ENHANCED ROAD FUNCTIONALITY WITH POROUS ASPHALT ON THE BEN SCHOEMAN HIGHWAY

T J DE KOCK [1], Z F JOUBERT [2], B M J A VERHAEGHE [3] AND F C RUST [4]

1) Director, Van Wyk & Louw Inc, Pretoria
2) Transvaal Provincial Administration (Roads Branch), Pretoria
3) Project Manager, Division of Roads & Transport Technology, CSIR, Pretoria
4) Programme Manager, Division for Roads & Transport Technology, CSIR, Pretoria

ABSTRACT

The degree to which a road is capable of accommodating traffic is dependent on functionality and economics. The higher the traffic the greater the challenge. Porous asphalt is currently one of the best alternatives to meet functionality requirements of highly trafficked urban roads. Porous asphalt offers definitive advantages in wet weather in respect of minimization of backsplash, better overall visibility, retention of skid resistance and road noise reduction. A need for porous asphalt surface courses exists in South Africa and specifically in the PWV area of the Transvaal.

1. INTRODUCTION

Open-graded asphalt (OGA) wearing courses have been used world-wide for more than 40 years (Visser et al [1974], 1). Initially it was used to improve skid resistance on roads which became too smooth. Over the years, due to its attributes it has developed into POROUS ASPHALT (PA). PA has become a useful tool to improve road safety and functionality.

In the RSA the first experimental section of open-graded asphalt (OGA) was laid in 1953. Since then in excess of 1,5 million m^2 OGA was laid on major roads and runways. Due to some doubt about what to do with OGA when it has lost its functionality, which under heavy traffic occurred within 5 years, a more cautious approach was followed for some years. With the advent of modified bituminous binders and particularly bitumen rubber most of the disadvantages associated with OGA could be overcome and the use of OGA and PA gained popularity. In most European countries it became policy to surface major roads with PA and some 50 million m^2 were laid up to 1991 (Verhaeghe [1993], 2).

The Roads Branch of the Transvaal Provincial Administration in its quest for the highest possible level of road functionality has approved the use of PA on the widening and rehabilitation of Ben Schoeman Highway (P206-1 between the Corlett Drive and Buccleugh interchanges). This road carries in the region of 95 000 vehicles per day. The TPA placed great emphasis on excellent road safety and functionality. This requirement was best satisfied by incorporating a PA overlay in the pavement design.

The object with a PA surface course was to provide adequate skid resistance in all weather conditions, the best possible wet weather and night time visibility, lowest achievable road noise, durability and maintainability, whilst giving due consideration to economics.

Porous and open-graded asphalt need to be distinguished by some definition albeit rudimentary. Until recently only open-graded asphalt was used in the RSA. Open-graded asphalt constitutes a mix complying to the requirements laid down in TRH8 (CSRA [1987], 3), a mix with 13 to 18% voids normally laid to thickness varying between 20 and 25 mm. In some countries this is called open-graded friction course (OGFC) or "popcorn" mix. Porous asphalt in the context of this paper is an asphalt having in excess of 20% voids, a Cantabro loss value of not more than 20% and a drainage capacity not less than 0,20 ℓ/sec.

2. ADVANTAGES OF USING POROUS ASPHALT

Road functionality is a multi-facetted concept. Factors influencing functionality comprise inter alia geometrics, atmospheric and environmental conditions, nature of roadside environment (built-up or not), traffic volume, general road safety, driver behaviour, road surface conditions, riding and structural quality. In this presentation only those aspects specifically related to the road surface, with emphasis on porous asphalt, are dealt with. The most relevant are:

2.1 Surface texture

It is generally accepted that coarser surface textures best promote road functionality by providing adequate skid resistance, adequate (micro) surface drainage and water displacement potential and lower the risk of aquaplaning.

On the other hand a coarse surface is associated with higher road noise levels (IRF [1992], 4), Horak et al [1993], 5), Nelson and Abbott [1990], 6). Elevated noise levels impede road functionality.

PA offers superior all weather skid resistance, surface drainability, low potential for aquaplaning and low road noise.

2.2 Drainability

A free draining road surface is advantageous to road functionality. A poorly drained road surface, one with depressions and ruts in which water can accumulate will cause backsplash behind wheels, uneven tracking, directional control and in severe cases aquaplaning. Such unevenness will also impact on riding quality.

