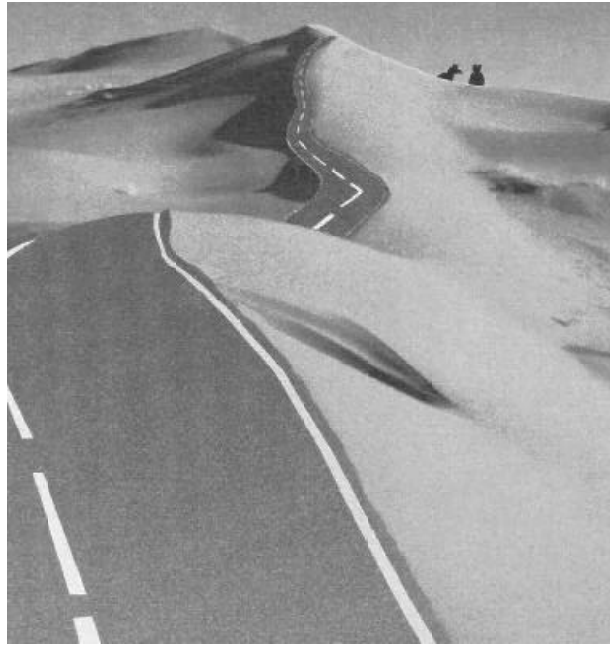


# APPROPRIATE STANDARDS FOR THE USE OF SAND ASPHALT



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## *Preface*

Manual 18 was produced as a guide for everyone involved in the use of sand as an aggregate for the production of premix asphalt. The guidelines contained in this document are based partly on the findings of the Sabita-sponsored research project Performance of Sand Asphalt (HH&O, 1990, 1991 and 1992). The background information required to produce this document is contained in two documents, namely "Engineering Performance of Sand Asphalt" (HH&O, 1992) and "Sand Asphalt - An Alternative Choice for the Road Ahead" (Onraët, 1993).



## *Scope*

This publication covers the mix ingredients of sand asphalt and looks at performance, applications and specifications. The manufacture and construction of sand asphalt are also considered with quality control and cost-effectiveness analysed. Sand asphalt is, indeed, a cost-effective asphalt surfacing alternative to surface seals for use in low volume road works.

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# Introduction

## Background

The use of sand as an aggregate for the production of premix asphalt — both hot and cold — goes back a long time and is widespread. The Cairo to Alexandria road was surfaced with sand asphalt in 1935 and it has been used for many years in northern Europe (eg in France, tapis sable a lapin and in the Low Countries, wet sand mix).

Closer to home, the first fully documented usage was in 1964 with the surfacing of the haul road at C.DM. Oranjemund (Marx, Faure, 1964). In the context of this manual, hot mix sand asphalt was developed over the last 20 years in various regions of South Africa in an attempt to produce a cost-effective alternative to conventional asphaltic surface treatment in appropriate circumstances, Many other projects across the borders have been reported, where similar technology has been used with much success (Netterberg, 1989). The product makes use of large deposits of under-utilised sands which comprise most of the aggregate and has been placed in many applications as a functionally acceptable surface for residential streets



Wearing course alternative to large shopping complex in Port Elizabeth

and parking areas in the Cape Town and Port Elizabeth areas.

## *Objective*

The research upon which this guideline is partly based was undertaken in an effort to formulate appropriate engineering control of sand asphalt. The appropriate standards are based upon the observation; and study of its engineering performance.

## *Methodology*

Firstly, an evaluation of the performance of existing sand asphalt projects was undertaken. Secondly, the engineering properties during both manufacture and construction were analysed. Thirdly, the influence of materials on the engineering properties of sand asphalt was studied in the laboratory. Lastly, all research was consolidated to form appropriate engineering standards for the use and expansion of sand asphalt as a cost-effective asphalt surfacing alternative to surface seals for use in low volume road works.

## Materials

### Sand

#### Cape Flats dune sand

Two typical sand deposits have been utilised, namely Philippi sand and Olieboom sand. Philippi sand has been used most extensively owing to sufficient deposits.

The Philippi sand is essentially a medium grained, single sized non-plastic dune sand. The sand generally has 100% passing the 2,00 mm sieve and less than 1% passing the 0,075 mm sieve, which is a crucial particle size for acceptable mix performance. Thus an appropriate filler is necessary to supplement this sand type.

#### Port Elizabeth pit sand

To date one sand deposit has been utilised, namely the Arlington pit sand. This is essentially a fine non-plastic sand. This sand also has generally 100% passing the 2,00 mm sieve and just over 2% passing the 0,075 mm sieve. Thus an appropriate filler is also necessary to achieve acceptable mix performance.

#### General regional sands

Research done in the mid '70s focused on the selection of nationally occurring sands for use in gap-graded asphalt mixes (Freeme, 1975). The study focused on the achievement of suitable engineering properties based on the sand properties. These criteria can be conservatively applied to sand asphalt because of the similar gap-graded structure.

The sands are divided into three categories as detailed in Table 1.

TABLE 1 Sand Selection Criteria (Freeme 1975)

Category A	Sands with a Sand Equivalent greater than 30	SE > 30
Category B	Sands with a Sand Equivalent between 15 and 30 but having either a fineness modulus greater than 1.0 and/or shape factor greater than 0.7	15 < SE < 30 and FM > 10 or SF > 0.7
Category C	Sands with a Sand Equivalent less than 15	SE < 15

Category A sands are suitable for sand asphalt, provided that inert filler is added to satisfy the grading recipe for minimum mix criteria.

Category B and C sands are not recommended for use in sand asphalt unless suitable performance can be proven.

Major well known sand deposits such as the Kalahari sands and the Red Berea sands have been assessed along with the Philippi sands and Arlington sand. These four sand types are all classed as Category A sands as per Table 2. The sand types used in sand asphalt thus far have typically 100% passing the 2,00 mm sieve.

Table 2 Sand Testing Results and Categorisation

SAND TYPE	S.E.	F.M.	S.F.	CATEGORY
Philippi	92.6%	1.93	0.74	A
Arlington	78.4%	1.94	0.54	A
Red Berea	81.3%	1.24	0.57	A
Kalahari	54.0%	1.42	0.41	A

## *Crushed aggregate*

The stone used so far has been a single size nominal 13,2mm crushed stone. In the Western Cape the stone is hornfels and in the Port Elizabeth area it is quartzite. At present the stone is that typically used in premix asphalt which conforms to SABS 1083.

## *Filler*

Filler is a very necessary aggregate fraction supplementing the natural sand fraction passing the 0,075 mm sieve to produce a mix with acceptable performance. The percentage added will depend on the passing 0,075 mm content of the natural sand grading.

The filler grading may vary considerably with the percentage passing the 0,075 mm sieve ranging between 70% and 100%. This must be taken into account when assessing the percentage passing the 0,075 mm sieve in the combined sand/aggregate grading.

