OPTIMIZING PAVEMENTS' ACOUSTIC PROPERTIES BY USING SUPERFINE TWINLAY POROUS ASPHALT WEARING COURSES

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ABSTRACT

The acoustic properties of a conventional thin single layer porous asphalt surface can be further optimized by introducing a thick double layer system (know as Twinlay) with a superfine top structure consisting of single-grain aggregate mixture. The superfine top structure assists in minimising tyre vibration (which will result in subsequent reduction in noise production) and also increases flow resistance which then gives us the desired short-wavelength texture. The Standing-Wave Apparatus or Impedance Tube can be used to assess the mixture's ability to absorb sound before construction of a pavement in the field. Compared to conventional porous asphalt surfaces Twinlay offers a number of advantages as mentioned in this paper. The purpose of the investigation was to minimise noise production by minimising tyre vibration, to optimise sound absorption and to compare locally designed Superfine Twinlay mix with the acoustically optimized European mixes which were manufactured using local aggregates. This paper gives results of an investigation into the acoustic properties of porous asphalt mixtures in the laboratory only, no field investigations were conducted.

1 BACKGROUND

A void content in excess of 20 percent is specified for a porous asphalt mix. A single layer of porous asphalt mixture is well known for its excellent sound absorption properties, but the voids in the mix are prematurely clogged by sand and road debris. It is known that due to clogging and ageing of the surface, both the absorption and texture degrades which will lead to a significant loss of reduction capacity (reduction in noise production, sound absorption and splash and spray) [5]. This soon diminished its excellent acoustic properties and reduced the permeability of rainwater subsequently having an adverse effect on the functional performance and road safety.

Due to European experience Twinlay porous asphalt surfaces were developed. Twinlay porous asphalt wearing courses offer solutions to the premature failure of the functional performance of porous asphalt surfacing. Twinlay is made up of two layers of porous asphalt, one layer on top of the other. The bottom layer is a coarse single grained aggregate (11/16) with a thin top layer of fine porous asphalt (4/8). The stone particles of the top layer settle into the top of the coarse structural texture of the bottom layer.

As opposed to the conventional porous asphalt wearing course, Twinlay offers the following advantages:

- The fine top layer acts as a sieve reducing the ingress of sand or dirt from clogging the coarse bottom layer consequently leaving the asphalt free draining. The dirt that penetrates the fine top layer can be easily removed by using a certain cleaning techniques.
- The fine surface texture of the top layer reduces tyre/road noise and the course bottom layer combined with the fine top layer provides a good sound absorption, this is also caused by the thickness of the overall layer.
- The difference in airflow resistance between the top layer and bottom layer has a positive effect on the self-cleaning capacity caused by traffic.
- The course bottom layer has a good discharge of rainwater to the side drains.

The disturbance caused by noise pollution is one of the most important environmental health consequences. Road traffic noise has been identified as the greatest noise pollutant in the industrialised world with the tyre/road interaction being the major contributor at high vehicle speeds [3]. Noise producing mechanism from vehicles on the road is subdivided into three main categories namely: power train, tyre/road interaction and aerodynamic noise. The control of traffic noise at the source has in recent years been focused on tyre-road noise, since this noise component appears to be the major contributor to wayside noise at traffic speeds above 50 km/h [4], [3].

The acoustic performance of Twinlay porous asphalt surface can be further optimised by an introduction of a superfine top layer, The top layer reduces the texture induced vibration which is at present the major source of tyre/road noise on porous surfaces [5]. Superfine Twinlay consists of a thin superfine top layer with aggregates retained mainly in the 1.18 and 2.36 mm sieves (1.18/2.36) and a coarse single grained bottom layer with aggregates retained mainly in the 9.5 and 13.2 mm sieves (9.5/13.2) and with bitumen rubber as a binder. The overall thickness of this layer is 7cm, the top and bottom layer being 2.5 cm and 4.5 cm respectively. This mixture has high porosity and optimal flow resistance. Figure 1 shows the structure of Superfine Twinlay.

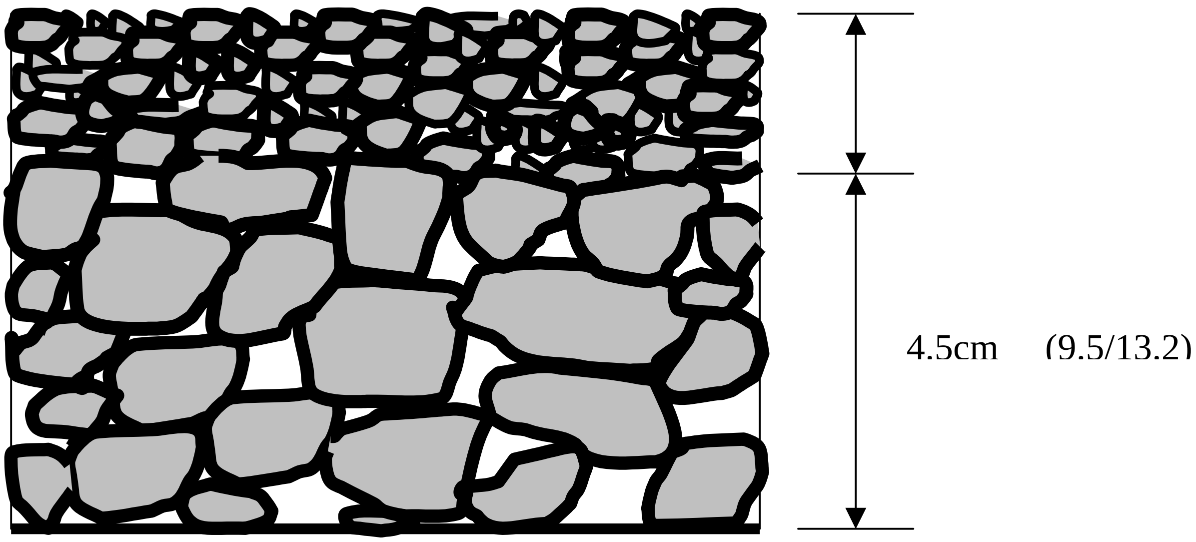

FIGURE 1: Structure of Superfine Twinlay

The overall properties of porous asphalt that need to be addressed during design can be categorised as follows [8]:

- Functional properties of porous asphalt
  1. Road safety aspects with regards to accidents
  2. Capacity effects - increase in traffic densities
  3. Environmental aspects with regards to noise pollution

- Structural properties of porous asphalt
  1. Properties of unconditioned porous asphalt (engineering properties often used to characterise porous asphalt are resistance to deformation, resistance to fatigue, indirect tensile strength and stiffness modulus (E-modulus from dynamic bending tests)
  2. Ageing and stripping characteristics
  3. Effects of temperature
  4. Overall effect on structural design and service life
  5. Effect of binder modification

2 INTRODUCTION TO THE INVESTIGATION

Road traffic noise is one of the major contributors to noise pollution therefore there is a great need to try and eradicate or at least retard rolling noise due to tyre/road interaction. It is also equally important to measure a mixture's ability to reduce noise in the laboratory. Characterizing a mixture's ability to attenuate noise in the laboratory during mix design is very important in-terms of avoiding the expense and time of constructing field sites for measurements. The Standing–Wave Tube Apparatus or Impedance Tube was used to measure sound power absorption coefficient of porous materials [12].

