialised mixing plant, transported to the site and placed by means of a paver or by handwork.

ASPHALT SURFACING

The layer or layers of asphalt paved on top of the base which come into contact with the wheels of vehicular traffic

ASPHALT BASE

The layer of asphalt paved between the subbase and the asphalt surfacing.

ASPHALT REINFORCING

Systems consisting of polymer and fibre-glass grids and fabrics, as well as steel meshes, which are installed either under or between asphalt layers as a means of retarding reflective cracking, improving rut resistance and fatigue properties of the asphalt layers.

MILLING

Excavating and removing a layer of asphalt exceeding 10 mm in thickness from an existing pavement by means of an approved milling machine.

PROJECT SPECIFICATIONS

The specifications relating to a specific project, and which contain supplementary and/or amending specifications to the standard specifications.

RECYCLING

The process of salvaging material, processing, and reusing it in the road pavement.

RECLAIMED ASPHALT (RA)

Reclaimed asphalt (RA) is asphalt that has been reclaimed using a milling machine or by crushing slabs ripped up from asphalt pavements, lumps from slabs, or asphalt from reject and surplus production.

RECYCLED ASPHALT

Asphalt mixes containing predetermined quantities of reclaimed asphalt that is prepared and mixed together with virgin aggregate to produce asphalt with at least similar qualities and performance characteristics as conventional asphalt.

ROLLER PASSES

Unless otherwise specified in the specifications or the project specifications, an area will be taken to have received one roller pass when a roller has passed once over and back over such area. Additional passes made only as a result of nominal overlapping so as to ensure full coverage shall not be taken into account.

WARM MIX ASPHALT (WMA)

Mixtures of aggregate, bituminous binder and mineral filler, where a WMA Technology is employed to enable the mix to be manufactured and paved at a significantly lower temperature than HMA, with its quality and performance being equal to or even exceeding that of HMA. WMA is produced at temperatures at least 20°C below those of HMA, and above 100°C.

WARM MIX ASPHALT TECHNOLOGIES

Technologies that may include WMA additives as well as other techniques and processes that enable asphalt to be produced at significantly reduced temperatures

TEST METHODS

Where reference is made to a test method in TMH1, this shall be replaced by the relevant SANS 3001 test method.

2 SCOPE

This specification covers the following work:

(a) The provisions of this specification shall apply throughout to Warm Mix Asphalt, except where explicitly specified otherwise. Warm Mix Asphalt, incorporates the use of technologies that enable the asphalt mix to be manufactured and paved at significantly lower temperature than conventional asphalt and which complies with the specified requirements. The contractor shall propose the WMA Technology that will be used.

(b) All the work in connection with the construction of asphalt bases and surfacing. It includes the procuring and furnishing of aggregate and bituminous binder, mixing at a central mixing plant, spreading and compaction of the mixture, all as specified for the construction of:

(i) Continuously graded asphalt base;

(ii) Continuously graded asphalt surfacing

(c) The widening of asphalt bases and surfacing, paving and hand placing asphalt in restricted areas and installing asphalt reinforcing where specified.

(d) Overlaying of existing surfaced pavements.

(e) The recycling of asphalt by reprocessing recovered materials, adding fresh aggregate, bituminous binders and other agents for obtaining an asphalt mix which will comply with the specified requirements, and placing the recycled material. The provisions of this specification shall apply throughout to recycled asphalt, except where explicitly specified otherwise.

3 MATERIALS

(a) Bituminous binders

(i) Conventional binders

The various bituminous binders specified shall comply with the relevant SABS specifications stated below:

Road-grade bitumens . . . . SANS 307

Bitumen emulsions . . . . SANS 309 (anionic)
SANS 548 (cationic)

The selection of binders shall be based on the properties of the binder recovered from the newly manufactured mix and shall take into account the WMA Technology used as well as the RA content of the mix. The following penetration grades of bitumen shall be used:

a) 40/50

b) 60/70

c) 80/100

(ii) For mixes with high reclaimed asphalt (RA) contents, an approved wax-based modifier may be used.

(iii) Homogeneous modified binders

Homogeneous modified binders are defined as industrial blends of polymer and bitumen where the blended components form a stable microscopic dispersion, or either or both form a stable continuous phase relative to each other.

The modified binder to be used shall be A-E1/A-E2/A-P1, A-H2.

The homogeneous modified binder shall be manufactured according to the guidelines contained in "Technical Guideline: The use of Modified Bituminous Binders in Road Construction (TG 1-2007): Asphalt Academy". The base bitumen shall conform to SANS 307, or a blend of SANS 307, or a blend of SANS 307 grades. The type as well as percentage of modifier is not prescribed, however the contractor shall indicate in the Pricing Schedule what polymer he shall be using. The properties of the homogeneous modified binder shall comply with the relevant requirements for binder class A-E1/A-E2/ A-P1* as listed in table 3.1.

Table 3.1 Properties of polymer-modified binder for hot-mix asphalt

Property	Unit	Test Method	Class		
Before aging			A-E1	A-E2	A-P1
Elastic Recovery @ 15^{o}C	%	MB-4	>50	>60	> 30
Softening Point[1]	^{o}C	MB-17	55-65	65-85	63-73
Force Ductility @ 5^{o}C	N	EN 13703	report[3]	report[3]	report[3]
Dynamic Vicosity@165^{o}C	Pa.s	MB-18	≤0.6	≤0.6	≤0.55
Storage stability @ 160^{o}C	^{o}C	MB-6	≤5	≤5	≤5
Flash point	^{o}C	ASTM D93	≥ 230	≥ 230	≥ 230
After aging (RTFOT)					
Mass change	%	MB-3	≤ 1.0	≤ 1.0	≤ 1.0
Elastic Recovery @ 15^{o}C	%	MB-4	>40	>50	report[2]
Dynamic Vicosity@165^{o}C	Pa.s	MB-18	report[2]	report[2]	report[2]

Notes

1. The prescribed method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
2. No limits are given and the values should be recorded for reporting purposes only as they may be used in future specifications.
3. No values given but the test can be used to rank various binders according to their low temperature cohesion properties.

(iv) The type and grade of bituminous binder to be used in each case shall be as specified hereinafter or in the project specifications.

(b) Virgin aggregates

Coarse and fine aggregate shall be clean and free from decomposed materials, vegetable matter and other deleterious substances.

Asphalt mixes shall be manufactured using different individual single size coarse aggregates fractions and crushed fine aggregates blended to conform to the specified grading requirements. The use of natural sands shall only be permitted if approved by the engineer and shall be limited to a maximum of 10% by mass of the total new aggregate fraction. All aggregate larger than 7 mm (6.75 mm) shall consist of individual nominal single sized aggregate.

Contractors shall note that commercial suppliers may not be able to supply all the required single size aggregates, in which instance arrangements will have to be made for additional on site screening. No additional payment shall be made for screening aggregate. The use of run of crusher type materials shall not be permitted.

(i) Resistance to crushing

The aggregate crushing value (ACV) of the coarse aggregate, when determined in accordance with TMH1 method B1, shall not exceed the following values for aggregate used for:

Base and surfacing 25

The minimum dry 10% FACT values of the – 14 mm (13.2 mm) + 10 mm (9.5 mm) fraction shall be as follows:

Base and surfacing . . . . 160 kN

The wet/dry ratio shall not be less than 75%

(ii) Shape of the aggregate

Base:

The flakiness index when determined in accordance with TMH 1 Method B3 shall not exceed 35 for the minus 28 mm (26.5 mm) sieve plus 20 mm (19 mm) sieve and minus 20 mm (19 mm) plus 14 mm (13.2 mm) sieve fractions respectively. In addition, at least 50% by mass of the individual fractions retained on each of the standard sieves with a square mesh size of 5 mm (4.75 mm) and larger shall have at least one fractured face.

Surfacing:

The flakiness index for surfacing asphalt shall not exceed the values given in table 3.2

Table 3.2

Nominal size of aggregate (mm)	Maximum flakiness index %	
	Grade 1	Grade 2
20 (19)	25	30
14 (13.2)	25	30
10 (9.5)	30	35
7 (6.7)	30	35

In addition, at least 95% of all particles shall have at least three fractured faces. The grade or grades specified in the project specifications and in the schedule of quantities shall be used.

(iii) Polishing

The polished stone value of aggregate, when determined in accordance with SABS method 848, shall not be less than the following values for aggregate used for:

Continuously surfacing 50

Aggregates with polishing values below that stated above may be approved for use by the engineer.

(iv) Adhesion

When tested in accordance with TMH 1 Method C5, the immersion index of a mixture of the binder and aggregate proposed for use shall not be less than 75%. The aggregate used for the test mixture shall have a grading within the actual limits for the mix concerned.

(v) Absorption

When tested in accordance with TMH 1 methods B14 and B15, the water absorption of the coarse aggregate shall not exceed 1% by mass, and that of the fine aggregate shall not exceed 1,5% by mass, unless otherwise permitted.
In addition, the total binder absorption of the combined coarse and fine aggregate blend shall not exceed 0.5%.

(vi) Sand equivalent

The total fine aggregate used in all asphalt mixes shall have a sand equivalent of at least 50, when tested in accordance with TMH 1 method B19, and the natural sand where it is permitted to be mixed with the aggregate shall have a sand equivalent of at least 70.