2.3 Visibility

Good visibility in all weather conditions is imperative for proper road functionality, particularly in situations where high traffic volumes must be accommodated on wide carriage ways ie. 3 and more traffic lanes per direction. Visibility not only relates to the ability of a driver to properly discern visually traffic ahead or behind in rainy conditions but also to the condition of road markings, road signs and roadside furniture.

During rainy conditions any downpour drains off on top of impermeable road surfaces. Smooth and uneven surfaces are conducive to the formation of a thin film which in turn impedes skid resistance, promotes the reflection of light, backsplash behind tyres and when thick enough, aquaplaning; all aspects with a negative impact on road functionality. Detritus, sludge, dust and mud deposited on the road surface become suspended in the run-off. When splashed up by wheels it soils windscreens, number plates and road signs and thus decrease visibility and retro-reflectivity.

By virtue of the fact that water drains through and not on a PA layer the abovementioned disadvantages are partially of totally eliminated.

2.4 Riding quality

Riding quality is a sensation experienced by a driver and which is related to vehicle characteristics, surface (un)evenness, visibility. Good riding quality is a prerequisite for a high level of road functionality. Initial construction irregularities, permanent deformations, ravelling and potholing of the surface all contribute to poorer drainability, visibility and riding quality. All these features impact negatively on road functionality. A well designed and constructed PA has superb riding quality.

2.5 Durability

Durability of a pavement (surfacing) is its ability to stay in the as-designed condition for a long period of time in spite of the number of wheel load repetitions it has to withstand. In addition to aspects already mentioned above road functionality is also influenced by durability of the pavement structure and particularly the surfacing. A road surface which is inclined to bleed, ravel, rut, pothole and deform easily will cause most of the deficiencies discussed above and result in poor road functionality.

3. BEN SCHOEMAN CASE STUDY

3.1 Construction aspects

3.1.1 Manufacturing of Porous Bitumen Rubber Asphalt (PBRA)

At the start of the PA construction variations in binder content and coating of the aggregate was experienced. A drop in temperature between the binder blender and the asphalt mixer was identified as the cause. The temperature drop increased the binder viscosity to such an extent that the pumps could not deliver at consistent flow rates and too high viscosities prevented ideal coating.

The feeder lines were isolated and the problems totally overcome.

3.1.2 Compaction

Compaction was done with static flat-wheel rollers. It was found that excessive passes and rollers ballasted too heavily crushed some of the coarser particles. By adjusting the number of passes and roller mass, this problem was overcome.

Laboratory compaction (Marshall) was done by applying 50 blows on either side of the briquettes. In some cases aggregate crushing could be observed and could be related to relative high Cantabro losses which did not correspond to values obtained on specimes cored from the road.

The influence of the number of blows on porosity, density and Cantabro loss was investigated as shown in Figure 3.1. It could be concluded that a decrease in the number of blows per side from 50 to 40, decreased the density by 0,5%, increased the voids by 0,5% and decreased the Cantabro loss by 25%. The compction effort was lowered to 40 blows per side and better correlation was obtained in respect of porosity and Cantabro loss on laboratory and road samples.

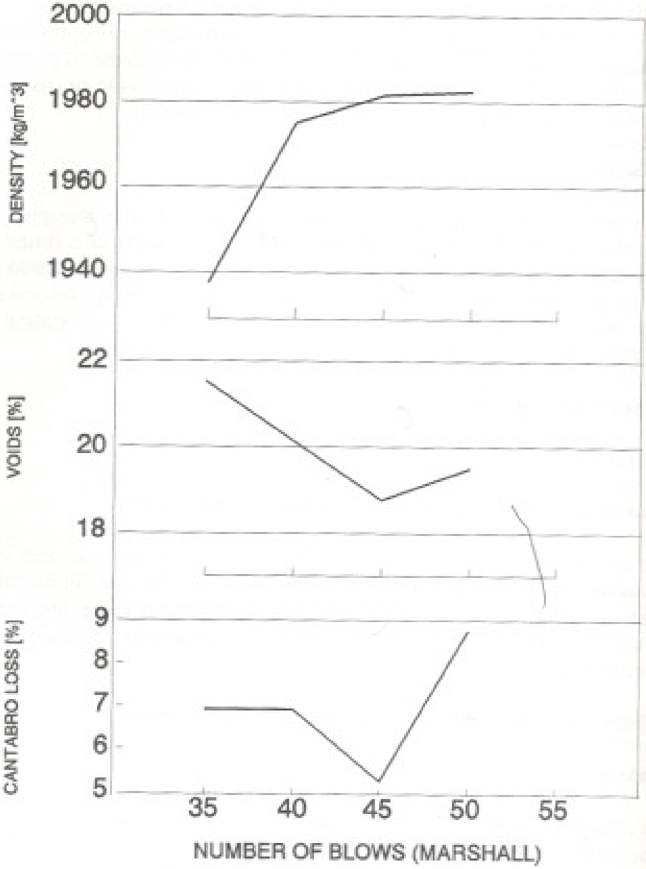

FIGURE 3.1 COMPACTION VS DENSITY, VOIDS & CANTABRO LOSS.