Comparison with respect to sound absorption was made between the different selected mix designs with different mix components as adopted for investigation (see Table 1).

TABLE 1: Mix designs investigated			
Mix type	**Overall layer thickness**	**Top**	**Bottom**
1. Conventional Porous Asphalt	4 cm	-	-
2. Superfine Twinlay (proposed)	7 cm	2.5 cm	4.5 cm
3. Superfine Twinlay	8 cm	3.0 cm	5.0 cm
4. Superfine Twinlay	9 cm	3.5 cm	5.5 cm
5. Cityfalt	7 cm	2.5 cm	4.5 cm
6. Conventional Twinlay	7 cm	2.5 cm	4.5 cm
7. Fluisterfalt	7 cm	2.5 cm	4.5 cm

The Department of Infrastructure and Maintenance, The Netherlands recently conducted a research with the aim of determining a low noise pavement or optimizing the pavements acoustic performance by using a double layer system instead of the normal single porous asphalt layer. Six different test sections were laid and compacted. The different pavement sections laid were: Cityfalt by Breda Wegenbouw, 2-laags ZOAB by HWZ, Twinlay by Heijmans, Microdrain by Heijmans, Duolay by KWS and Fluisterfalt by NBM. A series of tests were performed on the test sections e.g. Airdrain measurements, $\propto$-in-situ measurements and SPB measurements. Microdrain, Cityfalt, Fluisterfalt and Twinlay performed significantly better than other mix designs but for the purpose of this research project the researcher decided to use Cityfalt, Conventional Twinlay and Fluisterfalt. The reason for choosing Conventional Twinlay instead of Microdrain is that this research investigations' primary objective is to improve on the existing Twinlay. Microdrain is a latest development of Twinlay. It is therefore imperative that a comparison be made between Conventional Twinlay and other mix designs that showed a better acoustic performance.

It is important to note that South African sieve sizes and mix material components were used in the manufacturing of Cityfalt, Conventional Twinlay and Fluisterfalt Marshall samples.

3 OBJECTIVES

A Superfine Twinlay porous mix (with small chipping) subscribes to the requirements with regard to optimal flow resistance as well as to a shorter wave-length texture [2]. The primary objective of this investigation is to study the fundamental acoustical behavior of freshly compacted Superfine Twinlay briquette.

In summary, the objectives were:

- To assess the sound absorption of each mix design material under investigation.
- To monitor and quantify the absorption properties of each of the porous asphalt mix design as shown in Table 1, and to compare each one against the other for all the mixtures under investigation.
- To determine the influence that thickness has on the absorption coefficient of a porous layer.

4 DESCRIPTION OF METHODS USED

4.1 Sample preparation

4.1.1 Mix components and sieve analysis for porous asphalts of various compositions

Porous Asphalt mixes have a high void content (in excess of 20 percent) therefore the type of aggregate and grading used is very important. For the purpose of this research, aggregates from the Eerste River quarry were used and they also meet the requirements as recommended in the Sabita Manual 17[6].

There are three main variables that should be considered in trying to obtain the desired properties of porous asphalt mixtures and these are:

- Binder type – binder type and content are important as these have an impact on the structural integrity of the mix,
- Aggregate type – due to the open structure of the mix, aggregates must meet recommendation as in Sabita 17 [6],
- Filler type – in order to stiffen the binder a limited amount of filler must be added.

The tables below (Table 2 to Table 11) show the mix components and sieve analysis for the different mix designs adopted in the study.

Mix components for single layer Conventional Porous Asphalt.

TABLE 2: Mix components for Conventional Porous Asphalt	
Mix composition	**Layer (%)**
13.2 mm, Malmelsbury Hornfels, ex RMM Eerste River	42.7
9.5 mm, Malmelsbury Hornfels, ex RMM Eerste River	38.7
CRUSHER DUST, Malmelsbury Hornfels, ex RMM Eerste River	13.0
Filler (Hydrated Lime ex-Cape Lime)	0.2
Rubber bitumen	5.4

Grading curve for Conventional Porous Asphalt representing sieve analysis and percentage passing is shown in Figure 2.