(vii) Design requirements

The contractor shall, by conducting the necessary tests, satisfy himself that he will be able to produce a mixture meeting the design requirements specified hereinafter, using the aggregate he proposes to supply, within the grading limits specified.

(viii) Grading

The grading of the combined aggregate including any filler added in an approved working mix shall be within the limits stated in table 3.3 and table 3.4 for the various mixes. The approved grading shall be designated as the target grading. The mean grading of each lot of the working mix (minimum of 6 tests per lot) determined from samples obtained in a stratified random sampling procedure, shall conform to the approved target grading within the tolerances specified in table 3.5.

Table 3.3 Gradings for asphalt base

Sieve size (mm)	Percentage passing	
	Asphalt base 37.5 mm max.	Asphalt base 28 mm (26.5 mm) max

37.5		100	
28 (26.5)		84 - 94	100
20 (19.0)		71 - 84	85 – 95
14 (13.2)		59 – 75	71 – 84
10 (9.5)		50 – 67	62 – 78
5 (4.75)		36 – 53	42 – 60
2 (2.36)		25 – 42	30 – 47
1 (1.18)		18 – 33	21 – 37
0.600			15 – 30
0.300		9 – 21	11 – 24
0.150		6 – 17	8 – 19
0.075		4 - 12	5 - 12
Nominal mix proportions by mass	Aggregate	95%	94.5 %
	Binder	4%	4.5%
	Active filler	1.0 %	1.0 %

Table 3.4 Grading for asphalt surfacing

Sieve size (mm)		Percentage passing		
		Asphalt surfacing Coarse	Asphalt surfacing Medium	Asphalt surfacing Fine
28 (26.5)		100		
20 (19.0)		85 – 100		
14 (13.2)		71 – 84	100	
10 (9.5)		62 – 76	82 – 100	100
5 (4.75)		42 – 60	54 – 75	64 – 88
2 (2.36)		30 – 48	35 – 50	45 – 60
1 (1.18)		22 – 38	27 – 42	35 – 54
0.600		16 – 28	18 – 32	24 – 40
0.300		12 – 20	11 – 23	16 – 28
0.150		8 – 15	7 – 16	10 – 20
0.075		4 0 10	4 - 10	4 - 12
Nominal mix proportions by mass	Aggregate	93.5%	93.5%	93.0%
	Binder	5.5%	5.5%	6.0%
	Active filler	1.0 %	1.0 %	1.0%

Table 3.5 Tolerances

Sieve size (mm)	Permissible deviation from approved target grading
28 (26.5)	± 5
20 (19.0)	± 5
14 (13.2)	± 5
10 (9.5)	± 5
5 (4.75)	± 4
2 (2.36)	± 4
1 (1.18)	± 4
0.600	± 4
0.300	± 3
0.150	± 2
0.075	± 1

The approved target grading shall be determined after laying a trial section on site.

(ix) Additional requirements for asphalt bases

If approved by the engineer and if the specified requirements are met, the aggregate component may contain natural fines not obtained from the parent rock being crushed, on condition that such added material does not exceed 10% by mass, unless otherwise specified in the project specifications. The added fines shall have a liquid limit not more than 25% and a PI not more than 6. The contractor shall submit full details regarding the exact quantity and nature of such fine aggregate, before such permission will be considered. In the event of such added material being natural sand, its impact on rut resistance should be assessed by MMLS tests carried out on core samples obtained in a trial section planned well ahead of any production runs. The addition of natural fines shall be done using a separate cold feed bin.

(x) Moisture content

The moisture content of aggregates, sampled from the cold feed belt, shall not exceed the following limits at the time that it is introduced into the mix:

Coarse aggregate ……………………………………… 2%
Fine aggregate …………………………………………. 4%

(c) Fillers

If the grading of the combined aggregates for asphalt surfacing mixes shows a deficiency in fines, an approved filler may be used to improve the grading. Filler may consist of active filler as defined hereinafter or of inert material such as rock dust having the required grading necessary to improve the grading of the combined aggregates.

The engineer may order the use of any active filler to improve the adhesion properties of the aggregate.
Individual materials shall comply with the requirements of the relevant SABS or other specifications for such material. Active filler shall have at least 70% by mass passing the

0.075 mm sieve and a bulk density in toluene falling between 0.5 and 0.9 g/ml. The voids in dry compacted filler shall be between 0.3% and 0.5%, when tested in accordance with British Standard 812.

Active fillers shall be introduced to the mix prior to wetting with the binder. An active filler content of 1% by mass shall be used unless otherwise specified.

Only active filler added on the instructions of the engineer, for the purpose of improving adhesion, will be paid for. No payment will be made for filler added to improve the grading.

For tender purposes the active filler shall be hydrated lime.

(d) Asphalt reinforcing

Asphalt reinforcing shall be of the type specified in the project specifications and shall be obtained from an approved manufacturer.
Where the use of reinforcing for asphalt has been specified, the contractor shall, at least 1 month before the material is to be used, submit samples of the type he intends to use, together with complete specifications of the material, as well as the manufacturer's instructions for use, to the engineer for approval. Where the material does not carry the SABS mark or the mark of another acknowledged authority, the engineer may instruct the contractor to have the material tested by an approved laboratory and to submit the results.

(e) Reclaimed Asphalt

Reclaimed asphalt (RA) shall be asphalt that has been reclaimed using a milling machine or by crushing slabs ripped up from asphalt pavements, lumps from slabs, or asphalt from reject and surplus production.

RA shall be free of foreign material such as unbound granular base, broken concrete, remnants of geosynthetic grids of cloths, or other contaminants. Asphalt or material from old surface treatments containing tar shall not be used at all in any recycled asphalt mixes and shall be diligently separated and disposed of in a registered landfill site.

RA shall be prepared by crushing and screening to achieve a well graded, free flowing, and consistent product. The RA shall be screened into two separate fractions; a coarse fraction consisting of material passing the 16 mm and retained on the 8 mm sieve, and a fine fraction of material passing 8 mm.

The prepared RA shall be stockpiled in separate fractions, preferable under cover in an open sided shed. RA stockpiles shall not be covered with plastic sheets or tarpaulins except when rain is imminent, or while it is raining. All stockpiles shall be built on a hardened surface that is sloped to facilitate drainage

(i) Resistance to crushing

After extraction of the binder, the resistance to crushing of the aggregate in the coarse RA fraction shall be the same as that for new aggregate in Clause 3 (b) (i). The ACV and 10% FACT testing shall be carried out for every 500 tons of RA used, as well as after each change in type or visual quality of aggregate in the RA.

(ii) Grading

Grading tests shall be carried out at a frequency of one test per 100 tons of each fraction of RA used. The grading tests shall be carried out on the aggregate after extraction of the binder. The coarse RA fraction shall consist of material with 100% passing the 20 mm (19 mm) sieve size, and between 60% and 80% passing the 7 mm (6.7 mm) sieve size. The fine RA fraction shall consist of 90% to 100% passing the 7 mm (6.7 mm) sieve size.

(iii) Binder content

Binder content testing shall be carried out at a frequency of one test per 100 tons of each fraction of RA used.

(iv) Recovered binder properties

The Softening Point and Penetration of the binder recovered from each of the RA fractions shall be determined at a frequency of one test per 100 tons of each fraction of RA used.

(v) Moisture content

The moisture content of each of the RA fractions shall be determined at a frequency of one test per 100 tons of each fraction of RA used. The moisture content of the RA, sampled from the cold feed belt, shall not exceed 4%.

RA which has not been prepared and approved shall not be used in the asphalt mix.

(f) Asphalt for hot plant mix recycling

The maximum percentage of RA that is to be added to the mix shall be 12%, or as otherwise specified in the Project Specification.

(i) Bituminous binders

The provisions of subclause 3 (a) shall apply.

The grade of new binder used in the recycled asphalt mix shall be such that the mix of new and residual binder will comply with the requirements of the project specifications. Recycling agents such as blended oils and other additives may not be used without prior approval by the engineer.

(ii) Virgin aggregate

New aggregate required for use in recycled asphalt mixtures shall comply with the requirements of subclause 3 (b).

(iii) Combined aggregate

The aggregate mix obtained from new aggregate and the aggregate in the recovered asphalt, including any mineral filler, an approved quantity of which may be added in accordance with subclause 3 (c), shall comply with the requirements specified in the project specifications for the relevant recycled asphalt layer.

(v) Storing material for recycling

The contractor shall ensure that recovered materials such as asphalt or crushed stone are not unnecessarily polluted with unsuitable material and that these materials are not unnecessarily wasted.

Stockpiles of milled or crushed asphalt shall be shaped and formed in a manner that will prevent segregation as far as possible. The stockpiling of the recovered asphalt shall be done in a manner that will prevent consolidation as far as possible.
The recovered asphalt that is placed in the stockpile(s) shall be tested, carefully controlled and recorded with regard to origin and material properties to ensure a consistent recycled end product.
The preparation of stockpile sites and the stockpiling of recovered asphalt for recycling will not be paid for directly but full compensation therefore shall be included in the rates for the recycled asphalt.