3.1.3 Blotches on the completed surface

During the initial stages of construction the PA, randomly spaced blotches of fine material were observed. These blotches were the result of fines from the mix sticking to the roller drums, being scraped off and accumulating on the roller scrapers. When the accumulation exceeded the capacity of the scraper it dropped on the surface and was pressed into the PA by subsequent compaction.

Once the origin was identified adequate measures were introduced to totally overcome the problem. Tests proved that the overall drainability of the PA layer was not impaired by these blotches.

3.1.4 Inadequate drainability

The section of the Ben Schoeman Highway covered with PA is built on undulating terrain. Several long gradients in excess of 4% and curves are present. During lasting heavy thunderstorms it was found that the PA cannot cope with all the water and drainage takes place in and on top of the surface. This is most prevelant in troughs and where camber converts to superelevation and because run-off is more transverse than longitudinal.

At several isolated places inadequate drainage was observed where the abovementioned conditions do not occur. In situ drainage tests and void determination on cores taken from such places showed non-compliance with specification. These places were identified and the PA was replaced with new PA complying to specifications. Subsequent tests and observations proved that repairwork did not affect the overall drainability of the layer.

3.2 Skid resistance

Skid resistance of PA is well researched, documented and whether measured under wet or dry conditions is hardly speed dependent (Isering et al [199], 7). Measurements done on the Ben Schoeman Highway shortly after completion of the PA surface course fluctuated between 70 and 90 for speeds ranging between 35 and 55 km/h as shown in Figure 3.2.

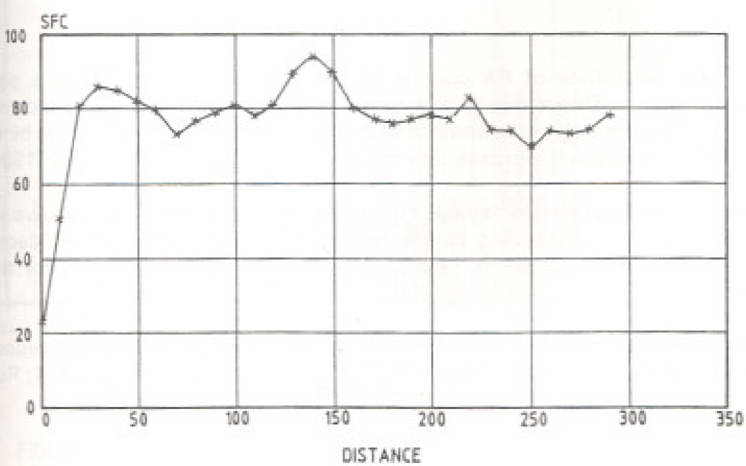

FIGURE 3.2 SFC VALUES ON P206-1 (BEN SCHOEMAN HIGHWAY)

In Table 3.1 values obtained on freshly constructed PA is compared with SFC values of DGA and a PCC pavement. Measurements were done by DRTT (CSIR). Typical results measured over a short section are shown in Figure 3.3 (Verhaeghe [1994], 14).