The filler type which has been extensively used is rock flour or cyclone and bag filler dust which is generated in the manufacturing process of conventional asphalt. Other imported fillers such as fly ash, dolomitic or quartzitic flour may also be used. Cement and hydrated lime are also suitable, but are generally too expensive in the context of sand asphalt.

## *Bitumen*

At present a 80/100 penetration grade bitumen (B8 road grade) is used. The target bitumen content has generally been maintained at 4.5% on most existing projects.





## Recipe for sand asphalt

Sand asphalt is produced as a recipe mix, with recommended percentage stone, sand, filler and bitumen combinations. The filler content is a major variable, influenced by the percentage passing the 0.075 mm sieve of the natural sand.

Table 3 Suggested Sand Asphalt Recipe Limits

SAND ASPHALT MIXTURE RECIPE	
AGGREGATE COMPONENTS	LIMITS (%)
Crushed stone	20 - 30
Natural sand	60 - 80
Percentage passing the 0.075 mm sieve (natural sand and filler)	6 - 10
Target bitumen content	4.5

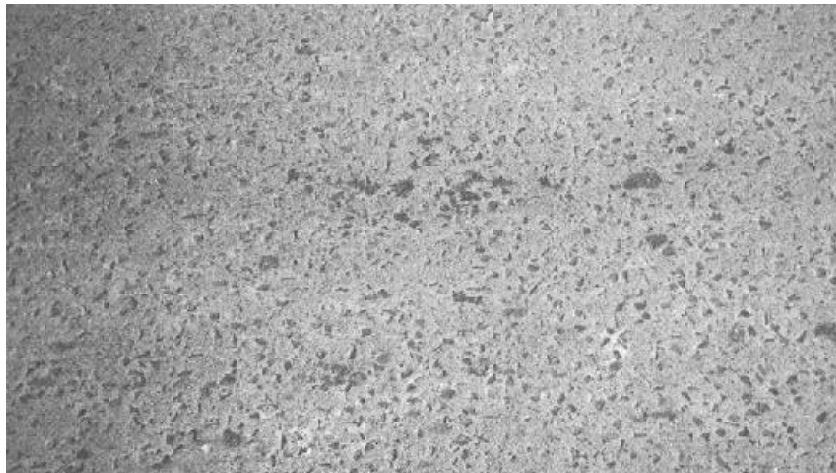


Sand asphalt is produced as a recipe mix, with recommended percentage stone, sand, filler and bitumen combinations

### Engineering properties

Engineering properties have been measured on the Cape Flats sand asphalt mix during manufacture and construction. The standard recipe is 30% 13,2 mm crushed stone, 64% natural Philippi sand, approximately 6% rock flour filler and a target bitumen content of 4,5%,

A laboratory study was also undertaken, where variations of the standard mix constituents were studied. The study involved varying the stone content between 0% and 40%, bitumen content between 4,5% and 5,5% and the filler grading. Two filler gradings were used - a fine sample with approximately 95% passing the 0,075 mm sieve and a coarse sample with approximately 73% passing the 0,075 mm sieve. The significance of these two gradings was such that the final grading of the sand asphalt with the fine filler had approximately 1,5% more passing the 0,075 mm sieve. This filler content was observed to have the greatest influence on the engineering properties of sand asphalt.



Good sand asphalt surface

TABLE 4 Engineering Properties of Sand Asphalt

ENGINEERING PROPERTY	STATISTICAL ANALYSIS		
	Mean (x)	Standard Deviation (Ø)	Sample size
Field Density (kg/m <sup>3</sup> )	2135	75,7	211
Marshall Density (kg/m <sup>3</sup> )	2254	53,2	566
Achieved Percentage Marshall Density (%)	942	2,6	211
Rices Density (%)	2510	17,0	566
Achieved Percentage Rices Density (%)	85	2,3	211
Field Voids (%)	15,7	3,2	211
Marshall Voids (%)	9,7	2,1	355
Permeability uncracked (litres/hour)	0,02	0,009	15
Permeability cracked (litres/hour)	2,1	0,84	4
Marshall Stability (kN)	8,0	2,9	566





It was found that negligible differences in the statistical results were evident when comparing engineering properties of samples taken during manufacture, samples taken from behind the paver and samples cored after construction (HHO, 1992). The means and standard deviations of all results is given in Table 4.



Fatigue cracking in sand asphalt



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### Density and voids

In normal construction practice, an analysis of actual results shows that a mean of 94,2% of Marshall density and 85% of Rice density are achieved. However, at the 90 percentile, 91% of Marshall and 82% of Rice densities are achieved.

Table 5 compares sand asphalt with current requirements in respect of density and voids and engineering properties for typical gap-graded, continuously graded and open graded asphalt mixes according to the TRH8, CSRA and recent tests at Transportek, CSIR, for mixes with unmodified binders (Verhaege, 1993).

In the laboratory, increasing the stone content from 0% to 40% results in a marked increase in density and a corresponding decrease in voids. This is shown in Figure 1 in Appendix A. An increase in the bitumen content from 4.5% to 5,5% results in a negligible increase in density and decrease of 2% in the voids. This is shown in Figure 4 of Appendix A. Changes in the filler grading did not produce significant differences in either density or voids. This is shown in Figure 6 of Appendix A.

### Structural Integrity

In general asphalt surfacings of less than 20 mm thickness are not regarded as providing any significant structural strength to the pavement. However, sand asphalt as a material has structural engineering properties very similar to conventional asphalt hot mixes at temperatures below 35°C. A mean Marshall stability of 8 kN is

achieved, as shown in Table 4 - 90% achieve a Marshall Stability of at least 5,1 kN,

Sand asphalt exhibits acceptable stiffness in terms of resilient modulus as well as fatigue life ranges comparable with other mixes with unmodified binders as is shown in Table 5. Fatigue testing gives an indication of the life expectancy of asphalt hot mix under traffic loading. Table 5 also includes existing ranges of structural criteria for standard asphalt mixes.

In the laboratory, it was found that increasing the stone content from 0% to 40% results in an increase in Marshall stability, resilient modulus and fatigue life. These results are presented in Figures 2 and 3 of Appendix A. Stone contents of between 20% and 30% provide acceptable structural integrity compared with standard asphalt hot mix. Increasing the bitumen content from 4,5% to 5,5% results in a small decrease in the Marshall stability and resilient modulus as is shown in Figure 5 of Appendix A.

The variation in the two filler gradings used had a marked influence on the structural integrity of sand asphalt.

The decrease in the minus 75 mm fraction resulted in a mix with far less deformation resistance and almost negligible fatigue life. The results of this testing are presented in Figures 7 and 8 of Appendix A.