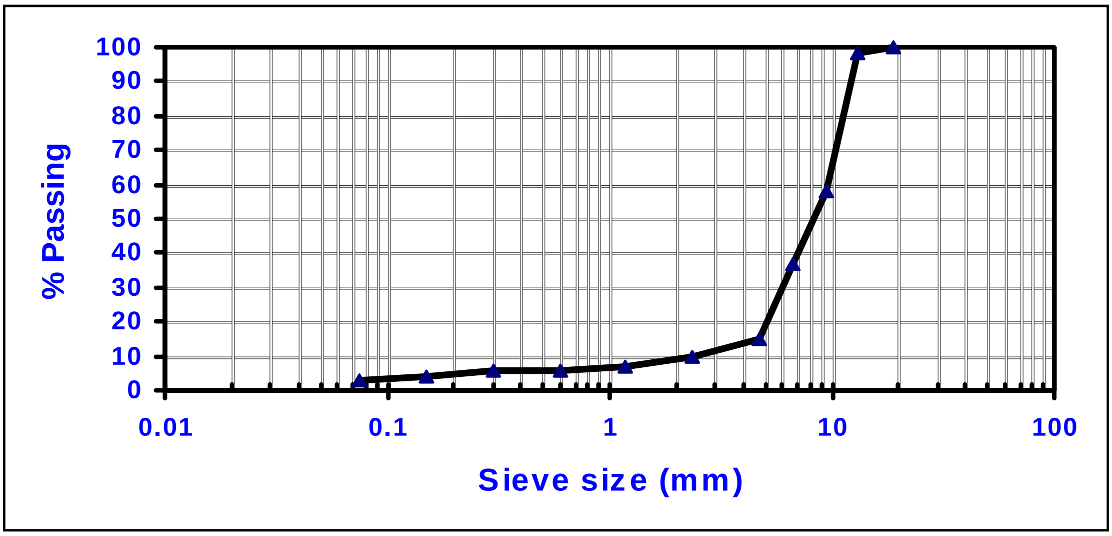

FIGURE 2: Conventional Porous Asphalt grading curve

Mix components for double layer Cityfalt by Breda Wegenbouw

TABLE 3: Mix components for Cityfalt			
Mix components using European materials	**Mix components using South African materials**	**Top layer (%)**	**Bottom layer (%)**
Grauwkwartsiet 5/8	Mineral aggregate 4.75/9.5	95.3	-
Nederlandse steenslag 8/11	Mineral aggregate 9.5/13.2	-	8.9
Nederlandse steenslag 11/16	Mineral aggregate 13.2/19.0	-	79.7
Brekerzand 0/2	Sand 0/2.36	-	6.5
Wigro 60K	Filler	4.2	4.4
Eigen stof	Filler	0.5	0.5
Arbocell ZZ8/1	Cellulose fibre	0.15	0.15
Sealoflex 5-50	Binder, SBS	5.1	4.2

Grading curve for Cityfalt representing sieve analysis against percentage passing is shown in Figure 3.

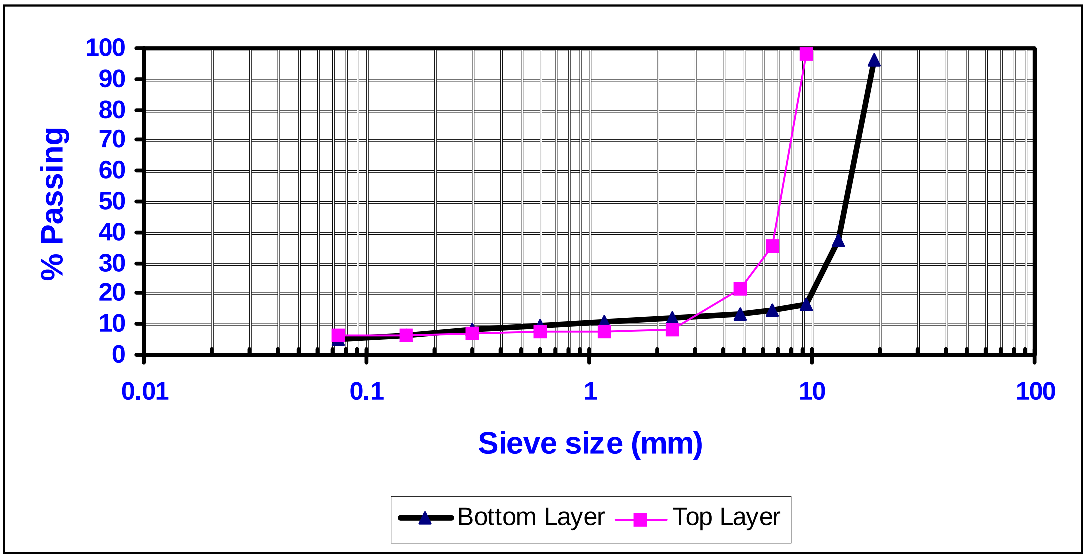

FIGURE 3: Cityfalt grading curve

Mix components for double layer Conventional Twinlay by Heijmans

TABLE 4: Mix components for Conventional Twinlay			
Mix components using European materials	**Mix components using South African materials**	**Top layer (%)**	**Bottom layer (%)**
Grauwkwartsiet 4/8	Mineral aggregates 4.75/9.5	93.7	-
Grauwkwartsiet 11/16	Mineral aggregates 13.5/19.0	-	88.9
Brekerzand	Crushed sand	-	8.5
Rhecal 40	Filler	5.3	1.6
Eigen stof	Filler	1.0	1.0
Rubberbitumen	Bitumen rubber binder	6.5	4.2

Grading curve for Conventional Twinlay representing sieve analysis against percentage passing is shown in Figure 4.

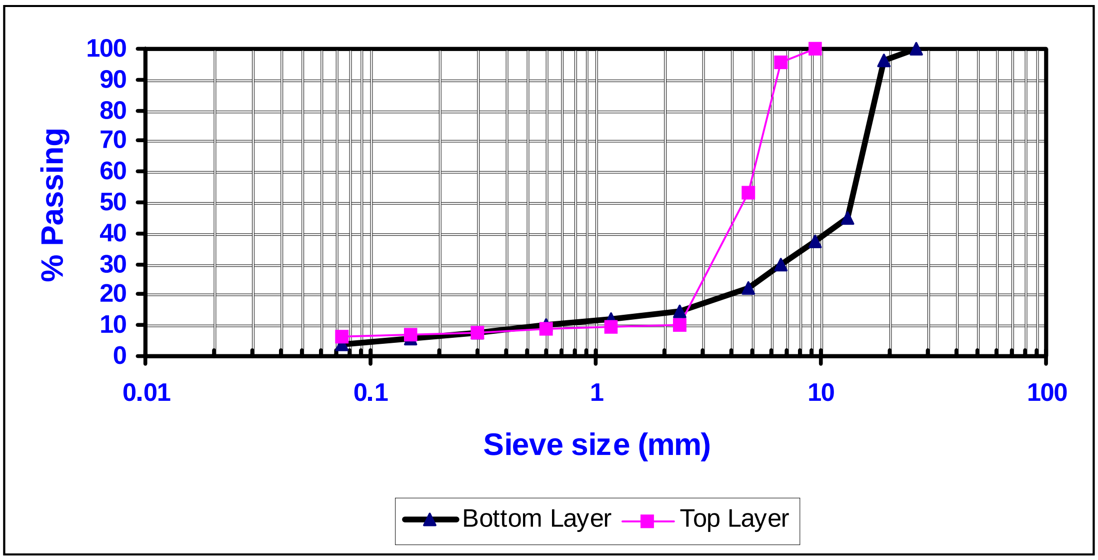

FIGURE 4: Conventional Twinlay grading curve

Mix components for double layer Fluisterfalt by NBM

TABLE 5: Mix components for Fluisterfalt			
Mix components using European materials	**Mix components using South African materials**	**Top layer (%)**	**Bottom layer (%)**
Grauwkwartsiet 4/8	Mineral aggregate 4.75/9.5	91.5	-
Grauwkwartsiet 11/16	Mineral aggregate 13.2/19.0	-	91.7
Nederlands Brekerzand	Crushed sand	4.9	4.8
Rhecom 60	Filler	3.6	3.5
Styrelf 26	Binder	5.3	4.8

Grading curve for Fluisterfalt representing sieve analysis against percentage passing is shown in Figure 5.