TABLE 3.1 : SKID RESISTANCE ON P206-1 AND N1-21

PAVEMENT TYPE	MEAN	STD DEV	n
PA (P206-1)	69,6	7,8	101
DGA (P206-1)	57,2	6,0	144
PCC (N1-21)	49,2	7,0	203

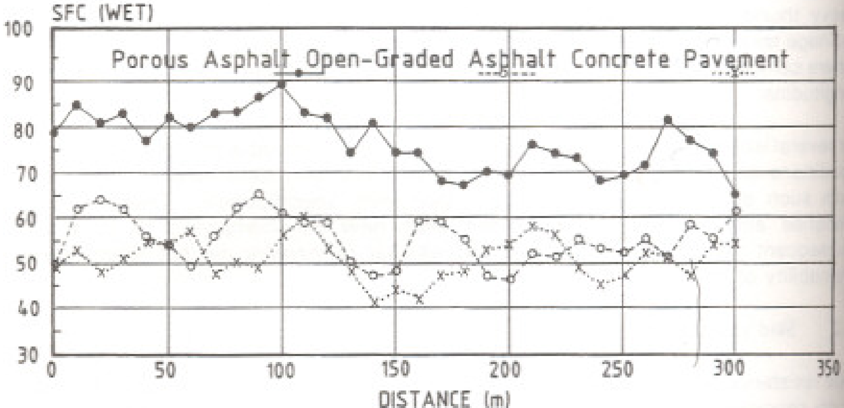

FIGURE 3.3 SKID RESISTANCE MEASUREMENTS: IMMEDIATELY AFTER CONSTRUCTION (AFTER VERHAEGHE)

The initial skid resistance of PA can be lower than values taken after a period of trafficking the layer. This is due to the fact that initially tyres are in contact with the binder film coating the aggregate and not with the aggregate itself. Once the binder film is worn off SFC values will increase (Isering et al [1990], 7 and Ruiz et al [1990], 8).

The decrease viewed in relation to values obtained on other surfaces still shows superior skid resistance of PA. According to analysis by Verhaeghe 70% of the "decreased" values are in excess of 60 kN as opposed to 11% for DGA and 10% for the PCC pavement.

The values measured on the PA on P206-1 are commensurate to those reported by several other instances (Nelson and Abbott [1990], 6; Isering et al [1990], 7; Ruiz et al [1990], 8).

There is less difference between the wet and dry skid resistance of PA than DGA, PCC and surface dressings. This can be attributed to the open structure of PA layers ensuring free draining in most cases. The wet skid resistance of PA is marginally lower than the dry SFC values. As a consequence of this and although statistics are not yet available to prove this, it can be concluded that PA has an advantage over other surface types in curbing wet weather accidents (Van der Zwan et al [1990], 9). In addition PA retains its skid resistance properties better than other surfacings (Sainton [1990], 10).

3.3 Drainability of PA

Drainability of PA is one of its biggest assets. The interconnecting voids in excess of 20% allows water falling thereon to penetrate the layer and prevent the formation of a continuous film on top. The interconnecting voids have the added advantage that pressures building up in front and under moving wheels are rapidly dissipated and thus preventing aquaplaning and airpumping.

To maintain porosity it is paramount that the mix must be so designed that the constructed layer will have voids in excess of 20% and adequate thickness. This void ratio is essential to ensure that clogging of the voids will be delayed as long as possible and thereby preserve the drainability and functionality. The degree of compliance achieved on the Ben Schoeman Highway is shown in Figure 3.4.

The use of an impervious layer on which PA's is laid, is mandatory.

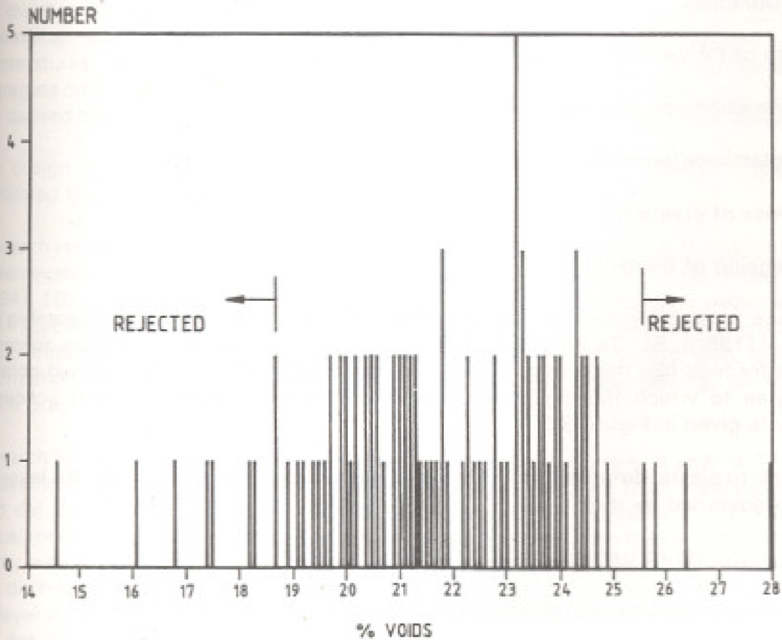

FIGURE 3.4 VOIDS VS TEST NUMBERS

3.4 Visibility

Good visibility is a major contributor to road functionality. PA has the advantage that it prevents the formation of a continuous water film during rainy weather. Such continuous film inevitably forms on impervious road surfaces. At night such a film mirrors oncoming lights. Even in daylight a continuous water film hampers observation of road markings. Smooth surfaces can reflect oncoming lights even in dry road conditions.