Sand asphalt has structural engineering properties very similar to conventional asphalt hot mixes at temperatures below 35°C

TABLE 5. Comparative Asphalt Mix Criteria

ENGINEERING PROPERTY	GAP GRADED ASPHALT (TRH8)	CONTINUOUS GRADED ASPHALT (TRH8)	OPEN GRADED ASPHALT (*)	SAND ASPHALT (90TH p) measured results
Marshall Stability (kN)	4,0 - 10,0	4,0 - 10,0	not applicable	5,1 - 17,0
Voids (%)	2,0 - 5,0	2,0 - 5,0	13,0 - 25,0	4,5 - 16,0
Marshall Density (%)	95%	95%	not applicable	91%
Rices Density (CSRA) (%)	92%	92%	not applicable	82%
Resilient Modulus (MPa) (*)	2 000 - 6000	4 000 - 10 000	not established	2 000 - 8 000
Fatigue Life (Repetitions) (*)	Not established	30 000 - 100 000	30 000 - 60 000	20 000 - 90 000

\* These results are not statistically proven (Verhaeghe, 1993)

### Permeability

A main requirement of thin asphalt surfacing is to provide a durable impermeable seal to the pavement layer works. Low permeability promotes long-term pavement durability and protects the pavement structure from ingress of water, leading to stripping and air causing oxidation of the binder.



Longitudinal cracking in sand asphalt



Crack sealing with slurry

One such non-destructive measurement of this property is a falling head permeability test performed with the Marvil Apparatus (Viljoen et al, 1983). During visual inspections of certain sand asphalt projects, local areas with construction induced cracking were observed. In a few instances these cracked sections have been sealed with bitumen slurries. The test was performed insitu to assess the general permeability of uncracked and cracked sand asphalt and the extent to which slurries are able to seal them. Results of this testing indicate that for all practical purposes sand asphalt is impermeable (HHO,

1992) with a mean permeability of 0,02 litres per hour measured on uncracked sections and 2,1 litres per hour on cracked sections where 6,0 litres per hour is considered to be an acceptable maximum in conventional asphalt surfaces. Sealing with various slurries render the cracked areas as impermeable as uncracked sections.

Although sand asphalt can be regarded as a mix having higher voids than continuously and semi-gap graded hot mix, the voids are disconnected as opposed to continuous mixes where the voids are interconnected, It was also found that no correlation existed between field density and permeability in the statistical ranges in which sand asphalt falls, This is given in Table 4 (HHO, 1992).

The bitumen content is kept as low as possible for economic reasons, A content of 4,5% is deemed to be a suitable cutoff minimum. Contents below this could lead to ravelling owing to inadequate bitumen film thickness of the large surface area of the combined aggregate. The small increase in density and decrease

in voids which is evident is not expected to play a significant role in decreasing the permeability of this already impervious mix.



## *Performance under traffic*

Another major requirement of sand asphalt is to provide an acceptable riding surface for the road user as well as providing a socially acceptable and user-friendly surface. Each project's performance has been rated on the approximate percentage of the surface area showing visible distress as well as the severity of the distress in accordance with the TRH6 and TRH12 criteria. The observed projects were in the Cape Town and Port Elizabeth areas and included new residential streets in large and small, low and medium cost residential developments, parking areas as well as overlays to various surfaces. All are between two and six years old.

## *Deformation*

Sand asphalt is currently paved to provide a compacted thickness of approximately 20 mm as a surfacing layer for low volume and low load applications, and consequently only a minor contribution to pavement deformation is expected. On all projects inspected only local minor deformation of consequence was observed. No traffic induced rutting or shoving was observed on any of the projects.

## *Cracking*

Three types of cracking have been observed on paved sand asphalt namely, construction induced cracks, cracks resulting from external factors and very limited traffic induced fatigue cracks.

Construction induced cracks were observed to occur during paving and compaction as fine (approximately 1 mm crack width) closely spaced (approximately 30 mm) cracks occurring parallel to the rolling axis. These cracks occurred only on residential streets where existing specifications called for 95% Marshall density and not on parking areas where this density requirement has not been enforced. Cracks induced by external factors (other cracks) were



Compaction cracking in sand asphalt

observed on most projects. These occurred as longitudinal, transverse cracks, These also occurred shortly after construction in lengths varying between a few centimetres up to many metres with crack widths between 1 mm and 3 mm. These cracks are probably caused by shrinkage and volume changes in the pavement support. They have not resulted in any

significant problems on any of the observed sections On one experimental section it was observed that increasing the stone content from 30% to 40% resulted in a reduction in the occurrence of this type of crack by a factor of up to four.

Fatigue cracks (traffic related) were not observed on any of the recent projects owing to low traffic loading, On one 14 year old experimental section, some severe fatigue cracks in the form of crocodile cracking were observed. These cracks were not, however, unique to sand asphalt and occurred with the same severity on adjacent continuously graded asphalt surfacing, indicating substrate distress common to both surfacing materials.

### Ravelling

Aggregate loss can occur during construction when either the mix is paved at below optimum temperature or backscatter is done using too cool a mix, Under



Ravelling of sand asphalt

traffic, a small portion of the sand, filler bitumen mortar is worn away, leaving the stone aggregate partially exposed. This wearing action, although classed as aggregate loss, has been observed to improve the skid resistance of the normal smooth surface texture of sand asphalt, creating an acceptable skid resistance for urban traffic.

Sand asphalt does not exhibit the stone loss associated with surface seals, especially in parking areas, its smooth texture provides an excellent recreation surface in the residential areas where it has been paved.

### *Disintegration*

The durability of all asphalt materials is affected by factors such as binder oxidation, ultraviolet radiation and temperature changes. Sand asphalt is particularly sensitive to petroleum products which soften the bitumen when spilled on the surface. Oil spillage has been observed to cause minor damage in the form of surface sand loss but petrol and diesel fuels readily dissolve the binder, leaving the sand to be removed by traffic. If the surfaces are left alone the spillage may evaporate leaving the surface intact.



*Disintegration of sand asphalt*

### *Rubble*

On many of the residential street projects in the Western Cape large proportions of the surface areas are covered by rubble in the form of debris and wind blown sand. An advantage of the smooth surface texture of sand asphalt is that clearing operations are made easier than with other rougher surface textures.

## Residential streets

Traffic in these areas is mainly low volume and low load. Sand asphalt has been paved on many small, medium cost and large, low cost residential developments mainly in the Cape Town area. The surface mix is applied on from 100 mm to 150 mm of natural gravel or crushed stone base with natural gravel subbase or sand selected layers as a support placed on the insitu sand sub-grade. After between one and 12 years of traffic, the mix is still performing as an effective wearing course.

The current surfacing options in these areas include gravel, conventional asphaltic hot mix, surface seals and sand asphalt. An appropriate choice between these options is made easier by looking at some of the socio-economic influences. These are summarised in Table 6.