(g) Warm Mix Asphalt (WMA) Technologies

The WMA technology shall be approved by the engineer and shall enable the asphalt mix to be manufactured and paved at the temperatures given in Table 7.1, or otherwise as specified in the project specifications. The technologies may include the addition of substances to the binder or into the mixer, or other processes such as foamed bitumen.

The contractor shall supply, at the time of tender, the following information regarding the particular WMA Technology that is to be used:

- a materials safety data sheet (MSDS),
- technical details regarding mixing plant and capabilities
- technical data including recommended dosage rates,
- details of the relationship between the treated binder viscosity versus temperature within the range of 90^{o}C and 160^{o}C.
- Penetration and Softening Point of the treated binder,
- detailed instructions regarding the way in which the WMA technology is blended with the binder and/or introduced into the asphalt mixing plant, and
- detailed information regarding mixing, paving, and compaction of the mix.

(h) General

All materials shall be handled and stockpiled in a manner that will prevent contamination, segregation or damage. Cement and lime shall be used in the order in which it has been received.

The contractor shall, as often as necessary, test and control the materials produced by himself or the materials received by him from suppliers to ensure that the materials always comply with the specified requirements.

Sufficient aggregate for a minimum of 3 days production shall be separately stockpiled and tested for conformance and uniformity prior to use. The test results shall be presented to the engineer.

In general the contractor will not be expected to construct layers in which the nominal maximum aggregate size exceeds two-thirds of the compacted layer thickness.

4 COMPOSITION OF ASPHALT BASE AND SURFACING MIXTURES

The rates of application and mix proportions of bituminous binder, aggregates and fillers which are given in table 3.3, are nominal rates and proportions and shall only be used for tendering purposes. The rates and proportions actually used shall be determined to suit the materials used and conditions prevailing during construction and any approved variation on a nominal mix in the bitumen content or active filler content, or aggregate content, shall be the subject of an adjustment in payment for binder or active filler variations as described in clause 15.

Before production or delivery of the asphalt the contractor shall submit samples of the materials he proposes to use in the mix, together with his proposed mix design as determined by an approved laboratory, to the engineer in accordance with table 4.1, so that the engineer may test the materials and confirm the use of the proposed mix if he is satisfied that it meets the specified requirements. When certain processes, such as foamed bitumen, are proposed, laboratory scale mix designs may not be possible. In addition to the materials samples, the contractor shall supply the engineer with samples of asphalt at minimum three different binder contents that have been manufactured full-scale in the asphalt mixing plant.

Table 4.1 Details of materials, samples sizes and period required for testing and approval

Material	Submission for quality approval only		Submission for quality approval & mix design	
	Minimum time to be allowed for testing & approval	Minimum quantity to be submitted	Minimum time to be allowed for testing, approval and mix design	Minimum quantity to be submitted
Aggregate	2 weeks	50 kg of each aggregate size	8 weeks	100 kg of each aggregate size
Filler	2 weeks	5 kg	8 weeks	25 kg
Binder	2 weeks	1 litre	8 weeks	5 litres

At least 4 weeks before paving with recycled material will commence, the contractor shall submit to the engineer full particulars regarding the recycling methods he intends to use.

Where recovered asphalt material is taken from a stockpile, it shall be done by excavating from the pile over its full depth. Where segregated material is fed into the mixing plant, the engineer will have the right to order the work to cease and to instruct the contractor to remix the stockpile, retest the mixed material and redesign the asphalt mixture all at his own cost.

At least 4 weeks before paving commences, the contractor shall submit to the engineer full particulars regarding the warm mix technologies that he intends to use.

As soon as the materials become available the contractor shall produce a working mix in the plant, with a minimum quantity of 10 tons, in accordance with the design mix. The working mix shall again be tested by him for compliance with the design requirements.

Samples of the working mix and the test results shall also be made available to the engineer, who will authorise the use of the working mix proportions approved for use in the trial section. Final approval of the working mix will be subject to the approval of the trial section. The composition of the approved working mix shall be maintained within the tolerances given in subclause 13 (b).

The nominal mix proportions (by mass) of the various asphalt mixes are set out in table 3.3.

Note: For recycled asphalt, where the RA content exceeds 15%, the nominal mix ratios of recovered asphalt, new aggregate, new bituminous binders, and active mineral filler to be used for tender purposes, shall be as specified in the project specifications.

The design of the asphalt mixes shall be in accordance with "Interim Guidelines for the Design of Hot-Mix Asphalt in South Africa (June 2001)", and appropriate research results, and shall follow the guidelines in "TRH 21:2009 Hot Mix Recycled Asphalt."

For Warm Mix Asphalt, the design of the asphalt mixes shall follow the guidelines given in "Interim Guideline and Specification for the manufacture and paving of Warm Mix Asphalt in South Africa".

The relevant asphalt mixes for the base and surfacing layers shall comply with the requirements in table 4.2

Table 4.2 Asphalt mix requirements: Base and Surfacing

Property	Continuously graded base mixes	Continuously graded surfacing mixes
Marshall Stability (kN)	8 – 18	8 – 18
Marshall Flow (mm)	2 – 6	2 – 6
Stability /Flow (kN/mm)	>2,5	> 2,5
VMA (%)	> 13	> 15
VFB (%)	65 – 75	65 – 75
Air voids (%)	4 – 6	4 – 6
Indirect tensile strength @ 25^{o}C (kPa)	> 1000	> 1000
Dynamic Creep Modulus @ 40^{o}C (MPa)	> 20	> 20
Modified Lottmann* (TSR)	> 0,7	> 0, 8
Air permeability @ 7% voids (cm^2)	< 1 x 10^{-8}	< 1 x 10^{-8}
Binder film thickness (microns)	5,5 – 8,0	5,5 – 8,0
Filler bitumen ratio	1 – 1,5	1 – 1,5
Immersion index (%)	75 min	75 min.

Note: See project specifications for the MMLS rut depth requirements for cores from trial sections and from the road during construction.

5 PLANT AND EQUIPMENT

(a) General

All plant shall be so designed and operated as to produce a mixture complying with the requirements of this specification. The plant and equipment used shall be of adequate rated capacity, in good working order and subject to the approval of the engineer. Obsolete or worn out plant will not be allowed on site.

Prior to the start of the work the contractor shall supply the engineer with copies of the manufacturer's handbooks and copies of check lists prepared in terms of IS0 9002 where applicable pertaining to the mixing, remixing and paving plants, containing details of the correct settings and adjustments of the plant.

Any alteration which has been or is being effected to any constructional plant, and which does not comply with the specifications of the manufacturer, shall be brought to the attention of the engineer.

(b) Mixing Plant

(i) Conventional binders

Asphalt shall be mixed by means of an approved type mixer of proven suitability for producing a mixture complying with all the requirements of the specifications.

The mixing plant may be either automatically or manually controlled but in the latter case, two control operators shall be provided.

The heating system of the tanks storing the binder shall be so designed that the binder will not be degraded during heating. A circulating system for the binder shall be provided which shall be of adequate size to ensure the proper and continuous circulation between storage tanks and mixer during the entire operating period.

Binder storage tanks shall be fitted with thermometers designed to provide a continuous record of the temperature of the binder in the tank. Copies of these records shall be supplied to the engineer on a daily basis.

Satisfactory means shall be provided to obtain the proper amount of binder in the mix within the tolerances specified, either by weighing or volumetric measurements. Suitable means shall be provided for maintaining the specified temperatures of the binder in the pipelines weigh buckets, spray bars and other containers or flow lines.

In the case of a drum type mixer, the system shall control the cold feeding of each aggregate fraction and of the filler by mass, by means of a load cell or another device regulating the feed automatically. The cold feed shall be regulated automatically in regard to the binder feed so as to maintain the required mix proportion.

Suitable dust collecting equipment shall be fitted to prevent pollution of the atmosphere in accordance with the provisions of Act 45 of 1965 and Act 85 of 1993.

The mixing plant shall be equipped with the following calibrated systems that shall provide electronic hardcopy records of:

- Burner fuel consumption using a sensitive flow meter, calibrated storage tank level indicator or load cell system
- Mixing cycle times (batch plant) and/or production rate
- Binder temperatures
- Aggregate temperatures on cold feed conveyor immediately prior to mixing

This information shall be recorded during production of the asphalt mix on an approved form.

- Mix temperature at the point of mix discharge shall be recorded on a continuous basis during production using an approved electronic measuring device. Temperature measurements of the mix in the skip shall be recorded and reported at intervals of not more than 50 tons during production of the mix

- Mix temperature in the delivery truck at the weighbridge
  The temperature of the mix in each delivery truck at the weighbridge shall be measured and reported

The temperature of the mix at the point of discharge as well as in the delivery truck shall be maintained within the limits specified in the Project Specification.

(ii) Homogeneous modified binder

In addition to the mixing plant requirements for conventional binder, refer to the requirements of the project specifications.

(iii) Recycling

In addition to the requirements set out in subclause 5(b), the mixing equipment shall be specially adapted to deal with recycling and any such adjustments shall be in accordance with the instructions of the manufacturer of the mixing plant. The recovered asphalt portion of the mix shall not be exposed directly to the heating source whilst the feeding rate and proportioning shall be accurately controlled. Before work is commenced, the contractor shall submit full details of his mixing equipment to the engineer for his approval.