The greatest disadvantage of a continuous water film on impervious surfaces, particularly in combination with high speed, is the generation of backsplash. The effect of backsplash on visibility, speed and road functionality is particularly prevelant on roads carrying large volumes of high speed traffic. Not only is driver vision greatly impaired but road signs and roadside furniture are soiled and may lead to loss of visibility and retroreflection. This is particularly applicable to delineators, danger warning signs, road markings and studs.

3.5 Riding quality

Porous asphalt is normally used on major roads and streets and placed on an impervious layer of asphalt or concrete. The asphalt mix is made with well gap-graded material and compacted with static rollers. All this results into a smooth surface of high riding quality. The gap-graded mix and static roller compaction ensure that the flat sides of the aggregate form the surface and this has the result that less vibrations are generated and a quieter ride is obtained.

3.6 Durability

Durability of PA comprises its ability to resist

- ravelling and disintegration
- plastic deformation
- loss of drainability
- ageing of the binder.

Resistance to ravelling and disintegration can be assured by monitoring Cantabro loss (Ruiz et al [1990], 8). To ensure durability of the binder itself the maximum content is aimed at for high film thickness without promoting drain-off and too low void content. The degree to which these requirements could be satisfied on the Ben Schoeman Highway is given in Figure 3.5.

Resistance to plastic deformation is related to the structural capacity of the PA layer and is mainly governed by the

- magnitude of traffic loading
- annual mean highest temperatures
- aggregate grading
- binder characteristics.

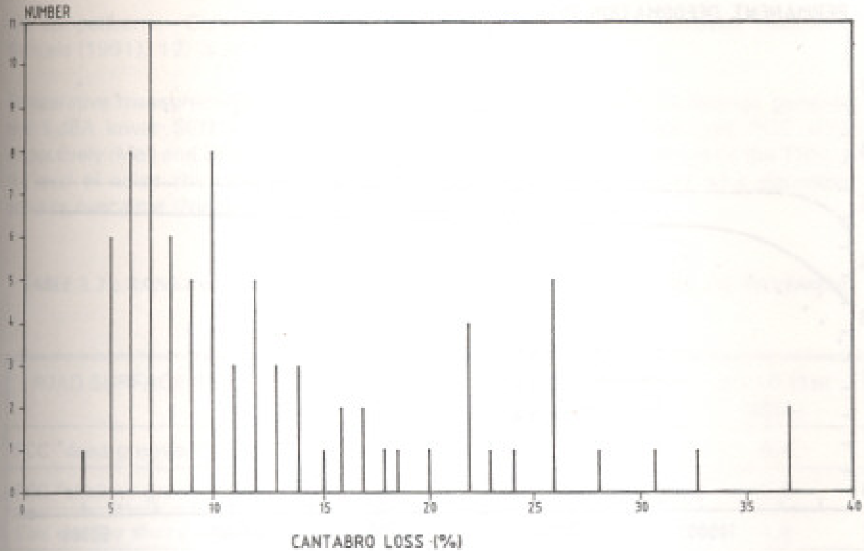

FIGURE 3.5 CANTABRO ABRASION (%) VS TEST NUMBERS

For the Ben Schoeman Highway a bitumen-rubber binder was chosen for its superior rheological properties and particularly its high viscosity and elasticity at road temperatures. The mix was compacted maximal without crushing the aggregate. Since aggregate crushing did occur due to excessive compaction as mentioned in 3.1.2 above it is derived that aggregate interlock is sufficient to ensure minimal plastic deformation.

The design of the PA mix was done in conjunction with DRTT (CSIR). DRTT also monitored the mix properties throughout the contract.

Research results have shown that resistance to permanent plastic deformation (rutting) is achievable through proper mix design (Sainton [1990], 10; Du Plessis et al [1994], 10). Du Plessis et al established that permanent deformation within a similar PBRA asphalt was in the order 1 mm after 175 000 ESALS. This is commensurate with results obtained by Sainton (9); results showing, after an initial setting-in, permanent deformation of 5 mm after 50 000 seconds of dynamic creep testing, as shown in Figure 3.6.