Good skid resistance is provided at this intersection in Khayelitsha, where aggregate is more exposed



**TABLE 6 Socio-economic Factors**  
(low volume application < 200 vehicles per day)

WEARING COURSE	SOCIAL FACTORS	ECONOMIC FACTORS
Gravel	<ul style="list-style-type: none"> <li>- poor riding surface</li> <li>- dusty in summer</li> <li>- muddy in winter</li> <li>- of no recreational value</li> </ul>	<ul style="list-style-type: none"> <li>- low construction cost</li> <li>- high maintenance</li> </ul>
Surface Stone Seal	<ul style="list-style-type: none"> <li>- good riding surface</li> <li>- difficult to keep clean</li> <li>- rough playing surface</li> </ul>	<ul style="list-style-type: none"> <li>- low/medium construction cost</li> <li>- moderate maintenance cost</li> </ul>
Hot-Mix Asphalt	<ul style="list-style-type: none"> <li>- good riding surface</li> <li>- easy to keep clean</li> <li>- semi-smooth playing surface</li> </ul>	<ul style="list-style-type: none"> <li>- high construction cost</li> <li>- low maintenance</li> </ul>
Sand Asphalt	<ul style="list-style-type: none"> <li>- very good riding surface</li> <li>- easy to keep clean</li> <li>- smooth playing surface</li> </ul>	<ul style="list-style-type: none"> <li>- medium construction cost</li> <li>- low maintenance</li> </ul>



### *Parking areas*

Traffic volume and loading associated with parking areas vary depending on the application. For the observed projects the application has been mainly parking areas at shopping complexes and other industries where usually light vehicle traffic is found. As has been mentioned in Chapter 3, very good performance has been observed up to four years after construction at many busy shopping complexes in both the Cape Town and Port Elizabeth areas.

The spillage of oil and fuels was noted at many parking areas. These petroleum spillages do, however, occur mainly in untrafficked areas under parked vehicles and were not observed to impair the functional performance of the surfaces.



### *Overlays*

A recent application of sand asphalt in the Cape Town area is as an overlay to parking areas and residential streets. The surfacing is applied after necessary maintenance repairs are completed.

The benefits of sand asphalt as an overlay are as follows:

- improves surface rideability
- provides an impermeable seal depending on the thickness;
- enhances the structural integrity of the pavement where stone seals and slurries do not



### *Application limitations*

Sand asphalt should not be paved as a structural load bearing layer for large volumes of heavy duty traffic.

Sand asphalt, like stone seals and slurries, is more sensitive to petroleum spillage than conventional hot mix asphalt.

Sand asphalt has a smooth surface texture and should not be used for high speed areas due to its low skid resistance.

Sand asphalt is not recommended as an overlay to concrete slabs. Due to the low binder content, it has poor flexibility and consequently low resistance to reflective cracking. Both joint movement in the concrete surface as well as the variable thickness required make a hot mix with a continuous grading and more flexible nature preferable.

## General

The objective of revised specifications is to encourage the current application and use of a cost-effective alternative asphalt surfacing to stone seals and slurries in the context of appropriate standards.

## Specifying Sand Asphalt

Sand asphalt should be specified as a recipe type mix with between 20% and 30% conventional crushed 13,2 mm stone, between 60% and 80% naturally occurring sand, a filler content such that the final percentage passing the 0,075mm sieve is between 6% and 10% and a target bitumen content of 4,5%.



### Access to future residential and industrial developments in Gordon's

Rices density A maximum permeability of 1 litre per hour using the Marvil apparatus or equivalent should be specified.

A sand asphalt surface may be specified for urban low volume and slow vehicle speed residential streets and parking areas with traffic loading not exceeding the TRH4 E 1/E2 category.

It should not be specified for areas where fuel spillage is expected in vehicle paths nor is it suitable as an overlay for concrete slabs.

A proposed specification is presented as Appendix B A standard pro forma mix design is given as Appendix C and a worked example of a complete design process is given as Appendix D.

In addition to the proposed specification of Marshall density, sand asphalt may be checked using an achievable 82%




### *General*

The manufacturing process of sand asphalt is almost identical to that of conventional hot mix asphalt. There are, however, a few factors which need to be mentioned.



### *Aggregates*



The sand used is expected to originate from natural deposits which may be variable and at times moist to saturated. These wet sands can cause the generation of steam within the mixing plant, which can have an adverse effect on the normal dust collection system. These collection systems often include filter bags which can become clogged and less efficient.

Saturated sands can reduce plant production rates for sand asphalt by up to 35%.



### *Stockpiles*

Once the natural sand source is accepted, a system of twin stockpiles must be adopted at the mixing facility. This means building up and testing one stockpile while using a second stockpile which has already been tested and passed as fit for use.

Aggregate stockpiles should be stored and used in such a way that contamination is prevented and adequate protection against wind-blown sand and dust is provided.



### *Hot storage*

Sand asphalt is not suitable for storage in surge bins or hot storage silos for extended periods. Clogging of the mix occurs and it becomes difficult to extract.

## Paving

The manufacture temperature of sand asphalt should not exceed 160°C, and during placement and compaction should be between 110°C and 140°C.

It is essential to ensure that the sand asphalt is placed on a well swept base with fresh prime or at least a substantial tack coat, to ensure adequate adhesion to the underlying support layer. In the event of poor bonding, the occurrence of roller-induced cracking will be increased.

Paving equipment must be in excellent condition because if screed plates are worn or not set correctly, paver-induced cracking and mat tearing will occur. The spreader box must be kept full at all times. In most instances this tearing is closed up by the kneading action of the pneumatic tyred roller (see compaction below).

It is important to note that to ensure good quality in the placement of sand asphalt, there is no second chance - it must be paved correctly first time due to the material not being conducive to handwork or remedial repair work.

## Compaction

Sand asphalt is usually a tender mix and as a result the surfacing needs to be protected from construction traffic and other damaging activities too soon after paving.

Compaction techniques will include static and vibratory steel wheeled as well as rubber wheeled pneumatic rolling in various combinations. Heavy vibratory or heavy static compaction should not be used. In an effort to achieve high densities, the mix has in many instances been subject to excessive compaction early in the compaction phase. This has increased the occurrence of fine, closely spaced cracks parallel to the rolling axis.

When this cracking occurs, excessive permeability has been observed and further sealing has, in the past, been necessary. Fine cracks can often be sealed with pneumatic roiling, but this sealing may be only superficial. There is evidence that the cracks remain beneath the surface and become evident later in the life of the pavement.

Strategies adopted to overcome construction cracking have also varied, with success being reported in many cases by the exclusion of vibratory compaction and applying the pneumatic roller in the breakdown position to assist the mix in bedding down. Other strategies have involved firstly the use of static steel wheeled rolling followed by pneumatic rolling. The linear load of the steel wheeled rollers is critical - the range should be from 10 to 23 kg/cm. It is advisable to reduce the ballast and tyre pressure if cracking occurs with the pneumatic roller. The recommended weight per wheel for this roller is 2 to 3 tonnes. In principle, a number of light rollers should be used to compact sand asphalt rather than fewer heavy rollers.