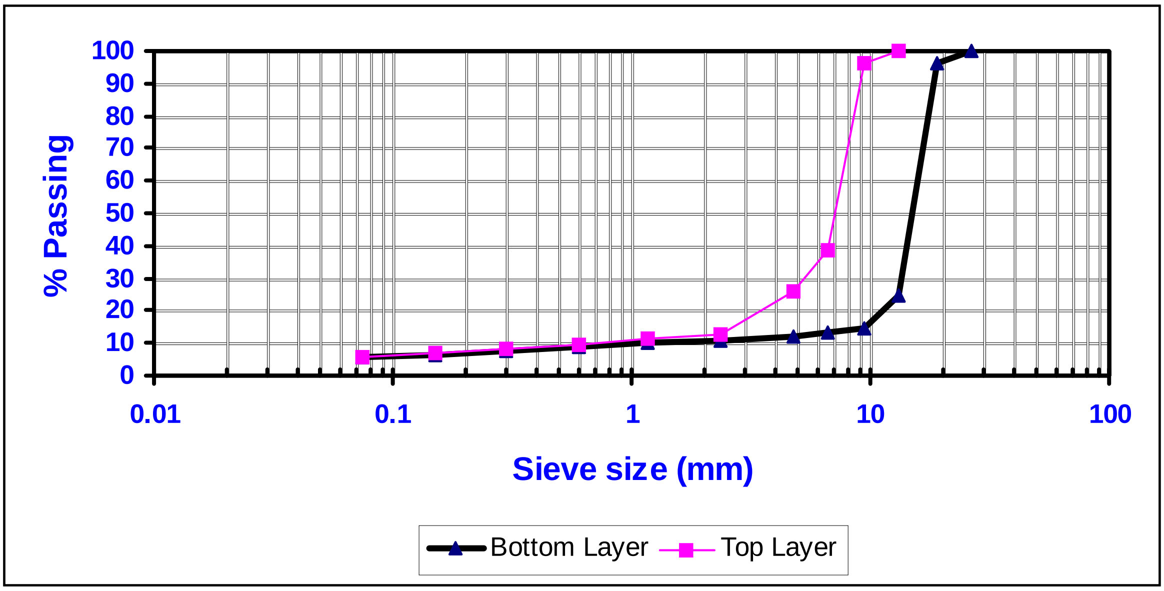

FIGURE 5: Fluisterfalt grading curve

Mix components for the double layer proposed Superfine Twinlay

TABLE 6: Mix components for Superfine Twinlay		
Mix composition	**Top layer (%)**	**Bottom layer (%)**
9.5/13.2 mm, Malmelsbury Hornfels, ex RMM Eerste River	-	84
1.18/2.36 mm, Malmelsbury Hornfels, ex RMM Eerste River	91.5	-
CRUSHER DUST, Malmelsbury Hornfels, ex RMM Eerste River	-	7
Filler (Cement)	3	3
Rubber bitumen	5.5	6

Grading curve for Superfine Twinlay representing sieve analysis against percentage passing is shown in Figure 6.

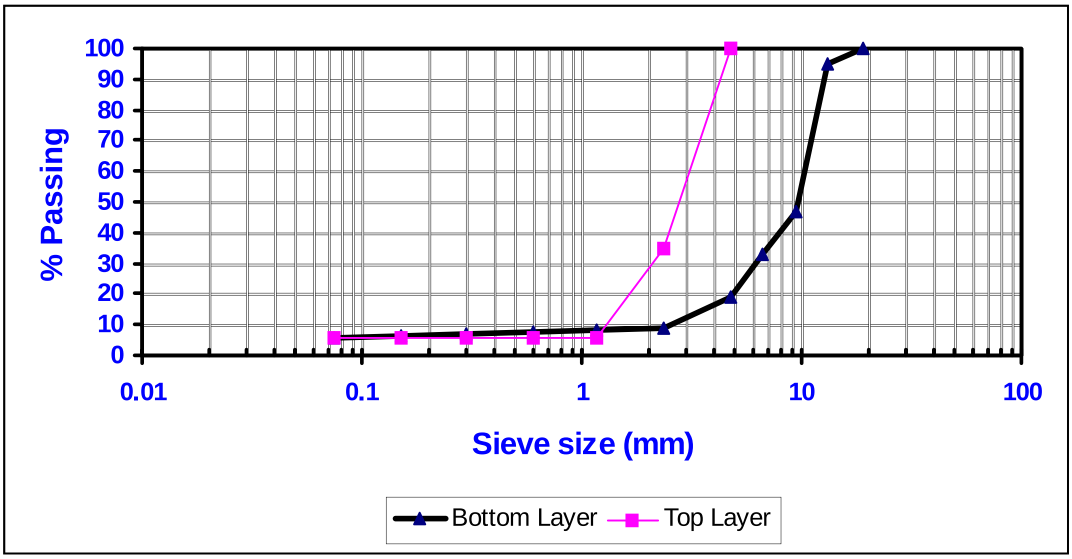

FIGURE 6: Superfine Twinlay grading curve

4.1.2 Mixing and compaction of the samples

The mix design procedure was performed in accordance with the Sabita manual 17 [6] and the mixing procedure according to Method C2 of (Technical Methods for Highways) TMH 1 [7] (Procedure for the making of asphalt specimens for the determination of resistance to flow and for voids analysis by the Marshall method")

Three briquettes per mix design were compacted in the laboratory using a standard Marshall hammer. 140^{o}C and 130^{o}C temperatures were used during mixing and compaction respectively as recommended for bitumen-rubber asphalt in the Sabita manual 17 [6]. The mixing and compaction temperatures were monitored using a laser thermometer. After extrusion from the metal moulds, the heights of the cooled Marshall specimens were measured to the nearest 0.01 mm by using a pair of Callipers. Photographs of freshly compacted Marshall briquettes are shown in Appendix A, Figure A-1, for Fluisterfalt, Cityfalt, Twinlay, Superfine Twinlay and Conventional Porous Asphalt.

5 TYRE/ROAD INTERACTIONS

Noise emission from road vehicles is composed of several different noise producing mechanisms and these can be divided into the following three main categories [3]:

1. Power-train – being engine, air intake, fan, exhaust, gearbox and transmission.
2. Tyre/road interaction.
3. Aerodynamic noise – due to air turbulence around the vehicle, only significant at speeds in excess of 200 km/h.