Research has shown that "the weighed average temperature over a year is 1 °C lower in pavements covered with PA than comparable structures with DGA wearing courses" (Van der Zwan et al [1990], 9). Similar statistics are not available in the RSA but if annual mean highest temperatures of the PWV is compared with that in the Netherlands it may well be that the relative difference in pavement temperature will exceed 1 °C. This difference in pavement temperature can be ascribed to the interconnecting voids of the layer which allow for continuous air circulation due to pumping and suction by tyres. Van der Zwan et al concludes that "the temperature in PA courses is likely to remain closer to air temperature than with closed surfacing layers". A lower pavement temperature augers well for prevention of permanent deformation.

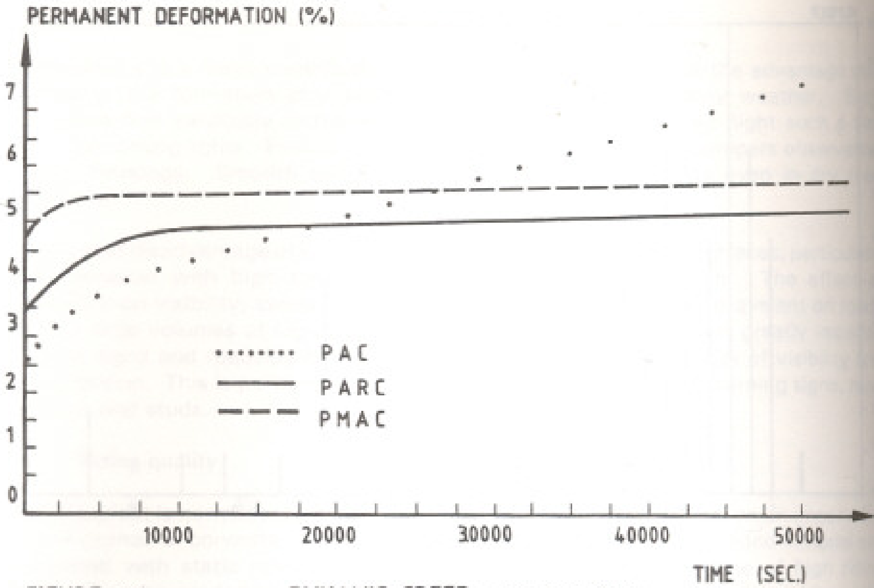

FIGURE 3.6 DYNAMIC CREEP (AFTER SAINTON)

Durability of the binder is best preserved by providing a thick binder film in the PA mix. A film thickness of 15 microns is achievable and should be prescribed (Horak et al [1994], 5). In addition carbon black, an anti-oxidant, is introduced into the bitumen-rubber blend through the rubber crumbs.

Preservation of porosity is a factor of traffic, mix properties and the environment. Traffic will in time compact the PA layer but the stability of the mix will prevent excessive compaction and associated decrease in voids. A well designed and constructed PA mix with voids in excess of 20% will resist excessive secondary compaction and clogging. High volume high speed traffic itself is beneficial for preservation of porosity. Air turbulances caused by traffic, pumping and suction caused by moving tyres, clean the voids.

A dusty environment combined with vehicle related detritus deposits will promote congestion of the voids. Congestion of voids is normally more significant on the lesser trafficked parts of the PA layer (between wheel paths, shoulders). Although cognizance should be taken of this, existing information and results indicate towards a functional service of in excess of 9 years (Sainton [1990], 10); Ruiz et al [1990], 8). P206-1 is situated in an urban area which is relatively dust free. It carries in the region of 95 000 vehicles per day and the cleaning of voids by the traffic should be considerable. Due to these aspects it is anticipated that the functional service of the PA layer will be 9 years or longer.

3.7 Noise abatement

The primary consideration for incorporating PA as a surfacing layer on P206-1 was road safety and functionality. The added advantage of road noise abatement is worth mentioning. Horak et al [1994], 7 and all contributors to TRR 1265 present information and comparisons. Comparative noise measurements done in Australia (Glazier and Samuels [1991], 12) is shown in Table 3.2.

Comparative measurements done in the RSA indicate that OGA surfacings generate 9 and 5 dBA lower SEN values than a coarse single seal and textured PCC surface respectively (Meij and BKS Inc [1991], 13). Of significance are findings of the TRRL that the level of noise abatement can be retained on PA layers in spite of a decrease of porosity over time (Nelson and Abbott [1990], 6).

