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Examination of the Effects Caused By Air Voids in Asphalt Mixture to Extend the Fatigue Service Life in Asphalt Roads

Mr BN Ngxongo[1] and Prof D Allopi[2]
Department of Civil Engineering and Surveying
[1,2]Durban University of Technology
P.O. Box 1334, Durban, 4000, South Africa

Abstract: Pavement deformation (rutting) of Asphalt is one of the most experienced distresses resulting in pavement permanent deformation in the service life of a road. Zhi et al, 2009 states that with an increase in traffic (light and heavy transport) and climatic changes, the road surface is exposed to constant and excessive traffic stress which may lead to permanent pavement deformation.

In service, asphalt model need to provide a safe, durable and stable, road surface with early failures. The stability of the asphalt is determined by the strength, flexibility and the degree of compaction in the progress of placing of the mixture. The strength of asphalt needs to be adequate to withstand the load without shear deformation that may occur between the particles.

The properties of asphalt mixture are influenced by the quality of its components such as binder, aggregates and air voids in mix and the mix design quantities.

A reduction in water damage can be attained by modifying the aggregate surface through chemical treatment or the addition of anti-stripping agents. However, complete covering of the particle by an asphalt film should decrease the quantity of water reaching the aggregate and reduce the deleterious effects of water on the aggregate. Building of roads with low air voids or good drainage may be the most influential effect in reducing water damage, by limiting the exposure of the asphalt aggregate bond to water.

This study has discovered that high voids reduce the stiffness strength of the asphalt mixture which decreases the road service life. Rubberize asphalt has high VIM and high stiffness which perform well. These display good characteristics of the rubber crumb binder that is best modifying agent in the asphalt mixtures that is able to resist fatigue on the road thus it can extend the road fatigue life and perform well under extreme heavy traffic load.

Keywords: air voids, asphalt, pavement, rutting

1. Introduction

The Main Road in Butterworth, Eastern Cape is permanently deformed at the wearing course surface, which has led to rutting. Rutting is always recognised as a substance distress for hot mix asphalt (HMA) and asphalt pavement performance in line with repetitive loadings.

Cross et al (1999) states that an in-place air voids exceeding 3% is required to decrease the probabilities of early stage of rutting. Zaumanis et al (2016) furthermore disputed that there is a critical air void of almost 3% below which strain rises rapidly.

Air voids are tiny spaces between the coated aggregate particles in the compacted HMA. At low voids the coated aggregate particles will climb over each other under the action of the load resulting in an increase in volume and shoving. This behaviour has also been experimented in the field in that pavements with inadequate compaction experience densification under traffic and mixtures with low voids often increase in voids when shoving takes place.

When the waterproofing layer of asphalt surrounding an aggregate particle is continuous, then water can penetrate the system by diffusing through the asphalt film, removing along the way those asphaltic components that are solubilized. If cracks occur in the film, then water can intrude to the asphalt aggregate interface, causing failure at or near the interface. The failure can be interfacial or cohesive either in the asphalt or in the aggregate.

When quality aggregates and an appropriate binder are used, the air void content and the effective volume of binder in the asphalt mixture are the two volumetric properties that most affect both the durability and fatigue cracking resistance of asphalt concrete mixtures.

Air voids are mainly measured by construction method, and the durability and fatigue life of asphalt mixtures. Asphalt mixtures with lower air void contents are less permeable to both air and water thus reducing binder age hardening and the potential for moisture damage.

Asphalt mixtures with lower air voids also have greater strength and are more resistant to fatigue damage.

Many asphalt technologists agree that the degree of compaction of asphalt, measured by the volume of air voids, is probably the most important factor affecting the performance of the mixture.

For dense graded mixtures it is generally agreed that the air void content of the pavement should be no higher than 8% and should never fall below 3% during the service life of the pavement.

2. Objectives of the study

The main aim of this study is to evaluate the characteristics of asphalt pavement permanent deformation due to air voids in order to obtain asphalt mixtures which will provide suitable percentage of air voids in the mix.

3. Study limitations

The study is based in Butterworth, Eastern Cape and is only limited to the evaluation of air voids and its effect on asphalt mixes.

4. Problem statement

The Main Road in Butterworth, Eastern Cape is permanently deformed at the wearing course surface, which has led to rutting.