It is possible to reduce road traffic noise by controlling noise from the source, this can be done by applying low-noise road surfaces e.g. porous asphalt surfaces. The control of traffic noise at the source has in recent years been focussed on tyre/road noise, since this noise component appears to be the major contributor to traffic noise at traffic speeds above 50 km/h as mentioned in Section 1.

The beneficial effects of porous asphalt surfaces on tyre/road noise are twofold [5]:

- The open structure of the surface reduces the compression and expansion of air in the tyre tread profile;
- The acoustic absorption suppresses mechanical and aerodynamic (due to air turbulence around the vehicle) noise generated by the rolling tyre on the road.

And the reduction in noise level results from [6]:

- Sound absorption by the voids of the layer;
- The elimination of air pumping at the tyre/pavement interface and;
- The excellent surface evenness of this type of wearing course when properly laid.

In the attempt of reducing road traffic noise with regard to rolling noise it is important to understand the tyre/road noise generation mechanism. Pavement-tyre contact noise depends on the type of tyre used (tread patterns etc) and also on the type of pavement overlays. The mechanism of tyre/road noise generation is complex but can be summarised into the three following phenomena [3], [5]:

- *Impact noise:* produced by the impact of the tyre treads on the surface of the overlay, its intensity depending on the geometry of both tread patterns and aggregates as well as on the overlay macrotexture.
- *Air pumping:* due to vibration of the air caught in the treads under the effect of stress caused by the tyre deformations.
- *Slip and stick:* this phenomenon is comparable to the *suction effect*, due to the grip of the tyre rubber on aggregates at the pavement surface.

The generation of pavement-tyre contact noise thus depends to a large extent on the aggregate grading size of the wearing course. Reducing the effects of one of the three above mentioned causes can increase the effects of the other two, which makes the reduction o f tyre/road noise a difficult task.

6 ABSORPTION MEASUREMENTS ON CORES

When a porous material is subjected to the action of acoustic pressure. The porous material not only undergoes elastic compression but there is also movement of the fluid (air) back and forth in voids within the material. The process of “absorption” is the conversion of acoustic energy into heat, which takes place as a result of:

- Friction between air particles and flow constrictions in the material,
- Internal friction of the material depending on the degree of elastic deformation.

The effectiveness of porous absorbers in absorbing sound depends on the following physical characteristics:

1. Porosity – which is the ratio of the interconnecting voids within the material to the total volume of the material.
2. Structural factor – which relates to the shape of the air voids and how they are interconnected.
3. Specific flow resistance – which is the resistance to airflow through the material and
4. Thickness of the porous material – which determines the frequency at which maximum absorption occurs.

The measurement of sound absorption of porous materials is considered to be very important since we need to evaluate the mixture's ability to reduce noise in the laboratory before laying it out in the field. The standing wave tube test was used to measure the sound absorption of the porous materials in the laboratory.

6.1 Basic assumptions

- 1000Hz is the dominating frequency for vehicle speeds above 70 km/h [10]. For acoustical optimisation to be obtained it is therefore important that the maximum absorption be placed at 1000Hz.
- That the acoustical absorption of a road surface is the main cause for the noise reduction to be observed alongside the road.
- The use of bitumen rubber as a binder will offer a higher absorption coefficient as opposed to conventional binder [4]. The mechanical impedance also has an influence on the amplitude (loudness) in the production of tyre/road noise. The mechanical impedance matching (or relative stiffness) of bitumen rubber generates a relatively lower noise as opposed to conventional densely graded asphalt [3].
- A double-layer of porous mixture behaves acoustically in a similar way as a single homogeneous layer of porous asphalt [5].
- Size of the aggregate is very important. If tyre vibration is to be minimised (which will result in subsequent decrease in noise production) and if the flow resistance is to be increased and if a short-wavelength texture is to be achieved a finer mixture in the top layer must be used. For instance instead of using 4/8 aggregates, superfine aggregates 1.18/2.36 can be used.
- The overall thickness of the porous layer has an influence on the frequency of maximum absorption coefficient. The result of this investigation will show us the influence thickness has on the absorption.

It is expected that a significantly higher A-level reduction of wayside noise will be achieved if most of the above assumptions are met

6.2 Theoretical predictions

The sound absorption coefficient (α) as a function of frequency of the porous layers was predicted using the following formulae [2]:

$$\alpha = 1 - \left| \frac{w - \rho c}{w + \rho c} \right|^2$$

Where

$$w = -j \frac{\rho c}{\sigma} \sqrt{\left(1 - j \frac{\Xi \sigma}{\omega \rho \chi}\right) \chi} \, . \cot \left[d \, . \frac{\omega}{c} \sqrt{\left(1 - j \frac{\Xi \sigma}{\omega \rho \chi}\right) \chi} \right]$$

And

$$\omega = 2\pi f$$

$$\Xi = \frac{10^{-2}}{1.7.k^2.\sigma^2.d} Ns.m^{-4}$$

σ : Porosity
ρ : Density of air (1.21 kg/m^3)
Ξ : Specific flow resistance of the porous material
d : Thickness of the layer
χ : Configuration or structural factor of the porous material

The above mentioned formulae were used to calculate the predicted sound power absorption coefficient (α) for all the mix design as shown in Table1 at each frequency up to 2000Hz. The graphs representing the result thereof are shown in Section 6.3.

6.3 Results from laboratory tests performed on the Standing-Wave Apparatus compared with predicted results

6.3.1 Porous Asphalt 4 cm

The graphical presentation of the results in Figure 7, 8, 9, 10, 11, 12 and 13 show the normal (vertical) incidence sound absorption coefficient as a function of frequency. The dots represent the measured results of three freshly compacted Marshall briquettes and the solid line represents the calculated predicted results. The absorption coefficient (α) was measured by means of a standardized method using an Impedance Tube or Standing Wave Apparatus into which Marshall briquettes were placed.