The following information shall be captured manually and reported on an approved form:

- Aggregate and RA proportions used in the mix

The frequency of recording and reporting proportions of aggregate and RA shall be:

- within the first 10 minutes after the start of production
- at intervals of 50 tons during production of the mix

(iv) Warm Mix Asphalt

In addition to the requirements of subclause 5(b), the asphalt plant shall be modified to suit the WMA technology used. Where applicable, systems that enable accurate and uniform addition as well as blending of substances into the binder and or the mixer shall be installed. When technologies are used where moisture is added to the binder to produce foam, a system shall be fitted that ensures a constant ratio of binder to water.

(c) Spreading equipment

(i) Paver

The mixture shall be laid by an approved type of self-propelled mechanical spreader and finisher capable of laying to the required widths, thicknesses, profile, camber or cross-fall, without causing segregation, dragging or other surface defects.
All pavers shall be fitted with automatic electronic screed controls to maintain the required levels, cambers and cross-falls. Pavers shall be fitted with a vibration system as well as a tamper bar that can be adjusted for stroke and frequency. A heating system shall be fitted

to the paver that is capable of heating the screed, vibration system and tamper bar to a uniform temperature.
Where levelling beams on multiple skids or sliding beams are used they shall be at least 12.0 m long, or as specified by the engineer.

(d) Rollers

(i) General requirements

The asphalt shall be compacted with at least one double drum vibrating roller with an operating mass of at least 7 tons, as well as with at least one pneumatic tyred roller with a ballasted operating mass that produces a load of 3 tons per wheel. The frequency as well as the amplitude of vibratory rollers shall be adjustable. Vibratory rollers shall be used only where there is no danger of damage being done to the asphalt, structures of bridge decks, or other layers. It will be indicated in the project specifications whether vibratory compaction equipment may be used on bridge decks and what the constraining parameters will be. The rollers shall be self-propelled and in good working condition, free from backlash, faulty steering mechanism and worn parts.
Rollers shall be equipped with adjustable scrapers to keep the drums clean and with efficient means of keeping the wheels wet to prevent mixes from sticking to the rollers. Release agents, approved by the engineer, may be used in place of water. When water is used, the volume of water sprayed onto the roller wheels shall be controlled so that it does not cause sudden cooling of the mat.

No leakages of any nature may occur in the rollers.

The mass and/or tyre pressures shall be such so as to ensure proper compaction to comply with the specifications of surface finish and density.

(ii) Homogeneous modified binder asphalt

The general requirements shall apply.

(e) Binder distributors

Where bituminous binders are to be sprayed onto areas before the asphalt is placed, the binder distributors shall:

(i) comply with TMH 2 and shall be covered by a valid certificate of compliance with TMH 2; issued by one of the centres for testing binder distributor mentioned in TMH 2; or

(ii) not have any fuel, oil or binder leaks;

(iv) have a straight and clean spraybar, all the spray heads of which shall be of the same type which open simultaneously and shall not leak when closed;

(v) have its spray heads all spraying at the same angle to the spraybar and adjusted to the correct level so as to obtain the required overlapping;

(vi) have its fans not interfering with one another

(vii) have its sieve undamaged and clean;

(viii) be under the direct control of an operator approved by the engineer on the grounds of a reference, in writing, or a certificate of competence signed by a representative of a road authority.

(f) Vehicles

The asphalt shall be transported from the mixing plant to the spreader in trucks having tight, clean, smooth beds and sides which have been treated to prevent adhesion of the mixture to the truck bodies. A thin film of soapy water, vegetable oil, or wax based released agents may be used to prevent adhesion but petroleum products shall not be used for this purpose. The use of diesel shall not be permitted for this purpose.

All vehicles used for transporting the asphalt mix shall be fitted with canvas (transport in excess of 10 km or cold. windy or rainy conditions prevailing) or other suitable approved covers (less than 10 km and moderate climatic conditions prevailing) to minimise temperature loss. Such covers shall be securely fixed over the heated asphalt from the time of departure at the mixing plant until immediately prior to the discharge of the asphalt into the paver.

(g) Mass-measuring device for asphalt mixes

Where payment per ton is specified, the contractor shall keep available at the mixing plant or on the site a suitable gauged, calibrated, mass-measuring device for measuring the asphalt mixes. The device shall be provided with a printer for printing the type of mix, the mass, the time and the date.
The printed data shall be submitted to the engineer.

6 GENERAL LIMITATIONS & REQUIREMENTS & THE STORAGE OF MIXED MATERIAL

(a) Weather conditions

Asphalt may be mixed and placed only under favourable weather conditions, and shall not be mixed or placed when rain is imminent or during misty or wet conditions. Paving shall cease when rain starts falling or when the surfaces to be paved are visibly wet.

The minimum air and base temperatures, and wind speeds that are suitable for paving work are shown in table 6.1.

Table 6.1 Minimum air temperatures versus base temperature and wind speed

Layer thickness		25 mm	40 – 60 mm	> 60 mm
Base temperature		18°C	10°C	4°C
Binder type	Wind speed (km/h)	Minimum air temperatures		
60/70 pen	0 - 10	10°C	5°C	2°C

A-E2, AP1		15^{o}C	10^{o}C	4^{o}C
60/70 pen	> 10	15^{o}C	10^{o}C	5^{o}C
A-E2, A-P1		18^{o}C	13^{o}C	10^{o}C

(b) Moisture

The mixing and placing of asphalt will not be allowed if:

(i) the moisture content of the aggregate affects the uniformity of temperature: or if

(ii) free water is present on the working surface: or if

(iii) the moisture content of the underlying layer, in the opinion of the engineer, is too high, or if the moisture content of the upper 50 mm of the granular base exceeds 50% of the optimum moisture content as determined by the engineer, even if the underlying layer has been previously primed.

No overlay shall be placed immediately after a rainy spell on an existing partly cracked and/or highly permeable surfacing resulting in the trapping of moisture in the pavement structure.
A minimum delay of 24 hours or such extended period as ordered by the engineer shall apply.

(c) Surface requirements

(i) Correction of base or subbase in the case of asphalt base.

The base (after the prime coat has been applied), or the subbase, as the case may be, shall be checked for smoothness and accuracy of grade, elevation and cross section. Any portion of the base or subbase, as the case may be, not complying with the specified requirements, shall be corrected with asphalt at the contractor's own expense, until the specified requirements are met. The engineer may, however, in his sole discretion, allow minor surface irregularities to remain, provided they can be taken up in the following asphalt layer without adversely affecting that layer.

The asphalt used for the correction of the base or subbase, shall be the same mixture as specified for the surfacing or as directed by the engineer, and the maximum size of aggregate used shall be dictated by the required thickness of the correction in each case.

Notwithstanding these provisions for the correction of the base or subbase, the engineer reserves the right to order the removal and reconstruction of the layer or of portions of the base and subbase layers not complying with the specified requirements, instead of allowing the correction of substandard work with asphalt material.

Where a prime coat is applied it shall be dry before further coats or layers are applied. The contractor shall not commence with the application of the tack coat and/or the paving without the written approval of the engineer.

The contractor's programme shall allow for delays that are a function of the type of prime, rate of application, base porosity and moisture content, and climatic conditions.

(ii) Cleaning of surface

Immediately before applying the tack coat, the surface shall be broomed and cleaned of all loose or deleterious material.

Where the prime coat (if any) has been damaged, it shall be repaired by hand brushing or spraying priming material over the damaged portions.

Where the surfacing is to be constructed on bridge decks, the concrete deck shall be thoroughly cleaned by washing and brushing to remove all loose material and allowed to dry.

(iii) Tack coat

A tack coat shall be applied to the surface to be paved.

The tack coat shall consist of a stable-grade bituminous emulsion diluted to have a 30% bitumen content and shall be applied at a rate of 0.55 l / m^2 or as directed by the engineer.

For bridge decks a tack coat consisting of 30% stable grade bituminous emulsion shall be applied to the surface at a rate of 0.4 l / m^2. The tack coat shall then be allowed to dry.

The use of hand operated equipment for the application of tack coats shall be at the sole discretion of the engineer and his approval shall be timeously obtained.

All exposed portions of kerbing, channelling and bridge railing, shall be protected when the tack coat is applied.

The tack coat shall be applied within the same day that the asphalt is paved.

Hand spraying shall only be permitted on areas approved by the engineer. The binder distributor shall be capable to apply the binder evenly over the full area. The equipment shall comply with subclause 5(e). Tack coat shall be applied to all transverse and longitudinal joints by hand utilizing a paint brush.

(d) Repairs and pre-treatment

(i) Preparation for placing the overlays

Preparation before the placing of overlays may consist of crack sealing or patching. The type of treatment to be applied, if any, will be specified in the project specifications or instructed in writing by the engineer.

(ii) Preparation where asphalt layers are to be widened or where surfacing over a section of the road width requires replacement.

The existing asphalt shall be removed by milling, where applicable, or as instructed by the engineer.

Where a road has to be widened, the overlay shall be cut back not less than 100 mm from the existing edge. Unless otherwise indicated on the drawings or instructed by the engineer, asphalt joints may not fall within a wheel track.

(e) Storage

Mixing shall not be allowed to take place more than four hours before paving begins unless provision has been made for storage. Storage of mixed material will only be permitted in approved silos, which are capable of maintaining the temperature of the mix uniform throughout. In any case storage will not be permitted for a period longer than 8 hours after mixing, unless otherwise approved by the engineer.