The main factor which contributes to the problems of asphalt fatigue is air voids in the asphalt mix, which decrease the road serviceability life span.

Rutting in asphalt layers is initiated by an asphalt mix that is too low in shear strength to resist the imposing of repeated higher axle loads, environmental condition and construction errors in the road.

5. Causes and effects of air voids in asphalt mix

Orhan et al (2015) states that the interlock between the aggregates weakens the asphalt strength due to the aggregates to push away from each other, thus increasing the air voids in the asphalt mixture which weakens the asphalt strength.

Segregation is also a common construction problem that significantly affects asphalt mixture durability. Areas of the pavement that are segregated coarse have lower binder content, higher air void content, and greater permeability compared to no segregated areas. These areas are prone to durability distresses including raveling, accelerated aging, and damage from moisture infiltration.

High air voids allow air and water to penetrate into the asphalt mixture resulting in more rapid aging and potential for moisture damage. Asphalt mixtures with low air voids are prone to rutting and shoving. One rule of thumb based on field performance data that is often cited for dense graded mixtures is that pavement life is reduced about 10% of each 1% increase in air voids above 7%.

The increase in compaction or decreased air voids has the effects to increase resistance to rutting except at very low air void contents where instability may occur.

When the asphalt pavement has a sufficient highly accessible air voids, the oxidation rate is largely determined by the temperature in the pavement. On the other hand, when the percentage of accessible air voids in the pavement is considerably lower, the hardening rate of binders in pavements is reduced significantly.

Kassir (2009) states that in order to mitigate the damage caused by stripping, it is essential to have the correct mix design for the paving application. However, even with the correct mix design, stripping can still occur due to improper compaction of the asphalt during placement at the job site. An under compacted mix will typically exhibit a higher percentage of air voids than is desirable. The voids provide a place for water to enter the pavement and to reside. Properly compacted mixes will have fewer voids where water can reside.

Asphalt mixes prepared with air voids in the range of $\leq$ 5% will significantly reduce moisture infiltration into the asphalt mix, even to the point of becoming nearly impervious. Asphalt mixes exhibiting air voids of $\geq$ 8% will allow an unimpeded influx of water into the asphalt matrix.

6. Methods and Materials

Below is the method and materials used during the laboratory investigation of the case study.

6.1 Methodology

The methodology adapted to meet the objectives of this study implicated a field investigation and laboratory investigation. All the tests were carried using Testing methods - TMH1. The laboratory investigation was conducted to characterize permanent deformation property of asphalt mixtures using the Dynamic Creep test.

6.2 Materials and equipments

Below is table 1 which illustrates the materials and equipment used in the case study.

Table 1: Materials and equipments

Material		
r	**Aggregate size**	**Description and source**
	13.2mm	Calcitic hornfels, crushed stones from Msobomvu Quarry
	9.5mm	Calcitic hornfels, crushed stones from Msobomvu Quarry
	6.7mm	Calcitic hornfels, crushed stones from Msobomvu Quarry
	4.75mm – Crusher Dust	Calcitic hornfels, crushed stones from Msobomvu Quarry
Binder		
Type	Bitumen – Medium Continuously Graded	60/70, Rubber crumb and AE-2 Polymer
Grade	Bulk Relative Density	1.025
Source	Mixing Temperature	140^{o}c-160^{o}c
Penetration	Compaction Temperature	160^{o}c

Equipment	**Qty**	**Equipment**	**Qty**
Marshall compaction mould 101.6 mm diameter and 87.3 mm height	1	2 litre Flask	1
Marshall Compaction hammer with 98.5 mm	1	Rubber Stopper, glass tube	1
Compaction pedestal consisting of 203x203x457 mm	1	Marshall breaking Head of two half-moon segments. Equipment to measure at least 25 KN – 50 KN.	1
Oven Hot Plate Capable of temperature 200 °C for aggregate and bituminous	1	Suitable flow meter to measure deformation for stability and flow	1
Mixing basins 300 mm diameter	3	Gloves for removing the briquette from hot water	1
Balance scale weight	1	Loading frame with mechanical hydraulics (2KN) for dynamic creep	1
Briquette moulds	16	Dial gauge indicator	1
Mixing Container	3	Suitable heating box maintain temperature of 40 °C	1
Thermometer measure up to 200 °C	1	Suitable timing device to measure time at every cycle loading	1
Water Bath to maintain temperature of 25 °C	1	Computer to record result for creep	1
Vacuum Pump of reducing Pressure Rice Method	1	Dynamic Creep Box and Vanier	1

		Calliper	

7. Research output

Below are the result obtained during the case study in order to determine the effect of air voids on asphalt mixes.