Unlike conventional hot mix asphalt, sand asphalt cannot be successfully compacted at temperatures above 140 C, because of the phenomenon known as "peeling". This occurs when the mat does not compact and the top +5 mm of the material peels off under the roller wheels. This is due to a cold skin developing. This skin then breaks up into pieces due to the hotter and softer mix beneath. Excessive water on the wheels of a steel wheeled roller can induce "peeling".



### *Surface markings*

It has been found that owing to the dense, impervious and smooth surface finish of sand asphalt, certain road marking paints do not bond well with the surface. The paint does not penetrate the layer, dries proud of the surface, and eventually frets or peels away.

In such instances, advice from road marking paint suppliers is advisable. Road marking should if possible be delayed by a few weeks after construction, so that traffic can roughen the surface.



### *Process control*

The aggregate quality should be checked for compliance with SABS 1083 and the sand must be clean, without organic matter, and comply with the sand equivalent requirements of SABS 1083 (See Table 1, page 12.)

Process control during manufacture must ensure that the recipe is adhered to by maintaining mix proportions. The combined grading should comply with the design grading within specified tolerances, bearing in mind the sand source. The filler content, i.e. the fraction passing the 75 micron sieve, is the most important fraction.

Binder content must also be determined for each sample and must comply with the design to a tolerance of plus or minus 2%. Great care must be exercised in sampling as any aggregate segregation will have a marked effect, not only on the combined grading but also on the binder content results. This is due to the surface area of a given mass of sand being so much greater than an equivalent mass of coarse aggregate.

Should the grading of the sand fraction of the combined grading fail outside the specified tolerances, then the sand source must be checked. It may be that the sand is naturally variable, in which case the sensitivity of the design should be investigated. Experience shows that voids, stability and flow are frequently not sensitive to the degree of grading variation normally occurring in sand deposits. The filler fraction is far more important.



### *Acceptance control*

Quality control is carried out after construction to assess the finished sand asphalt layer against the requirements of the specification. Firstly, a visual inspection must be carried out for:

- roller induced cracking or "peeling"
- paver screed drag or tear cracking
- major surface blemishes caused by excessive or careless handwork.

Secondly, the water permeability of the layer should be checked. Refer to Chapter 3 for discussion on acceptable values.

Finally, compacted density must be measured using a thin layer nuclear densimeter. Cored or slab cut samples are not suitable for density measurements of sand asphalt. The thickness of the layer and the nature of the material are such that it is impossible to recover an undisturbed sample. It is suggested that a minimum density of 91% Marshall is acceptable or 82% maximum theoretical density (Rice's).

Cracked, blemished, excessively permeable and low density areas must be sealed with a:

- bitumen emulsion fog spray
- application of a filled bitumen emulsion
- slurry seal



Quality control is carried out after construction to assess the finished sand asphalt layer against the requirements of the specification.



### *Initial direct costs*

A direct cost comparison between sand asphalt and conventional hot mix can be made but when comparing it with stone seals of various types, the costing is more complicated as economies of scale must be considered. Prices per square metre on the road are substantially effected by volume and location.

There are specific circumstances under which the employment of sand asphalt as a wearing course for lightly trafficked roads should be considered. They are:

- When the road passes through sandy terrain where aggregate is not readily available or very expensive, eg Kalahari Namib deserts
- Where there is a plentiful supply of easily won dune sand, eg Cape Flats
- Where there is commercially available sand, either wind or water born, which is significantly cheaper than crushed aggregate, eg Port Elizabeth, Durban. In this context, the older mine dumps of the Witwatersrand have been a source of sand suitable for premix asphalt and very much cheaper than crushed aggregate.



Access to residential areas for lower income group housing developments in Khayelitsha, Cape

In these circumstances a direct cost comparison with conventional hot mix using crushed aggregate shows sand asphalt to be up to 20% cheaper ex-plant. Because it is possible to pave a thinner layer, a saving of up to 35% per square metre can be achieved.

Stone (chip) seals are generally cheaper than thin sand asphalt layers by up to 30% but the introductory remarks apply. In addition, where pedestrian activity is significant, the coarser surface of the seal may be socially unacceptable and chip whip-off in early life a real hazard.



### *Life Cycle Costs*

Numerous sand asphalt applications in southern Africa are many years old. A portfolio of projects would include amongst others:

- Consolidated Diamond Mines, Oranjemund, Namibia; 1963
- Jwaneng Sand Asphalt Experiment, Botswana. 1979
- Various applications, including parking areas, Port Elizabeth, Durban and Johannesburg
- Residential streets, Mitchell's Plain and Khayelitsha, Cape 1988 onwards.

The last named have received a lot of attention and inspection reveals that apart from localised areas of construction-induced cracking, little maintenance has been required. Where it has, this has been limited to fog sprays and slurry sealing. In general these streets show no significant signs of traffic related distress.

It is not possible to carry out a life cycle cost analysis of sand asphalt in general at this stage owing to limited long-term performance data. However, it is expected to offer substantial savings in user costs and in maintenance over its lifetime when compared to stone seals. In comparison with conventional hot mix asphalt it is indicated from inspection that at temperatures below 350C a similar life span can be expected in terms of structural integrity. As a consequence of sand asphalt's lower initial cost and of maintenance observed to date, a lower life cycle cost is indicated for lightly trafficked roads.

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*Appendix*

**A**

*Engineering Performance Results*

*A1 - Influence of Stone Content*

*A2 - Influence of Bitumen Content*

*A3 - Influence of Filler Type*

## A1 - Influence of Stone Content

FIGURE 1 Marshall density/Void content vs Stone Content  
(Cape Flats sand recipe mix)  
(Bitumen 4,5%, fine filler)