For the predicted calculations the following parameters were used:
σ : 20 percent
ρ : Density of air (1.21 kg/m^3)
d : 4 cm
χ : 5 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

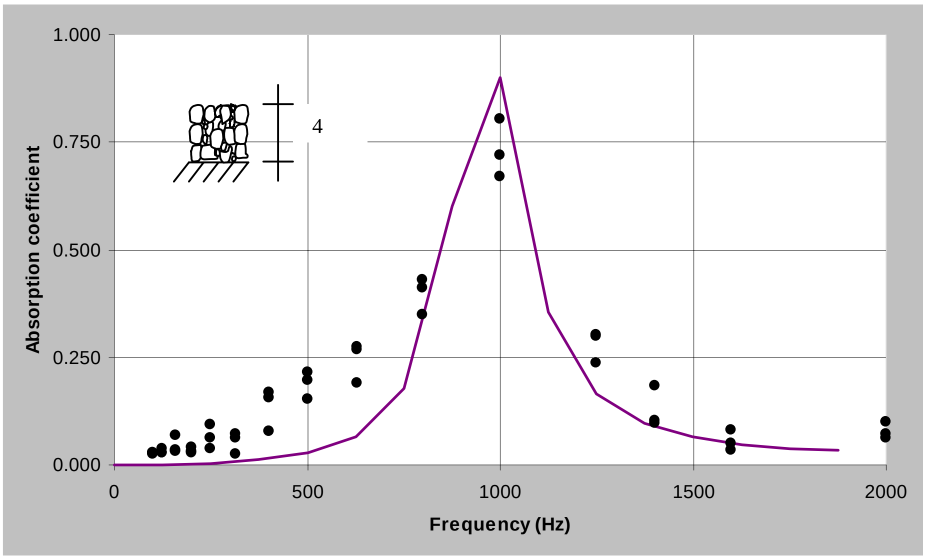

FIGURE 7. Absorption Coefficient vs. frequency of 4 cm Porous Asphalt cores

6.3.2 Cityfalt 7 cm

For the predicted calculations the following parameters were used:

σ : 25 percent
ρ : Density of air (1.21 kg/m^3)
d : 7 cm
χ : 5 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

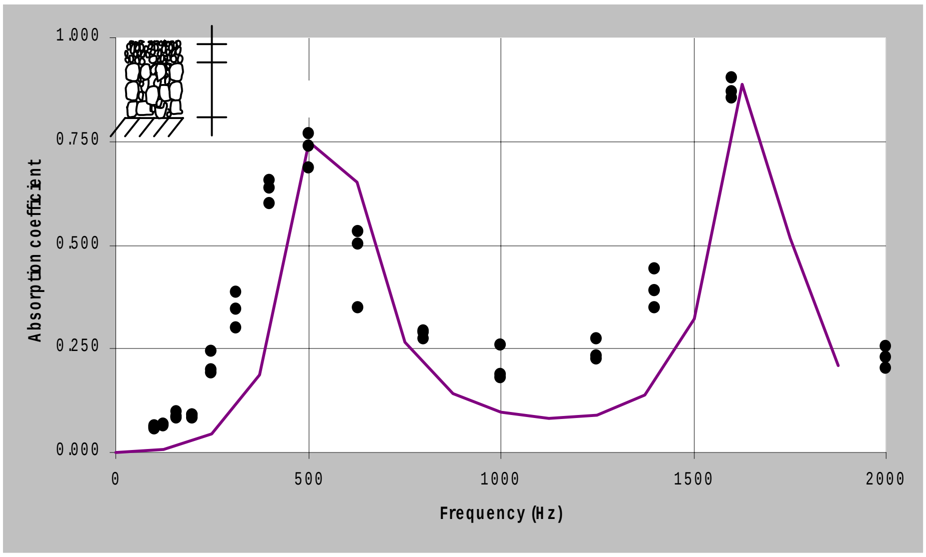

FIGURE 8. Absorption Coefficient vs. frequency of 7 cm Cityfalt cores

6.3.3 Fluisterfalt 7 cm

For the predicted calculations the following parameters were used:

σ : 24 percent
ρ : Density of air (1.21 kg/m^3)
d : 7 cm
χ : 4.6 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

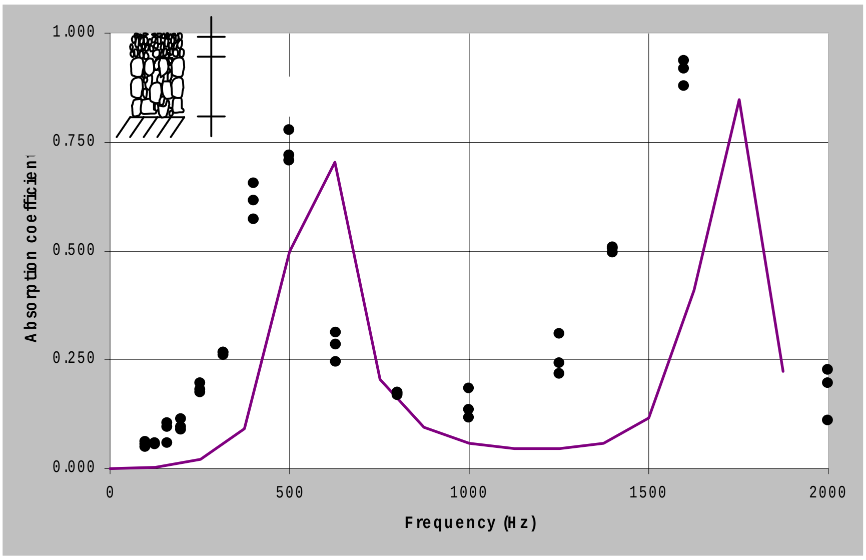

FIGURE 9. Absorption Coefficient vs. freq. of 7 cm Fluisterfalt cores

6.3.4 Conventional Twinlay 7 cm

For the predicted calculations the following parameters were used:

σ : 23 percent
ρ : Density of air (1.21 kg/m^3)
d : 7 cm
χ : 4.6 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

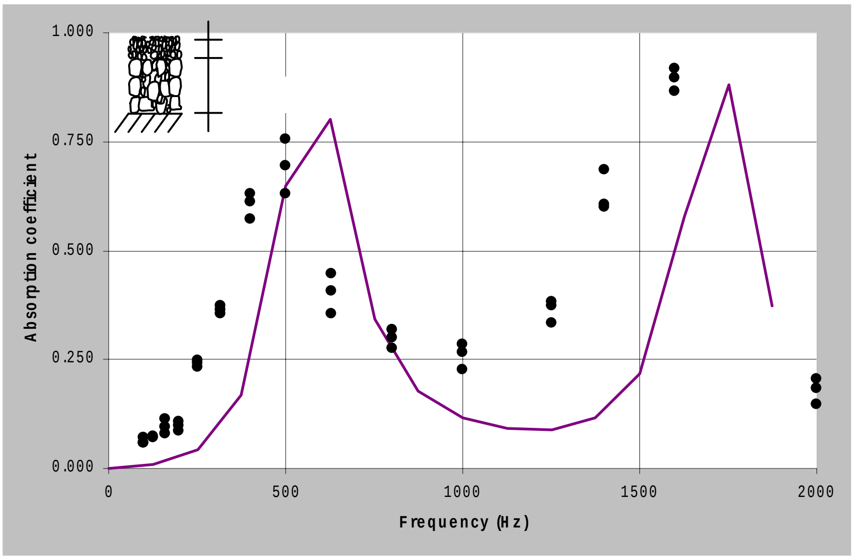

FIGURE 10. Absorption Coefficient vs. freq. of 7 cm Conventional Twinlay cores

6.3.5 Superfine Twinlay 7 cm

For the predicted calculations the following parameters were used:

σ : 24 percent
ρ : Density of air (1.21 kg/m^3)
d : 7 cm
χ : 5 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

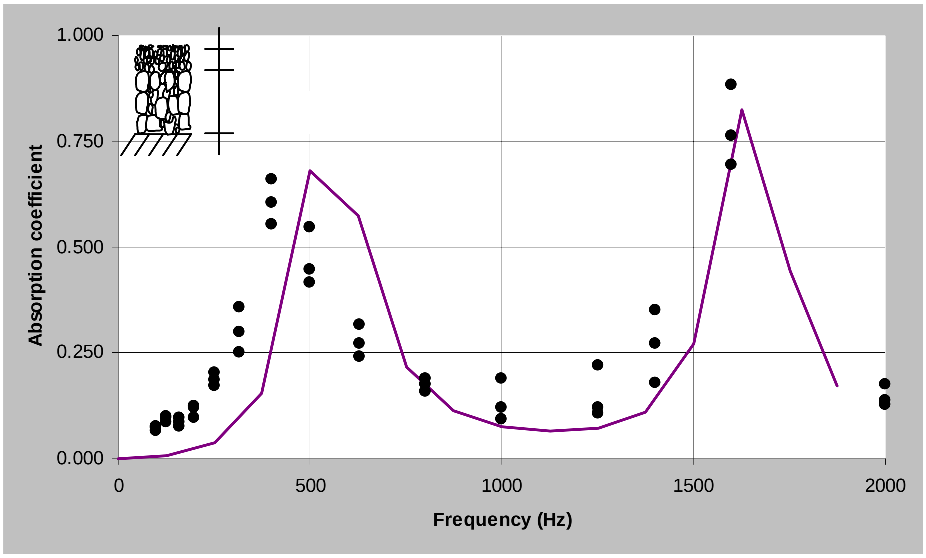

FIGURE 11. Absorption Coefficient vs. freq. of 7 cm Superfine Twinlay Marshall cores

6.3.6 Superfine Twinlay 8 cm

For the predicted calculations the following parameters were used:

σ : 24 percent
ρ : Density of air (1.21 kg/m^3)
d : 8 cm
χ : 5 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

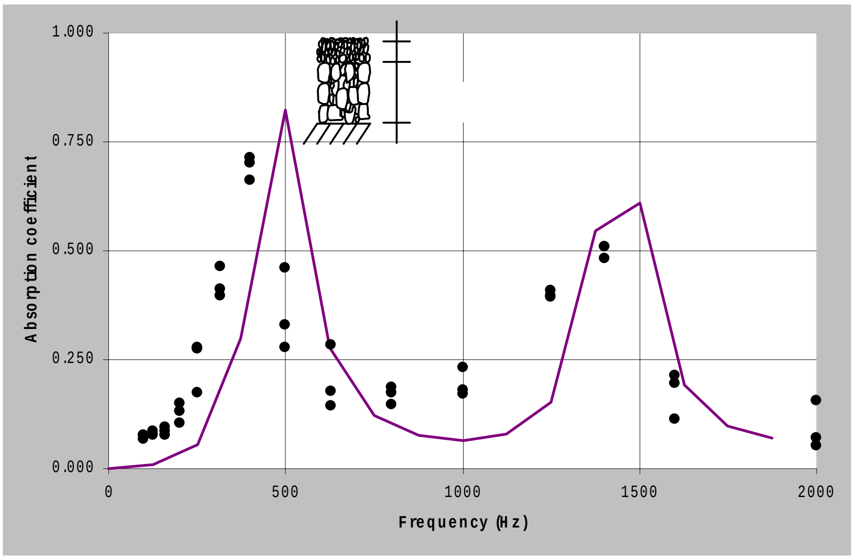

FIGURE 12. Absorption Coefficient vs. freq. of 8 cm Superfine Twinlay cores

6.3.7 Superfine Twinlay 9 cm

For the predicted calculations the following parameters were used:

σ : 24 percent
ρ : Density of air (1.21 kg/m^3)
d : 9 cm
χ : 5 (an assumed value, for common stone chippings ranges from χ = 3 to 7) [2].

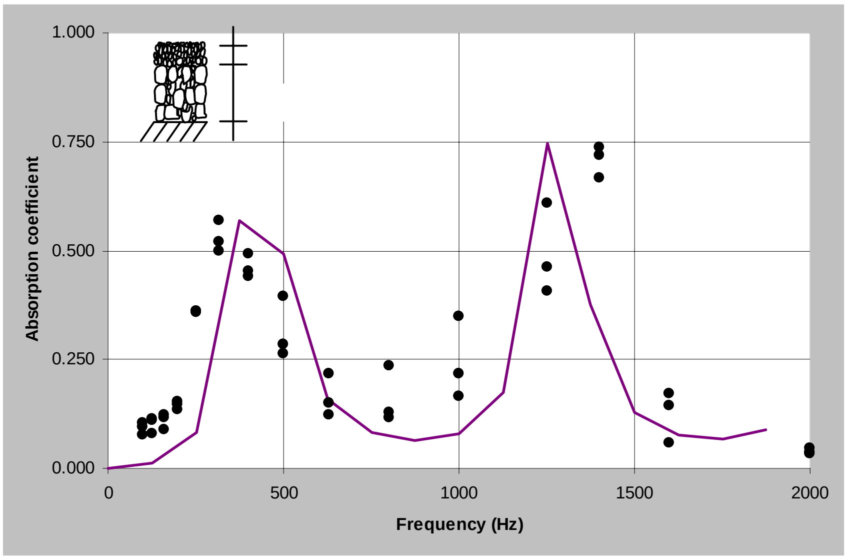

FIGURE 13. Absorption Coefficient vs. freq. of 9 cm Superfine Twinlay cores

The above results indicate a good correlation between the measured and predicted results. However, a minor deviation was noted from the measured results and the predicted calculations. This was probably due to the fact that for Twinlay, Fluisterfalt and Cityfalt, South African aggregates, materials and sieve sizes were used instead of the original European aggregates, materials and sieve sizes. And also partly due to slight errors experienced during testing of the Marshall briquettes on the Standing-Wave Apparatus.