TABLE 3.2 : RANKING OF SURFACE TYPES ON COMPARING PAIRS OF PAVEMENT TYPES AND TRAFFIC NOISE

ROAD SURFACE TYPE	AVERAGE L10 (1h) dB(A)	σ L10 (1h) dB(A)	σ L10 (1h) dB(A)
PCC "deep grooved"	87,2	7,4	9,4
PCC "shallow grooved"	83,6	3,8	5,8
Cold overlay slurry seal	82,6	2,8	4,8
PCC "hessian dragged"	81,0	1,2	3,2
Dense graded asphalt	79,8	0	2,0
OGAC (PA)	77,8	- 2,0	0

3.8 Economics

It is the first time in the RSA that a PA surface course is used on a road like the Ben Schoeman Highway, carrying in the order of 95 000 vehicles per day and consequently no reference data exists against which cost comparisons can be made. The 40 mm layer was done at a rate of R16-20/m^2 which is comparable with dense grade bitumen-rubber asphalt of similar thickness. The structural contribution of PA however is not on par with that of DGA mixes. Structural contribution of PA is generally set at 50% of that of DGA (Isering et al [1990], 7); Van der Zwan et al [1990], 9). In the structural design of the Ben Schoeman Highway no contribution to the structural capacity was allocated to the PA surface course. Whatever structural contribution is rendered is regarded as a bonus.

The main reason for utilizing PA was road functionality and thereby reducing delays and accidents. Reduction of average speed by backsplash on a wet road surface is common knowledge. Such speed reductions combined with decreased skid resistance and impaired driver vision is conducive to traffic accidents. Reasoning from this premises and considering only slight impairment of vision and skid resistance of wet PA surfaces it can be concluded that the wet weather accident rate should only be marginally above that in dry weather. In the Netherlands it was found that the number of accidents per million vehicle kilometre travelled is 3,5 times higher on wet than on dry DGA surfaces (Van der Zwan et al [1990], 9), that skid resistance of wet PA is comparable to dry PA surfaces and that therefore a substantial decrease in wet weather accidents can be anticipated. This reduction in accidents will result in considerable over-all life cycle savings.

No comparable accident statistics are as yet available for P206-1. Most recent accidents are given in Figure 3.7. Insufficient information in respect of the post construction phase prevents conclusive comparisons although it appears that a dramatic decrease was effected during January and February 1994. It would appear that substantial potential savings can be affected through the use of PA surfacings but further research is necessary to gather information regarding accidents and traffic flow in all weather conditions.

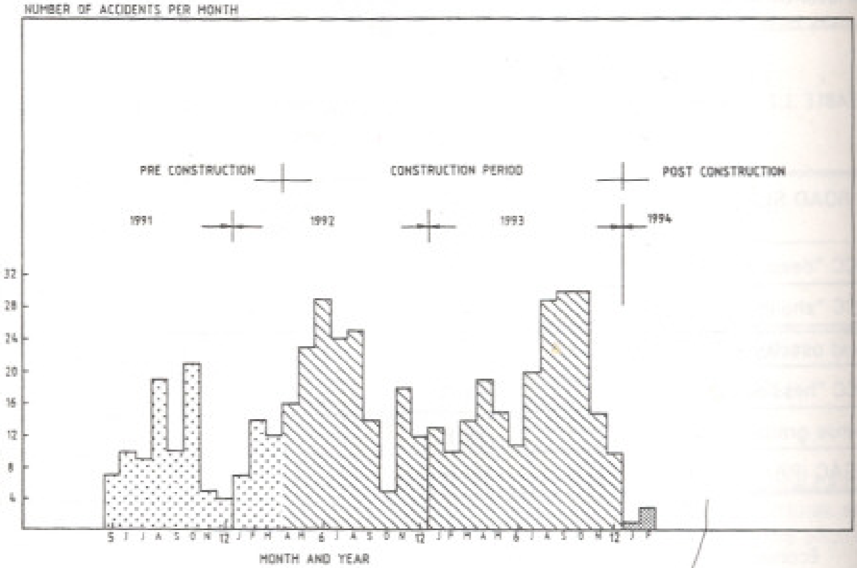

FIGURE 3.7 ACCIDENT STATISTICTS : MAY 1991 TILL FEBRUARY 1994

4. RECOMMENDATIONS BASED ON PRACTICAL EXPERIENCE

4.1 Construction

Critical aspects which must be tightly monitored and controlled during the manufacturing and paving of the mix are

- binder viscosity to ensure reliable pump delivery and proper coating
- grading of the aggregate to ensure adequate voids and minimize Cantabro loss
- compaction to ensure maximal densification without crushing the aggregate
- soiling of the freshly laid PA layer by fines scraped off the roller drums or other detritus.