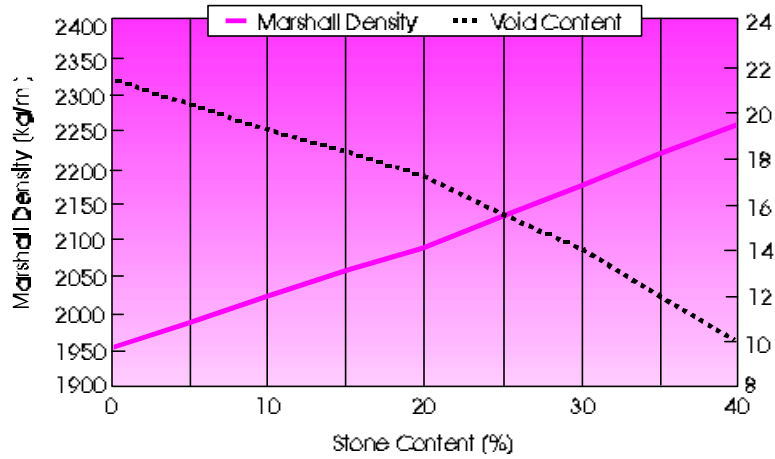
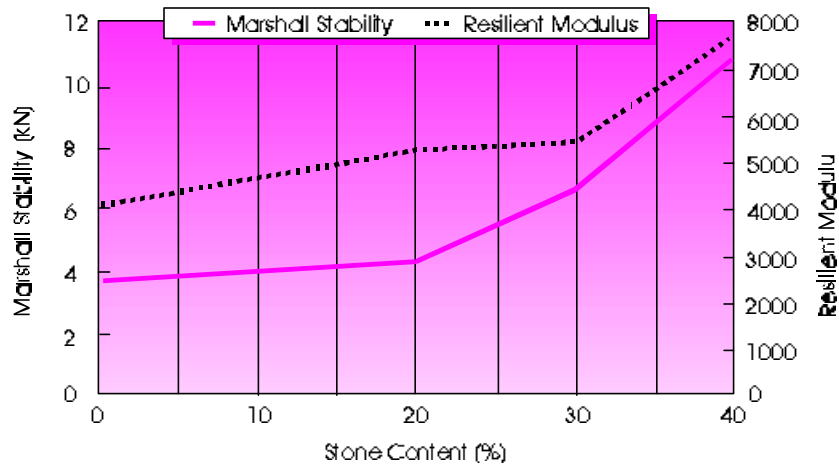
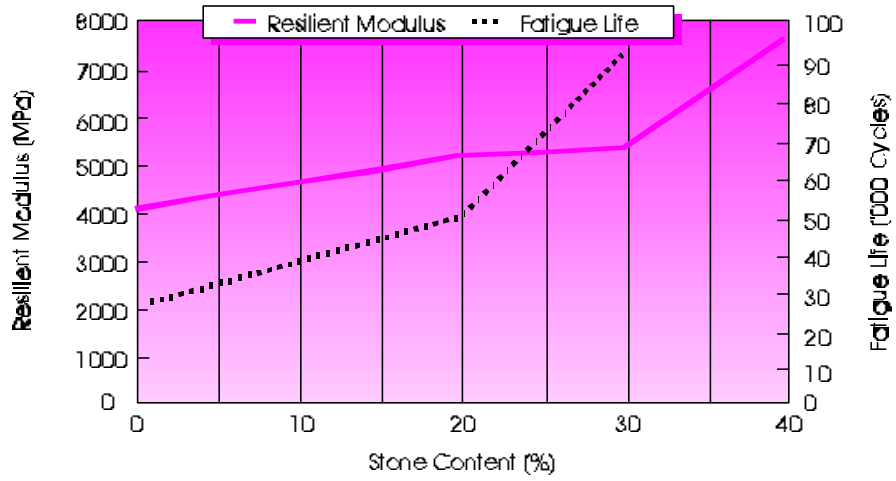


FIGURE 2 Marshall Stability/Resilient Modulus vs Stone Content  
(Cape Flats sand recipe mix)  
(Bitumen 4,5%, fine filler)

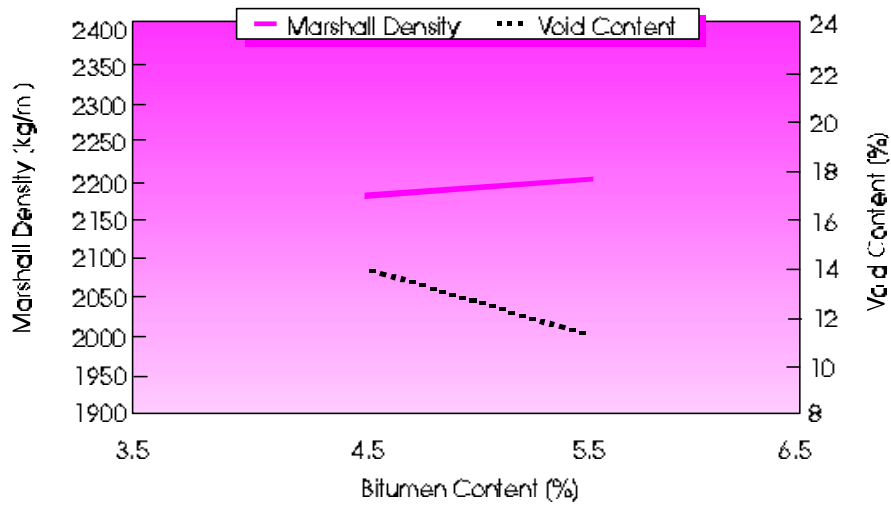


**FIGURE 3** Resilient Modulus/Fatigue Life vs Stone Content  
 (Cape Flats sand recipe mix)  
 (Bitumen 4,5% fine filler)

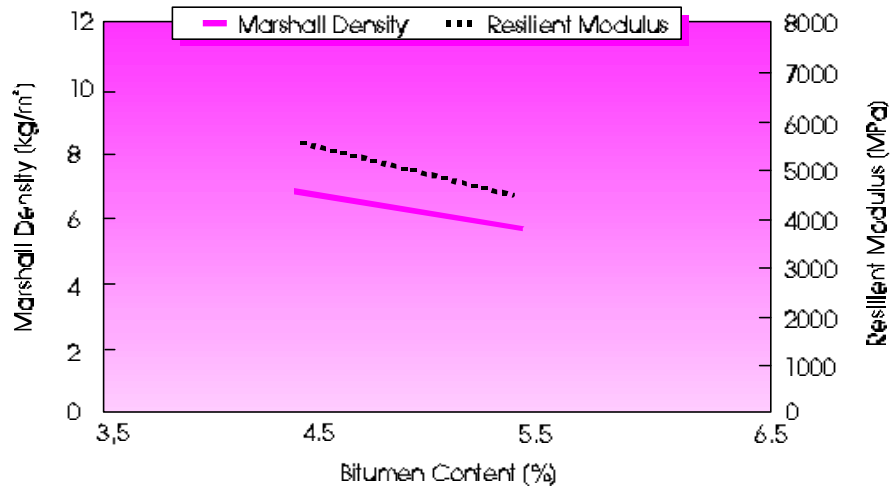


**A2 - Influence of Bitumen Content**

**FIGURE 4** Marshall Density/Void Content vs Bitumen Content  
 (Cape Flats sand recipe mix)  
 (Stone content 30%, fine filler)