The other contributing factor might have been the fact that the structural factor values were assumed and not measured.

6.4 Results analysis

6.4.1 A comparative analysis of the results

In interpreting the results, the 4 cm thick single porous asphalt layer displays a higher absorption coefficient (α) over a narrow frequency band at 1000Hz frequency as opposed to double layer 7 cm thick Superfine Twinlay, 8 cm thick Superfine Twinlay, 9 cm thick Superfine Twinlay, Cityfalt, Twinlay and Fluisterfalt with more than two peaks over a broad frequency band. The 4 cm thick homogeneous porous asphalt will produce a long wave-length texture compared to the other double layer mixtures, meaning that there will be an increase in tyre vibration leading to noise production.

Cityfalt, Twinlay and Fluisterfalt show a better sound absorption coefficient with short wave-length over a broader frequency band than all the other mixtures under investigation.

6.4.2 The influence of thickness on the absorption coefficient

The summarised results of the average absorption coefficient at the first maximum points $f\alpha_{, max}$ (Hz) for all mix design under investigation are shown in Figure 14.

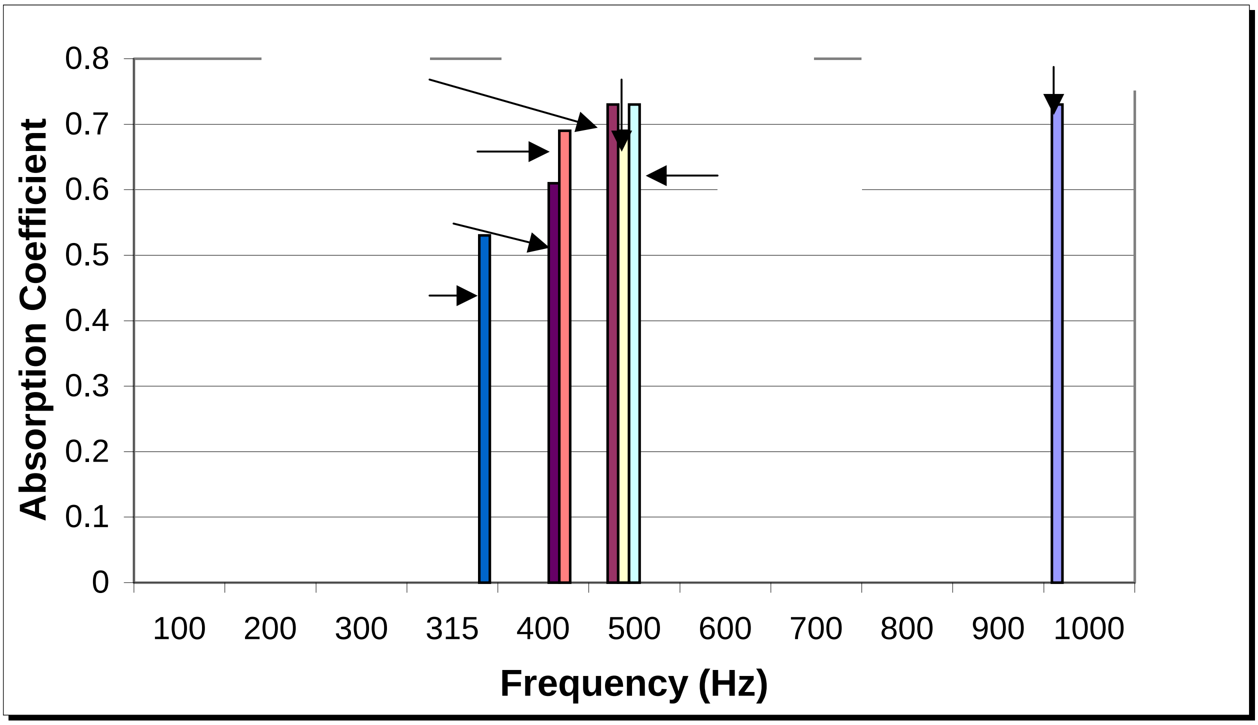

FIGURE 14. Absorption Coefficient the first maximum point as a function of frequency for 7, 8 and 9 cm thick Superfine Twinlay, 7 cm Conventional Twinlay, 7 cm Fluisterfalt and 7 cm Cityfalt and 4 cm Conventional Porous asphalt.

A 4 cm single layer of porous asphalt gives us a high absorption at 1000Hz meaning that it has been acoustically optimized with a narrow frequency band. Increasing the thickness from 7 cm to 8 cm gives us a higher sound absorption. If we further increase the thickness to 9 cm the frequency of the first maximum point of absorption shifts further down to a lower frequency with a lower absorption at that point as indicated in Table 8.

7 CONCLUSIONS AND RECOMMENDATION

In general, rolling noise is very much dependent on the type of wearing course, wearing courses with rough macrotexture tend to generate greater rolling noise. A double layer (know as Twinlay) porous asphalt construction offers a higher sound absorption coefficient (α) on a broad frequency range as opposed to a single homogeneous porous asphalt layer construction. The excellent acoustic performance of double layer construction is due to the thin top layer with small aggregate sizes. The small aggregate size increases the flow resistance and subsequently providing the desired short-wave length. It can therefore be concluded that the stone grading and the resulting surface texture is an extremely important parameter. The effectiveness of using finer aggregates in the top structure can be easily monitored by conducting a Static Pass By (SPB) Method of measuring road traffic noise. The double layer construction also provides low and high speed reductions. The 4 cm thick homogeneous porous asphalt has a high absorption coefficient at a frequency of 1000Hz meaning that it is acoustically optimized but with a narrow frequency band. The long-wave length texture of this material is in opposition with the requirement of optimal flow resistance and short-wave length texture.

In order for the double layer construction to be acoustically optimized we need to ensure that the maximum absorption coefficient is shifted to the desired frequency of 1000Hz. This can be achieved by reducing the layer thickness or the configuration factor. There is also a need to try and strike a balance between excellent sound absorption and good water drainage. The 9 cm thick Superfine Twinlay offers solutions on improving low frequency performance of sound absorbing porous road surfaces.

8 ACKNOWLEDGEMENTS

The author would like to thank NRF for financial support and the also thank Colas Asphalt Eerste River for all their assistance. Last but not least the author would like to thank all the people who believed in me and made me believe in myself.

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10 APPENDIX A

Figure A-1: Photographs of Marshall briquettes, from left to right, Fluisterfalt, Cityfalt, Twinlay, Superfine Twinlay and Conventional Porous Asphalt.