4.2 Repair work

No problems were encountered to replace non-complying patches with new PA. Such repaired patches are hardly visible and do not affect the overall drainability of the layer.

This augers well for future mandatory repair work.

4.3 Design

Accumulation of rainwater at the lower ends of steep gradients and cross-overs from camber to superelevation warrants investigations into designs that will eliminate or minimize detrimental effects on road functionality due to this. Transverse or skew collector drains to intersect longitudinal drainage may offer solutions.

4.4 Research/monitoring

The performance of PA under South African conditions are not known. Research results show that performance will be up to expectations. To be able to adjudicate the performance it is recommended to monitor the PA on the Ben Schoeman Highway in respect of rutting, skid resistance, durability, noise abatement, drainability, the latter both in terms of secondary compaction and clogging of voids. If clogging of voids decreases the void content of the layer, means and ways of cleaning the layer need to be researched.

The extent to which the PA on the Ben Schoeman Highway will influence road accidents warrants further research.

5. CONCLUSIONS

The utilization of PA as a surface course offers an important opportunity to the pavement engineer to promote road functionality. By incorporating a PA surface layer in the pavement design for P206-1 between Corlett Drive and Buccleugh the requirements of the TPA Roads Branch for superior road safety and functionality were achieved to great extent. Road safety and functionality is brought about by utilizing the advantageous properties of PA i.e. high wet weather skid resistance, excellent wet weather and night time visibility, superior riding quality and a durable surface layer.Although it is early days with regard to quantify the economics of a PA, initial indications are that savings (substantial) may be in the offing.

ACKNOWLEDGEMENTS

The authors acknowledge the permission of the Deputy Director-General : Roads of the Transvaal Provincial Administration and the Director of the Division for Roads and Transport Technology to publish this paper.

REFERENCES

1. Visser A T, de Wet L F, Marais G P [1974]. Resurfacing of the Ben Schoeman Highway with gap-graded asphalt. Capsa'74, Durban, RSA.

2. Verhaeghe B M J A [1993], Civil Engineering, Nov 1993. ISSN 1021 - 2000.

3. Committee for State Road Authorities [CSRA] [1987]. Selection and Design of Hot-Mix Asphalt Surfacings for Highways. Technical Recommendations for Highways TRH8, Department of Transport, Pretoria, 1987.

4. International Road Federation [1992], Contribution towards reduction of traffic noise, Geneve, 1992.

5. Horak E, Verhaeghe B M J A, Rust F C, Van Heerden C [1994]. The use of porous asphalt on major roads in Johannesburg. Paper presented at Capsa'94, Cape Town 1994.

6. Nelson P M and Abbott P G [1990]. Acoustical performance of pervious macadam for high-speed roads. TRR No 1265 Washington DC, 1990.

7. Isering T, Köster H and Scazziga [1990]. Experience with porous asphalt in Switzerland. TRR 1265, Washington DC, 1990.

8. Ruiz A, Alberola R, Pèrez F and Sànchez B [1990]. Porous asphalt mixtures in Spain. TRR 1265, Washington DC, 1990.

9. Van der Zwan J Th, Goeman Th, Gruis H J A J, Swart J H and Oldenburger R H [1990]. Porous asphalt wearing courses in the Netherlands: State of the art review. TRR 1265. Washington DC, 1990.

10. Sainton A [1990]. Advantages of asphalt rubber binder for porous asphalt concrete. TRR 1265, Washington DC, 1990.

11. Du Plessis J L, Verhaeghe B M J A, Rust F C. Heavy Vehicle Simulator testing of porous asphalt trial sections for TPA. DPVT report C/263 CSIR, Pretoria. 1994.

12. Glazier G and Samuels S. Effects of road surface texture on traffic and vehicle noise. TRR 1312, Washington DC 1991.

13. Meij G V and BKS Inc. SARB. Dwarssnitstandaarde en padreserwewydtes vir K-roetes. SARB Report RR 89/071. Chief Directorate : National Roads. Pretoria 1991.

14. Verhaeghe B M J A. Constructability and post-construction evaluation of ARM-R-Drain on the Ben Schoeman Highway. DRTT-c/237-7 CSIR, Pretoria, 1994.