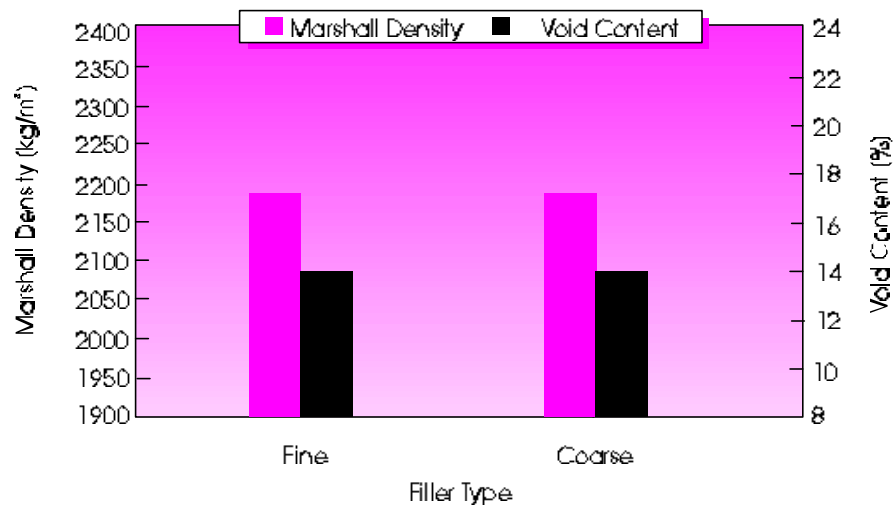


**FIGURE 5** Marshall Density/Resilient Modulus vs Bit. Content  
 (Cape Flats sand recipe mix)  
 (Stone content 30%, fine filler)

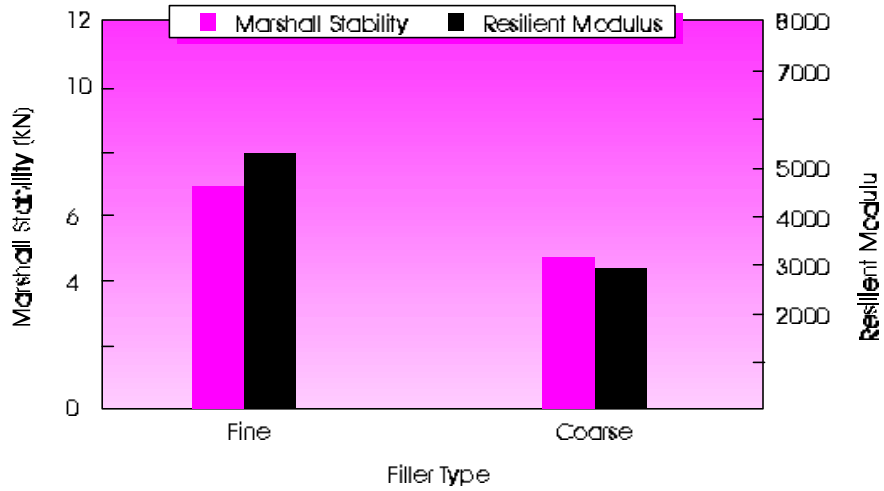


### A3 - Influence of Filler Type

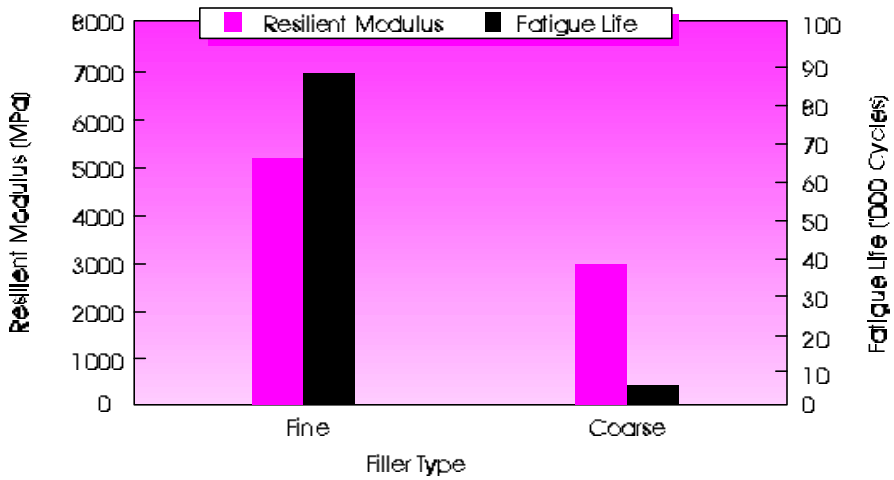
**FIGURE 6** Marshall Density/Void Content vs Filler Type  
 (Cape Flats sand recipe mix)  
 (Stone content 30%, bitumen 4,5%)



**FIGURE 7** Marshall Stability/Resilient Modulus vs Filler Type  
 (Cape Flats sand recipe mix)  
 (Stone content 30%, bitumen 4,5%)



**FIGURE 8** Resilient Modulus/Fatigue Life vs Filler Type  
 (Cape Flats sand recipe mix)  
 (Stone content 30%, bitumen 4,5%)





## Proposed Sand Asphalt Specification

### Scope

The sand asphalt is intended as an alternative to conventional bituminous surface treatment methods.

### Definition

“Sand asphalt surface layer” is a recipe-type hot mix asphalt in which the aggregate consists of natural or crusher sand, mineral filler and some 13,22 mm aggregate.

### Materials

#### Prime

Prime shall consist of a cut-back bitumen of type and grade designation MC-30 or MC-70 complying with the applicable requirements of SABS 308.

#### Tack coat

Tack coat shall consist of a bitumen emulsion complying with the applicable requirements of SABS 309 or SABS 1260 and of sufficient stability to allow for dilution.

#### Bituminous binder

The bituminous binder shall be a penetration grade bitumen of between 60 and 100 penetration, complying with the applicable requirements of SABS 307

#### Aggregates

13 mm crushed aggregates for use in sand asphalt surface mixes shall be obtained from an approved commercial source and shall comply with the requirements of SABS 1083 for Grade S or Grade N as ordered. Sand for use in asphalt surface mixes shall be obtained from an approved source and shall have a minimum sand equivalent value of 30.

### **Mineral filler**

Mineral filler shall consist of dust which is recovered from the normal hot mix plant cyclones and/or bag filter installation during the manufacturing process.

### **Mix composition**

#### **Combined aggregate**

The sand asphalt surface layer shall consist of a recipe mix in which:

- between 25% and 40% of the combined aggregates shall consist of a nominal 13,22 mm aggregate;
- at least 60% of the combined aggregate shall pass the 2,0 mm sieve;
- the mean value of the percentage passing the 0,075 mm sieve of any construction lot (normally a day's work) shall be between 6% and 9%.

#### **Binder content**

The sand asphalt mix shall have a nominal binder content of 4,5%.

#### **Design**

The contractor shall submit his recipe mix to the engineer for approval. As a guide, the mix should have the following properties:  
Marshall stability: 3.5kN minimum  
Static Creep Modulus 35MPa minimum

## **Construction**

#### **Temperature of the mix**

The temperature of the sand asphalt mix on arrival on site shall not exceed 170°C and during compaction shall not be lower than 110°C.

#### **Application of sand asphalt**

##### **Prime coat**

The surface of the base or sub-base, as the case may be, shall be cleaned and approval shall be obtained before any further work is done.

Prime coat of the type and grade specified shall be sprayed at the rate of application as ordered by the engineer

#### **Tack coat**

Where in the opinion of the engineer, the primed surface has become so contaminated or aged that a satisfactory bond will not be achieved with the sand asphalt surface layer, a tack coat shall be applied. Where ordered by the engineer, a tack coat shall be applied at the rate of 0,25 litres per square meter net cold binder.