7 PRODUCING AND TRANSPORTING THE MIXTURE

(a) Mixing and storage temperatures of binder

Bituminous binders shall be stored at temperatures not exceeding those given in table 7.1, or as specified in the project specifications.

Table 7.1 Binder storage temperatures

MATERIAL	MAXIMUM STORAGE TEMPERATURE	
	Under 24 hours (°C)	Over 24 hours (°C)
40/50 penetration grade bitumen	175	145
60/70 penetration grade bitumen	175	135
80/100 penetration grade bitumen	175	125
Homogeneous modified binders	See project specifications	

Blending of bitumen with WMA technologies shall be carried out within the temperature range recommended by the suppliers.

The minimum binder temperature for WMA technologies shall be within the temperature range recommended by the asphalt supplier.

The aggregates, RA, and bituminous binders shall be heated at the mixing plant to such temperatures that the mixed product shall have a temperature within the ranges given in table 7.2, or as specified in the project specifications.

Table 7.2 Manufacturing and paving temperatures

BINDER TYPE	Manufacturing (°C)	Upon arrival at paver (°C)
40/50 pen	130 - 140	120 - 140
60/70 pen	120 - 130	110 - 130
A–P1	140 - 150	130 - 150
A-E2	140 - 150	130 - 150

(b) Production of the mixture

(i) Using batch plants

(1) Batching

Each fraction of the aggregate and binder shall be measured separately and accurately in the proportions by mass in which they are to be mixed. If filler is used, it shall be measured separately on a scale of suitable capacity and sensitivity. The error in the weighing apparatus used shall not exceed 2% for each batch. A homogeneous mixture and uniform coating of binder must be achieved and the moisture content of the asphalt mixture shall not exceed 0.5%. Once the final mix temperature has been agreed upon it may not be altered without the prior consent of the engineer.

(2) Mixing

The aggregate, filler and binder shall be mixed until a homogeneous mixture is obtained in which all particles are uniformly coated and the moisture content of the asphalt mixture shall not exceed 0.5%. Care shall be taken to avoid excessively long mixing times that can cause hardening of the binder.

(ii) Using drum-type mixing plants

The aggregate and filler shall be accurately proportioned and conveyed into the drum-mixing unit. The calibrated amount of binder shall be sprayed onto the aggregates at the correct position so that no excessive hardening of the binder shall take place. A homogeneous mixture and uniform coating of binder must be achieved and the moisture content of the asphalt mixture shall not exceed 0.5%. Once the final mix temperature has been agreed upon it may not be altered without the prior consent of the engineer.

Pre blending of aggregate fractions shall not be permitted and the contractor shall ensure that sufficient cold-feed bins are installed to accommodate each individual aggregate fraction, including the filler.

The moisture content of the asphalt mixture shall be tested according to method C11 of TMH1.

(c) Transporting the mixture

The mixture shall be transported from the mixing plant to the works in trucks complying with the requirements of subclause 5(f). Deliveries shall be made so that spreading and rolling of all the mixtures prepared for a day's run, can be completed during daylight, unless artificial lighting, as approved by the engineer, is provided. Any asphalt that has become wet due to rain or any other cause shall be rejected. Hauling over freshly laid material is not permitted.

Special precautions shall be taken by the contractor to ensure that the temperature of the total mass of asphalt does not decrease by more than 10^{o}C from point of dispatch to the point where it is to be paved. The use of canvas or other suitable approved covers is obligatory.

The contractor shall ensure that trucks used to haul asphalt are not overloaded and the legal axle loads are not exceeded. Before any asphalt can be transported, the contractor must provide the engineer with the certified carrying capacity of each truck intended for the purpose of transporting the mix. The contractor shall provide the engineer with a weighbridge ticket before discharging into the paver hopper.

ANY truck that is overloaded shall not be allowed to discharge its load and shall return to the depot/batching plant for adjustment of the load. In addition a penalty shall be applied for the overload.

(d) Small quantities of asphalt

A small quantity of asphalt shall be a quantity of less than 10 tons of a specified composition to be specially produced on occasion. For a small quantity of asphalt of less than 10 tons extra payment will be made if its use has been instructed by the engineer, in writing, and where, in the opinion of the engineer it is necessary:

(i) in accordance with the approved working programme of the contractor, and/or

(ii) for the safety of the work or the travelling public on account of weather conditions or abnormal traffic conditions.

No extra payment will be made where small quantities of asphalt are required in consequence of the negligence of the contractor, or of poor work or bad planning done by the contractor, or because he did not execute the works in accordance with his approved programme.

(g) Approval of asphalt mixture

Before any asphalt is placed on the road, the engineer shall approve the mix design. The approval process shall be as follows:

The contractor shall prepare and submit a laboratory design mix with test results at four different bitumen contents. The design mix shall be submitted on the prescribed form D3 of TMH 10: "Instruction for the Completion of As-Built Materials Data Sheets" with all the necessary test results completed. In addition, the proposed asphalt mixture shall be subjected to gyratory testing. All the expenses in preparing and submitting the laboratory design mix shall be to the contractor's cost.

Samples of all aggregate and bitumen shall be submitted with the laboratory design mix to enable the engineer to carry out check design testing as necessary. The above design and aggregate shall be submitted to the engineer at least eight weeks before it is intended to commence with any asphalt production.

After approval is obtained for the laboratory design mix, a plant mix at varying binder contents of approximately 40 to 50 tons each shall be produced. The purpose of the plant mix is for the contractor to prove that the laboratory design mix can be produced successfully. The engineer shall conduct the necessary testing on the plant mix. The plant mix shall not be placed on the road. During the production of the plant mix, the engineer shall be afforded the opportunity to inspect the asphalt plant.

After the plant mix is approved, permission shall be given for laying a trial section at varying binder contents in accordance with the requirements of clause 11 of this specification. The engineer may require that the mix be further assessed by means of MMLS testing, the cost of which will be borne by the Employer. Mass production of asphalt shall only commence after approval of the trial section, which should be given within a maximum of ten days.

The engineer may instruct the contractor at any time to halt his paving process and to review the whole or part of the above process should a change of aggregate properties or binder type occur, the specified asphalt requirements are not being met and/or a consistent asphalt mixture is not being produced.

8 SPREADING THE MIXTURE

(a) The mixture shall be delivered to the paver in such a manner that the paver will never be forced to stop for lack of asphalt. The temperature of the mixture shall be checked by measuring it in a random pattern in the truck immediately before emptying, and shall not be less than the minimum mix delivery temperature specified in table 7.2 or as specified in the project specification. The adjustment of the screed, tamping bars, feed screws, hopper feed, etc, shall be checked frequently to ensure uniform spreading of the mix. If segregation or tearing occurs, the spreading operations shall immediately be suspended until the cause is determined and corrected.

The addition and removal of material behind the paver shall not be allowed and the paver shall be capable of spreading the mixture to the correct amounts that will provide the required compacted thickness without resorting to spotting, picking-up or otherwise shifting or disturbing the mixture.

Paving shall, if possible, commence at the bottom of the grades and the lower edges of super-elevated curves. Paving shall be done upgrade on grades steeper than 5%.

Spreading shall be so arranged that longitudinal joints do not coincide with joints in lower layers of asphalt base, paver laid crushed stone bases or surfacing.

The mixer capacity and the operating speed of the paver are to be so co-ordinated as to ensure continuous laying and to avoid intermittent stopping of the paver.

(b) In the case of overlays, guide wires will normally not be required during the placing of the mix unless specified in the project specifications. In all cases, including levelling courses, the paver shall be provided with approved skid beams with electronically controlled equipment that can ensure a constant crossfall and can even out local irregularities.

(c) Asphalt shall be placed in restricted areas with the aid of smaller specially equipped pavers, hand tools, or other approved equipment. The space concerned shall be properly filled with asphalt, without leaving any gaps between the fresh asphalt and the existing pavement layers. On restricted areas, inaccessible to the paving equipment used, the mixture may be placed by hand or other means to obtain the specified results. Paving shall be carried out in a manner which will avoid segregation and which will allow control of levels.

All the provisions in regard to temperature, mix composition, uniformity, etc., shall remain applicable, but layer thickness and control shall be such that the requirements for compaction and surface tolerances can still be attained.

9 JOINTS

All joints between adjacent sections of the work shall be made by cutting back the layer against which the material is to be placed. All loose and incompletely compacted material shall be removed. A cutting wheel shall be used for cutting longitudinal joints.

Joints shall be either at right angles or parallel to the centre line, and unless otherwise, approved, joints in the final layer of the surfacing shall correspond with the lane markings. Joints in lower layers shall be offset not less than 150 mm on either side of the edges of the traffic lanes.

Before a new layer is placed next to an existing layer the cut edge of the existing layer shall be painted with a thin coat of bituminous emulsion of the same type used for the tack coat, if so directed by the engineer.

Joints shall be neat and shall have the same texture and density as the remainder of the asphalt course. All joints shall be marked out with chalk lines prior to cutting.

The outside edges of the completed asphalt layer shall be trimmed along the shoulder, and parallel to the centre line, to give a finished width, as shown on the drawings, within the tolerances specified.