#### **Surface thickness required**

The surfacing shall be a sand asphalt surface treatment, having a minimum average thickness for a day's work of not less than 20 mm.

#### **Paving**

The sand asphalt surface treatment shall be paver laid, although in places inaccessible to the paver, the sand asphalt may be placed by hand. Such handwork shall be kept a minimum to the satisfaction of the engineer.

#### **Trial section**

The contractor shall construct the first lot of work as a trial section in which he shall demonstrate to the engineer that he can achieve with his paving and rolling equipment a satisfactory surface finish and compaction such that a surface is produced with a permeability of not more than 2 litres per hour, as determined by the Marvil test. The engineer will carry out field density and materials property control tests on the trial section. Providing that satisfactory densities and surface finish are achieved, further work will be judged on the basis of the contractor's trial section method and surface finish. Routine tests will be carried out on the material's properties and the engineer may from time to time carry out field density tests. Payment will be made for the construction of trial sections only as ordered by the engineer.

### Quality control

The results achieved for the trial section shall be used as a basis for both mix and paving quality control. The working mix composition will be judged according to the proposed grading and binder content using the tolerances specified below:

### Mixed Aggregate

SIEVE SIZE (mm)	TOLERANCE (%)
4,75	10
2,36	10
0,300	8
0,075	2

### Binder content

The bituminous binder content of the sand asphalt mix shall not deviate from the specified value by more than 0,5% (m/m).

### Application tolerances

#### Thickness

The thickness determined from cores cut from the layer shall not, at any point, be less than the specified minimum average thickness for the day's work by an amount of more than 5 mm.

#### Prime and tack coats

The rates of application of each prime and tack coat shall not differ from the specified rate of application order by the engineer, by more than 5%.

### Weather limitations

#### Prime and tack coat

No prime or tack coat shall be applied:

- during rainy or foggy weather;
- when the wind is, in the opinion of the engineer, blowing sufficiently to interfere with the spray work;
- in the case of prime application, when the temperature of the road surface, immediately before the intended time of the application of prime, is below, or in the opinion of the engineer, likely to fall below 10°C.

- if the moisture content of the base is more than the greater of 3% or 50% of the optimum moisture content as determined by the engineer

### **Sand asphalt**

No sand asphalt shall be applied:

- if the moisture content of the upper 50 mm of the base is more than the greater of 3%, or 50% of the optimum moisture content, as determined by the engineer;
- when there is free water present on the road surface;
- when the road surface temperature is below 10°C

### **Surface cracking - remedial work**

Where surface cracks occur and, in the opinion of the engineer, the permeability of the sand asphalt surface treatment will allow ingress of water that will adversely affect either the sand asphalt or the underlying base, areas of cracked surface must be treated with Petraseal, Viaseal or similar. This treatment shall be continued until the specified permeability is achieved. The work shall be carried out at the contractor's expense.

### **Measurement and payment**

Sand asphalt shall be measured by mass determined from weighbridge tickets. The tendered rates shall cover all costs for materials mixing, labour, transport, placing and compacting the sand asphalt surface layer.

### **Product performance guarantee system (PPGS)**

Reference may be made to Sabita's PPGS. In terms of such a system, the contractor may be required to or may be encouraged to offer a guarantee covering the performance of a sand asphalt mix. As sand asphalt is based upon the use of a naturally occurring material, the terms of the guarantee must, of necessity, be based on the contractor's experience of his product's performance. In this event, the control of the product will rest entirely with the contractor, both with respect to composition and application.

Notwithstanding the contractor's guarantee, however, the engineer may consider controlling the permeability of the sand asphalt layer to ensure that the underlying structure is protected from water.



## Pro Forma for Mix Design of Sand Asphalt

- Obtain a sand source
- Test for sand equivalence
- Test for shape factor
- Test for fitness of modulus
- Categorise the sand into A, B or C - if B or C reject source
- Check grading variability - add filler to satisfy 0,075mm criteria
- make up the combined aggregate grading - add stone
- Ifabricate Marshall briquettes — 4.5% bitumen content
- Test for Marshall stability
- If criteria are met - accept sand filler content
- If criteria are not met - increase filler - reject sand.

SAND ASPHALT MIX DESIGN									
Sand source				Stone source					
SAND EVALUATION									
Sample	1			2			3		
Sand Equivalence									
Fineness Modulus									
Shape Factor									
Category									
Average % passing 0,075 sieve				Required % Filler					
MIX DESIGN RECIPE									
Stone%				Sand %			Filler %		Bitumen %
MARSHALL TESTING									
Samples	1			2			3		
Marshall Stability									
90th Percentile Marshall Stability									

## Worked design example

### Engineering challenge

A local council wants to provide surfaced roads for the residential streets of proposed low cost serviced plot developments.

A fairly large sand source is in close proximity to the proposed development. A sand asphalt surfacing is investigated to keep initial costs down. Traffic volumes are expected to be low and more emphasis is placed on providing clean, socially friendly surfaces.

### Mix design

#### Step 1.

Representative samples of sand are obtained and tested for sand equivalence, fineness, modulus and shape factor.

The average results are as follows:

SE - 82% FM - 1.3 SF - 0,6

The sand is classed as an A category sand.

#### Step 2.

The grading of the sand is assessed and the result is as follows:

AGGREGATE SIZE (mm)	PERCENTAGE PASSING
6,70	100
4,75	98,0
2,36	97,0
1,18	96,0
0,600	93,0
0,300	70,0
0,150	15,0
0,075	7,0

The fines content passing the 0,075mm sieve is 7.0%, which is an acceptable fines content to warrant a first attempt at mix design without extra filler being added.

#### **Step 3.**

A recipe mix is tentatively produced using the most economical proportions. It is suspected that the mix will not have sufficient stability owing to the fact that the percentage passing the 0,075mm sieve in the final grading will be slightly below 6.0% ( $0.755 \times 7\%$ )

13.2mm crushed dolerite - 20.0%  
Natural sand - 75.5%  
80/100 pen: BB grade bitumen - 4.5%

#### **Step 4.**

A series of Marshall briquettes is fabricated. The results give an average Marshall stability of 2 kN, which is less than the recommended value of 3.5 kN. The recipe is not acceptable.

#### **Step 5.**

A nominal amount (2%) rock flour filler is added to the recipe mix. Step 4 is repeated. The results give an average Marshall stability of 5 kN. The mix design is accepted.

#### ***Final design recipe***

The final proposed recipe design for the sand asphalt surfacing is as follows:

13,2 mm crushed Dolerite - 20.0%  
Natural sand - 73.5%  
Rock flour filler - 2.0%  
80/100 pen: BB Grade bitumen - 4.5%

#### ***Structural design***

This process is no different from standard structural design of pavements in the low volume traffic category making use of thin asphaltic surfacings.