Any fresh mixture spread accidentally onto existing work at a joint shall be carefully removed by brooming it back with stiff brooms onto the uncompacted work, so as to avoid the formation of irregularities at the joint. Whenever the paving operation is stopped due to lack of mixture, the contractor shall form a proper joint as specified above, if so directed by the engineer.

Where the difference in level between the new work and the existing road surface exceeds 25mm, joints shall be treated as follows:

Transverse steps at the end of a day's work shall be tapered off at a slope of 1 vertical to 20 horizontal (1:20) to tie in with the existing surface. The tapered section shall be removed before surfacing is recommenced and a joint formed in accordance with clause 9 of the specification.

Longitudinal joints exposed to traffic shall be provided with a taper of compacted asphalt material over the full length of the exposed joint. The width of the taper shall be at least 5 times the difference in level between the old and new work.

All costs involved in the provision and removal of these temporary ramps shall be deemed to have been included in the rates tendered for the relevant asphalt pay item.

10 COMPACTION

The mix shall be rolled as soon as possible after it has been laid by a combination of vibratory and static steel-wheel and pneumatic-tyred rollers in a sequence predetermined and approved during the laying of trial sections. Such rolling shall commence and be continued only for so long as it is effective and does not have any detrimental effect. The use of pneumatic-tyred rollers for continuously-graded asphalt with modified binders shall be assessed in the trial section.

As many rollers shall be used as is necessary to provide the specified pavement density and the required surface texture. During rolling of asphalt surfacing, the roller wheels shall be kept moist with only sufficient water to avoid picking up the material. A release agent, approved by the engineer, may be used instead of water.

After longitudinal joints and edges have been compacted, rolling shall start longitudinally at the sides and gradually progress towards the centre of the pavement, except on super-elevated curves, or where the area to be paved has a cross-fall, when rolling shall begin on the low side and progress to the higher side, uniformly lapping each preceding track, covering the entire surface. During breakdown-rolling the rollers shall move at a slow but uniform speed (not to exceed 5 km/h) with the drive roller nearest the paver, unless otherwise specified on account of steep gradients.

Three-wheeled steel rollers, with large diameter rear wheels are preferable to tandem rollers and may be used in conjunction with pneumatic tyred rollers, provided pick-up of the asphalt on the wheels does not occur.

The contractor shall take adequate precautions to eliminate pick-up.

The sequence of rollers used in compaction is at the discretion of the contractor provided the completed pavement shall have a density as measured on recovered core equal to or greater than 97 per cent, minus the percentage voids in the approved production mix, of the maximum voidless density, determined as described in TMH1 method C4.
Compaction shall be within the limits specified in the applicable statistical judgement scheme in COLTO clause 8206 or clause 8305.

For thin layer asphalt (less than 25 mm) the compaction requirements shall be specified in the project specifications.

The contractor shall utilize a calibrated nuclear gauge for process control during compaction operations. Notwithstanding this requirement, the acceptance control carried out for compaction by the engineer shall still be based on cores taken from the compacted layer.

The following requirements shall apply to rolling and compacting generally:

(a) The material shall not be excessively displaced in a longitudinal or transverse direction especially when changing gears, stopping or starting rollers.
(b) No cracks or hair cracks shall be formed and the bond with the underlying layer shall not be broken.
(c) The density shall be uniform over the whole area of the layer and extend over the full depth of the layer.
(d) Rollers shall not be left standing on the asphalt layer before it has been fully compacted and before the layer surface temperature has dropped below 60^{o} C.
(e) In restricted areas where the specified rollers cannot be used, compaction shall be carried out with hand-operated mechanical compaction equipment or approved smaller vibratory rollers. The prescribed density requirements remain applicable throughout over the full layer thickness irrespective of the method of compaction.

11 LAYING TRIAL SECTIONS

Before the contractor commences with the construction of any asphalt base or surfacing, he shall demonstrate, by laying a trial section of at least 100 tons, as specified, the area depending on the required layer thickness, that the equipment and processes that he proposes to use, will enable him to construct the particular asphalt course in accordance with the specified requirements.

The engineer may require that up to 3 different binder contents be incorporated in one such trial section to verify the laboratory design phase.
Amongst others the contractor shall submit the results of MMLS rut depth tests obtained from the testing of cores extracted from the completed trial section in locations determined by stratified random sampling methods, and/or, if specified, dynamic creep test results obtained from briquettes prepared from material obtained by stratified random sampling methods at the manufacturing plant or behind the paver as directed by the engineer.
A maximum period of 10 days shall be allowed to verify the results of the MMLS rut depth tests unless otherwise specified in the project specifications.

Only when such a trial section has been satisfactorily laid and finished, and complies with the specified requirements, will the contractor be allowed to commence with construction of the permanent work.

If the contractor should make any alterations in the methods, processes, equipment or materials used, or if he is unable to comply consistently with the specifications, the engineer may require that further trial sections be laid at the contractor's cost before allowing the contractor to continue with the permanent work.

The intention of this clause is to avoid any experimentation by the contractor on the permanent work.

The trial sections shall be laid where indicated by the engineer. The contractor shall prepare the surface on which to lay the trial section and shall also, if required, remove the trial section after completion and restore the surfaces on which it was constructed, all at the contractor's cost.

Provision is made for payment of the first approved trial section of any particular mix type, but subsequent trial sections with the same mix type shall be at the contractor's own cost. Payment will be made for the specified area of each approved first trial section for any particular mix type.

The construction equipment and techniques as well as the mix properties applicable to the approved trial section shall not be changed without prior approval by the engineer.

12 PROTECTION AND MAINTENANCE

The contractor shall protect asphalt base and asphalt surfacing from all damage until the work is finally accepted by the engineer and he shall maintain the surfacing work until the issue of the maintenance certificate. Excepting fair wear and tear on surfacing any damage occurring to the completed base or surfacing during the maintenance period, or any defects which may develop due to faulty workmanship, shall be made good by the contractor at his own expense and to the satisfaction of the engineer.

13 CONSTRUCTION TOLERANCES AND FINISH REQUIREMENTS

(a) Construction tolerances

(The application to overlays is specified in subclause 13 (e))

The completed sections of asphalt base and surfacing shall comply with the requirements for grade, width, thickness, cross section and smoothness stated below.

(i) Level and grade

The lot will comply with the requirements for surface levels if at least 90% of all surface levels are within the specified H_{90} tolerance, before any level corrections are made. Individual spots, where the surface level deviates by more than specified the H_{max} tolerance, shall be repaired to bring them to within the H_{90} tolerance.

H_{90} ………………………………………………………….. ± 15 mm
H_{max} ……………………………………………………... ± 20 mm

Deviation from the specified longitudinal grade due to deviations from the specified levels shall not exceed the values given below:

Length of variation in grade (m)	Maximum variation from specified grade %
2	0.354
5	0.224
10	0.158
20	0.112
30	0.091

(ii) Width

The average width of both asphalt base and surfacing shall be at least equal to that shown on the drawings and nowhere shall the outer edge of the layer be inside the lines shown on the drawings by more than 15 mm in the case of both asphalt base and asphalt surfacing.

(iii) Thickness

The layer will comply with the requirements specified for layer thickness if at least 90% of all the thickness measurements taken are equal to or thicker than the specified thickness, minus the specified D_{90} tolerance, before any thickness corrections are made, and the mean layer thickness for the lot is not less than the specified layer thickness minus the specified D_{ave} tolerance:

D_{90} base	= 15 mm	surfacing = 5 mm
D_{max} base	= 20 mm	surfacing = 8 mm
D_{ave} base	= 5 mm	surfacing = 2 mm

Thickness shall be determined from carefully controlled levels taken before and after construction in exactly the same position and/or from cores drilled from the completed layer.

(iv) Cross section

When tested with a 3 m straight-edge laid at right angles to the road centre line the surface shall not deviate from the bottom of the straight-edge by more than 6 mm for freeways and more than 10 mm for other roads.
At any transverse section the difference in level between any two points shall not vary from their difference in level computed from the cross section shown on the drawings by more than 15 mm for freeways and 20 mm for other roads.

(v) Surface regularity

When tested with a rolling straight-edge the number of surface irregularities shall not exceed those given below (applied to base and surfacing)

(1) Average number of irregularities per 100 m equal to or exceeding the specified value when taken over 300 m - 600 m lengths:

Freeways (3 mm irregularities) 3

Other roads (5 mm irregularities) 2

(2) Number of irregularities equal to or exceeding the specified value when taken over 100 m sections:

Freeways (3 mm irregularities) 5

Other roads (5 mm irregularities) 3

(3) The maximum value of any individual irregularity when measured with the rolling straight-edge or a 3 m straight-edge laid parallel to the road centre line:

Freeways . . . . 4 mm

Other roads . . . . 8 mm

(vi) Multiple-layer base

Where the base is constructed from more than one layer, the requirements specified shall apply to the combined layers in respect of width and thickness. The requirements for cross section, smoothness and grade shall apply to the final layer only, but the lower layers shall be constructed so as to ensure that these requirements in the final layer can be met.

(b) Gradings

The combined aggregate and filler grading shall not deviate from the approved target grading for the working mix by more than that given in table 3.4. The mean grading of each lot of the working mix (minimum of 6 tests per lot) shall be determined from samples obtained in a stratified random sampling procedure.

(c) Binder content

The binder content shall be within the limits specified in the applicable statistical judgement scheme in COLTO clause 8206 or clause 8305.

(d) Voids

The voids in the mix shall be within the limits specified in the applicable statistical judgement scheme in COLTO clause 8206.

(e) Construction tolerances for overlays

(i) When the overlay is constructed to specified levels on a layer that has also been constructed or milled to specified levels by the contractor, all the tolerance requirements of subclause 13 (a) shall be applicable.

(ii) When the overlay is constructed to specified levels on an existing layer, or on a layer which has been constructed or milled by the contractor, but which has not been constructed or milled to specified levels, all the tolerance requirements of subclause 13 (a) shall be applicable except those of subclause 13(a)(iii) which relate to thickness.

(iii) When the overlay is not constructed to specified levels and no guide wires are used, but an electronically controlled paver and a skid beam, the following tolerances shall apply:

The outer edges of the overlay shall nowhere be more than 15 mm inside or outside the lines shown on the drawings, and shall be parallel to the road centre line.

The minimum thickness shall be the specified nominal thickness.

The maximum thickness shall be the specified nominal thickness ± 10 mm.

The surface regularity shall be measured with a 3.0 m straightedge and no irregularity may exceed a value of 6 mm.

14 QUALITY OF MATERIALS AND WORKMANSHIP

(a) Sampling

Sampling of asphalt mixes shall be carried out according to method MB7 of TMH5, or as prescribed by the engineer.

Sampling for acceptance control for bitumen content and grading shall be carried out immediately behind the paver or as otherwise prescribed by the engineer.

Sampling of the binder shall be carried out at the discharge point of the delivery vehicle or adjacent to the discharge point into the mixer. Binder sampling shall comply with the relevant procedure as described in ASTM D140.

(b) Coring of asphalt layers

If required in the project specifications, the contractor shall provide suitable coring machines capable of cutting 100 mm diameter cores from the completed asphalt layers. The contractor will be paid in accordance with item 16.7 for cutting cores ordered by the engineer. The cost of extracting cores for process control shall be included in the contractor's prices for the construction of asphalt pavement layers and will not be paid for separately. The coring equipment, the programme, and the procedures must be approved by the engineer.
If the contractor does not adhere to the approved programme, the engineer may temporarily suspend the paving operations.
All core holes shall be neatly repaired with asphalt and compacted to the specified density. Wherever possible the cores shall be filled with the same mix as used for the layer tested.

A suitable coring machine shall be available on a daily basis when asphalt paving is taking place. Cores shall only be drilled, when the road temperature is 20^{o}C or less. Core holes shall be filled with hot mix asphalt and compacted, all within 24 hours of the core being drilled. Coring shall be carried out within 48 hours after the paving has been completed and supplied to the engineer. The test results of cores shall be submitted to the engineer within 24 hours after coring.

(c) Routine inspection and tests

Routine inspection and tests will be carried out by the engineer to determine the quality of the materials and workmanship for compliance with the requirements of this section.

Tests results and measurements will be assessed in accordance with the provisions of COLTO section 8200 or COLTO section 8300 as specified in the project specifications.

The contractor shall keep accurate records of:

(i) The position where every truckload of asphalt is paved (chainage, lane, time and date).

(ii) The temperatures of the asphalt in the trucks both at the mixing plant and at the paving equipment immediately prior to discharging the load.

(iii) The truck and load number from which control samples are taken. All samples taken shall be appropriately numbered.

(d) Special tests

n-Heptane-Xylene Equivalent (Spot test) (AASHTO-T102)

If the engineer suspects that bitumen or asphalt has been overheated, he may order that the bitumen, or the bitumen recovered from the asphalt, be subjected to the Spot Test. Recovery of binder for use in the Spot Test shall be carried out according to an approved method.

Any bitumen having an n-Heptane-Xylene equivalent in excess of 36, or in excess of the manufacturers test result on the dispatched stock, shall be considered to have been overheated and shall be deemed to be rejected unless proven otherwise.

15 VARIATION FROM SPECIFIED NOMINAL RATES OF APPLICATION OR NOMINAL MIX PROPORTIONS

The various sections of these specifications specify nominal rates of application or nominal mix proportions for materials such as bituminous materials, aggregates, fillers, and the like. Tenderers shall base their tenders on these nominal rates of application and mix proportions.

Where such nominal rates of application or mix proportions are specified, provision is made for deviations in the quantities of material in consequence of the rates of application or mix proportions prescribed by the engineer in each particular case in consideration of the available materials and the conditions on the site.

Where the actual rates of application or mix proportions used in the works vary from the specified nominal rates and mix proportions, adjustment of compensation will be made -

(a) as a payment to the contractor in respect of any authorized increase in quantities which exceed those specified, where such increase has been ordered, in writing, by the engineer;

or

(b) as a refund to the employer in respect of the decrease in quantities which are less than those specified, irrespective of whether such decrease results from an authorized decrease in the rates of application or mix proportions, or from unauthorised reductions on the part of the contractor.

Payment for a prescribed rate of application or mix proportion shall be based on the actual rate of application or mix proportion used, provided that this does not exceed the prescribed rate of application or mix proportion, plus any tolerance in the rate of application or mix proportion allowed. If the actual rate of application or mix proportion exceeds the prescribed rate or proportion, payment shall be based on the prescribed rate of application or mix proportion plus any tolerance allowed. If the actual rate of application or mix proportion is below the prescribed rate of application or mix proportion ordered, payment shall be based on the actual rate of application or mix proportion regardless of any tolerance allowed. Notwithstanding the above, the engineer shall be fully entitled to reject work that has not been constructed In accordance with the specifications or the rates of application or mix proportions prescribed by him.

The employer shall be refunded for any decrease in the specified rates of application or mix proportions at the same rate per unit of measurement as that tendered by the contractor for additional materials required by an increase in the rates of application or mix proportions.

16 MEASUREMENT AND PAYMENT

Items 16.11 and 16.12 are applicable solely to work that has to be executed in a restricted area of which the width is less than 3,0 m or the length is less than 150,0 m.

Item **Unit**

16.1 Asphalt base (state specified thickness, type of bitumen and maximum size of aggregate):

(a) Continuously graded . . . . . . square metre (m^2)

The unit of measurement shall be the square metre of asphalt base constructed to the thickness specified. When specified in the project specifications and/or indicated in the schedule of quantities, the unit of measurement shall be the ton of asphalt constructed as specified and measured according to certified weighbridge tickets issued in respect of mixture used. No payment will be made for material wasted.

The tendered rates shall include full compensation for procuring, furnishing, heating, mixing, placing and compaction of all materials including up to 12% RA, as well as process control testing, protecting and maintaining the work as specified.

When the unit of measurement is a ton of asphalt, the tendered rate shall also include full compensation for supplying and installing a weighbridge, and for weighing the material.

Item **Unit**

16.2 Asphalt surfacing (state specified thickness and type of bitumen):

(a) Continuously graded (grade stated) . . . . ………………..square metre (m^2)

The unit of measurement shall be the square metre of asphalt surfacing constructed to the thickness specified. When specified in the project specifications and/or indicated in the schedule of quantities, the unit of measurement shall be the ton of asphalt constructed as specified and measured according to certified weighbridge tickets issued in respect of mixture used. In the case of asphalt resurfacing, measurement by ton shall be obligatory.
No payment will be made for material wasted

The tendered rates shall include full compensation for procuring, furnishing, heating, mixing, placing and compaction of all materials including up to 12% RA, as specified as well as process control testing, protecting and maintaining the work as specified. When the unit of measurement is a ton of asphalt, the tendered rate shall also include full compensation for supplying and installing a weighbridge, and for weighing the material.

Item **Unit**

16.3 Tack coat of 30%
Stable grade emulsion . . . . litre (l)

The unit of measurement shall be the litre of 30% stable grade emulsion applied as specified.
The tendered rate shall include for the procuring, furnishing and application of the material as specified.

Item **Unit**

16.4 Binder variations: (state type) . . . . ton (t)

The unit of measurement in respect of increases or decreases in the bituminous binder from that specified in the nominal mix shall be the ton.

Payment for variations shall be made as specified in clause 15.

Item **Unit**

16.5 Variation in active filler content:

(a) Cement . . . .ton (t)

(b) Lime . . . .ton (t)

(c) Milled granulated blast-furnace slag ……ton (t)

(d) Fly-ash . . . . ….….…….ton (t)

The unit of measurement in respect of increases or decreases in the active filler content for base and surfacing mixtures from that specified in the nominal mix shall be the ton. No payment shall be made for inert filler added by the contractor.

Payment for variations shall be made as specified in clause 15.

Item **Unit**

16.6 Trial sections (nominal thickness indicated) . . . .…….……square metre (m^2)

The unit of measurement shall be the square metre of asphalt trial section constructed as ordered. The tendered rate shall include full compensation for the construction of the trial section of asphalt base or surfacing complete as specified, and for the application of a tack coat.

Item **Unit**

16.7 100 mm cores in asphalt paving . . . . …… number (No)

The unit of measurement shall be the number of 100 mm cores drilled irrespective of depth of core and recovered as instructed by the engineer for his own testing. No separate payment shall be made for cores drilled as part of the contractor's obligations under process control, the cost of which shall be included in the prices tendered for the various items of asphalt paving.
The tendered rate shall include full compensation for drilling the cores as directed, for all plant, fuel, labour and other incidentals necessary and for repairing.

Item **Unit**

16.8 Asphalt layer constructed for rehabilitation purposes in accordance with the provisions of subsubclause 13 (e)(i):

(a) Base constructed with asphalt containing up to 12% RA
(State specified thickness, type of bitumen and maximum size of aggregate)

(i) Continuously graded . . . . …………………square metre (m^2)

(b) Surfacing or overlay constructed with asphalt containing up to 12% RA (state specified thickness, type of bitumen and maximum size of aggregate)

(i) Continuously graded . . . . ……………….. square metre (m^2)

(c) Base constructed with recycled asphalt containing more than 12% RA
(State specified thickness) . . . . square metre (m^2)

(d) Surfacing or overlay constructed with recycled asphalt containing more than 12% RA
(State specified thickness) . . . . . square metre (m^2)

The unit of measurement for subitems (a) and (b) shall be a square metre of asphalt base, surfacing or overlay constructed to the specified thickness. The quantity shall be calculated from the authorized dimensions.
The unit of measurement for subitems (c) and (d) shall be a square metre of asphalt base, surfacing or overlay constructed with recycled asphalt consisting of recovered asphalt and new materials mixed in the prescribed ratio.
The quantity shall be calculated from the authorized dimensions.
The tendered rate for subitems (a) and (b) shall include full compensation for procuring, providing, heating, mixing, placing and compacting the material, process control tests, and protection and maintenance, all complete as specified.

Item **Unit**

16.9 Asphalt layer constructed for rehabilitation purposes in accordance with the provisions of subsubclauses 13(e)(ii) or 13(e)(iii):

(a) Base constructed with asphalt containing up to 12% RA
(State type of bitumen and maximum size of aggregate:

(i) Continuously graded . . . . ………………..ton (t)

(b) Surfacing or overlay constructed with asphalt containing up to 12% RA
(State type of bitumen and maximum size of aggregate)

(i) Continuously graded . . . . ………………..ton (t)

(c) Base constructed with recycled asphalt containing more than 12% RA ……………… ton (t)

(d) Surfacing or overlay constructed with recycled asphalt containing more than 12% RA. …………………………………………………………..ton (t)

The unit of measurement for subitems (a) and (b) shall be a ton of asphalt placed. The quantity shall be determined by means of certified weighbridge tickets issued in respect of the asphalt mix used. No payment will be made for asphalt placed outside the tolerances specified.

The unit of measurement for sub item (a) shall be the ton of asphalt base placed in compacted layer thickness not exceeding 60mm, and measured according to certified weighbridge tickets issued in respect of the mixture used.

The unit of measure for sub item (b) shall be the ton of asphalt overlay placed to the nominal thickness specified and measured according to certified weighbridge tickets issued in respect of the mixture used.

No payment shall be made for excess width and wastage of asphalt, and the mass of such excess or wasted material shall be deducted from the recorded delivery for payment purposes. No payment shall be made for asphalt in excess of the mean spread rate(s), which shall be determined as follows:

S = $\frac{1000}{AXB}$ m^2/ton where,

S = Mean spread rate in m^2/ton

A = Average bulk relative density achieved on the road in ton/m^3

B = (specified asphalt thickness in mm) + 5mm

The unit of measurement for subitems (c) and (d) shall be a ton of recycled asphalt consisting of recovered asphalt and new materials mixed in the prescribed ratio. The quantity shall be determined by means of certified weighbridge tickets issued in respect of the asphalt mix
used. No payment will be made for asphalt placed outside the tolerances specified.
The tendered rate for subItems (a) and (b) shall include full compensation for procuring, providing, heating, mixing, placing and compacting the material, process control tests, and protection and maintenance, all complete as specified.

The tendered rate shall also include full compensation for joint forming, temporary ramping of construction joints between paving operations when new work is opened to traffic (including ramping material), breaking up and disposal of temporary ramps and waste material, weighing the material on the specified weighbridge and cleaning the surface.

The tendered rate for subitems (c) and (d) shall include full compensation for supplying the new materials, taking recovered asphalt from stockpile, blending the materials in accordance with the nominal mix ratios specified in the project specifications, heating, mixing, placing and compacting the material, process control tests, and protection and maintenance, all complete as specified.
Payment will distinguish between different types of recycled asphalt in accordance with the project specifications. No extra payment will be made for small quantities of recycled asphalt.

Item **Unit**

16.11 Extra over items 16.1, 16.2, 16.8 and 16.9 for placing small quantities of asphalt of less than 10 tons specially produced
as specified in subclause 7(d) . . . . ………… ton (t)

The unit of measurement shall be a ton of asphalt of a specified composition, less than 10 tons of which is produced on occasion, as specified, and measured in accordance with the certified weighbridge tickets issued in regard to the mix used.
The tendered rate shall be paid as extra over the rates tendered for the items mentioned above, and shall include full compensation for all additional costs to produce and place small quantities of asphalt on the instruction of the engineer.
Payment will not distinguish between various types of asphalt or various types of asphalt layers.

Item **Unit**

16.12 Placing and compacting asphalt in restricted areas:

(a) Extra over items 16.1, 16.2 and 16.8. . . . . square metre (m^2)

(b) Extra over item 16.9 . . . . ……………………….ton (t)

The unit of measurement shall be a square metre or a ton of asphalt (in accordance with the unit of measurement for the item concerned), placed in restricted areas, the quantity of which shall be measured as specified for the item of payment concerned.
The tendered rates shall include full compensation for additional costs for executing the work in restricted areas.

Item **Unit**

16.13 Extra over item 16.3 for applying tack coat
in restricted areas . . . . ………………………litre (l)

The unit of measurement shall be a litre of 30% stable grade emulsion applied in restricted areas. The tendered rate shall include full compensation for additional costs for applying the tack coat in restricted areas, irrespective of the method of application.

Item **Unit**

16.14 Application of tack
coat to the edges of a layer . . . . ……………………………litre (l)

The unit of measurement shall be a litre of 30% stable grade emulsion applied to the edge of a layer against which asphalt has to be placed.
The tendered rate shall include full compensation for obtaining, procuring and applying the material, irrespective of the layer thickness, the method of application, or the size of the area over which it has to be applied.

Item **Unit**

16.15 Asphalt reinforcing complete
(state type) . . . . ………………………….square metre (m^2)

The unit of measurement shall be a square metre of reinforcing placed, complete as specified and accepted by the engineer. The tendered rate shall include full compensation for procuring, providing, placing and fixing all materials (irrespective of the quantity of reinforcing required) overlapping and cut-offs included, and for all transport, equipment, tools, labour, supervision and all other costs necessary for installing and protecting the reinforcing until the asphalt prime coat has been placed. The tendered rate shall also include full compensation for all special preparatory work required. If it is necessary to repair cracks in the underlying seal or asphalt layer, separate payment will be made therefore under the appropriate items of payment.

Item **Unit**

16.17 Backfilling of excavations for patching with:

(a) Asphalt base . . . . ton (t)

(b) Asphalt surfacing . . . . ton (t)

The unit of measurement shall be a ton of asphalt placed in accordance with the specified requirements. The quantity will be computed in accordance with the certified weighbridge tickets issued in respect of the asphalt mix.

Payment will not be made for wasted material.

The tendered rate shall include full compensation for procuring and providing all materials. irrespective of its origin, for all mixing, placing, compacting and finishing as specified, for all transport, work in restricted areas, and also for all machinery, equipment, labour, supervision and other incidentals for executing the work, complete as specified.

Payment for asphalt base and surfacing will not distinguish between the various types of asphalt. Item 16.10 for small quantities of asphalt shall not apply to patching.

Item **Unit**

16.18 Aggregate variations ....ton (t)

The unit of measurement in respect of increases or decreases in the aggregate content from that specified in the nominal mix shall be the ton.

Payment for variations shall be made as specified in clause 15.

Item **Unit**

16.19 Penalty for overloading .... ton (t)

The unit of measurement for the calculation of the penalty shall be the ton of mix transported in excess of the legal load. The rate applied shall be twice the contractor's tendered rate for placing the mix under 16.1, 16.2 or 16.9.

For the purposes of the calculation, the so called 5% grace shall not be used. The following example is provided:

Tare Weight of vehicle certified by RTI weighbridge = 6 tons
Maximum carrying capacity certified by RTI weighbridge = 8 tons
Gross vehicle mass = 14 tons
Actual Load (Weighbridge ticket) = 14.6tons
Overload = 0.6 tons

Contractors rate tendered under item B42.01 = R350/ton

Penalty = 2 x R350/ton x 0.6 tons
= R 420.00

Item **Unit**

16.20 Haulage and preparation of RA .... ton (t)

The unit of measurement shall be the ton of RA transported from a designated site to the asphalt mixing plant as well as its preparation. No payment will be made for material wasted

The tendered rates shall include full compensation for transporting the RA, measured it in accordance with the certified weighbridge tickets as well as crushing, screening, and stockpiling it in separate fractions as specified in clause 3(e).