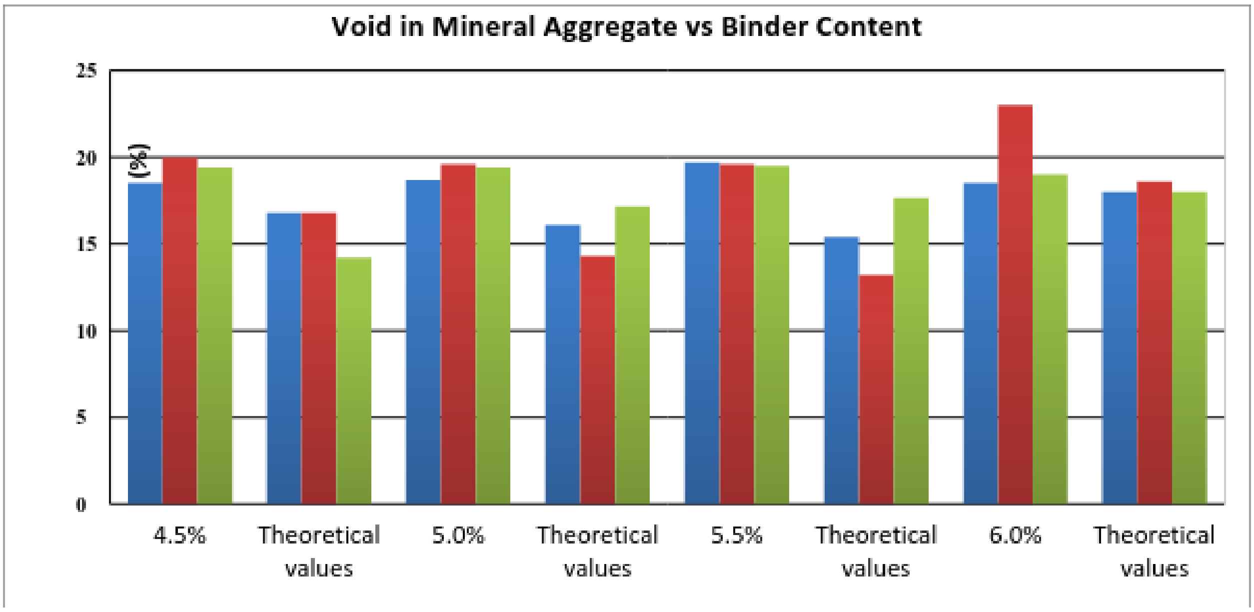

Figure 1: Air voids in the mineral aggregate versus binder content.

The above result shows that the more the dry aggregate, the more VMA in the dry aggregate, the more space is available for the binder. A high stiffness is observed at higher binder content which is at 6.0% binder content where the value of the VMA is 23% over a theoretical value of18.6% by Cross et al (1999), thus resulting in a good fatigue resistance and a durable binder film thickness.

When the aggregate gradation is changed, the density of the HMA increases with a minimum VMA and the HMA is low in durability due to the thin film binder in the asphalt mix. In order to counter this and economize the binder content, one must lower the VMA and the pavement quality will be improved.

Too much air voids allow access of water to penetrate through the HMA thus leading to pavement failure in terms of rutting. On the other hand, too low air voids lead to pavement flushing.

Current findings indicates that the 4.75mm aggregate causes rutting on an asphalt pavement quicker than the aggregates lower then 4.75mm. However the aggregates lower than 4.75mm causes the asphalt pavement to quickly develop cracks.

When using AE-2 Polymer, an increase in the binder content has no significant ranging from 4,5% to 6.0%. However this is not in line with Amir et al (2012) who states that for AE-2 at 4.4% binder, the aggregate degration is 14.2% versus 19.4% of findings from the current study.

In addtion, Zhi et al (2009) is in line with the current study for a AE-2 Polymer binder where he agues that increasing the binder percentage, the aggregate gradition remains the same. This is from his finding where the binder content is 5.3%, the aggregate gradation is 17.16% and for a 6.2% binder content, the aggreagate gradiation is 18.0%.

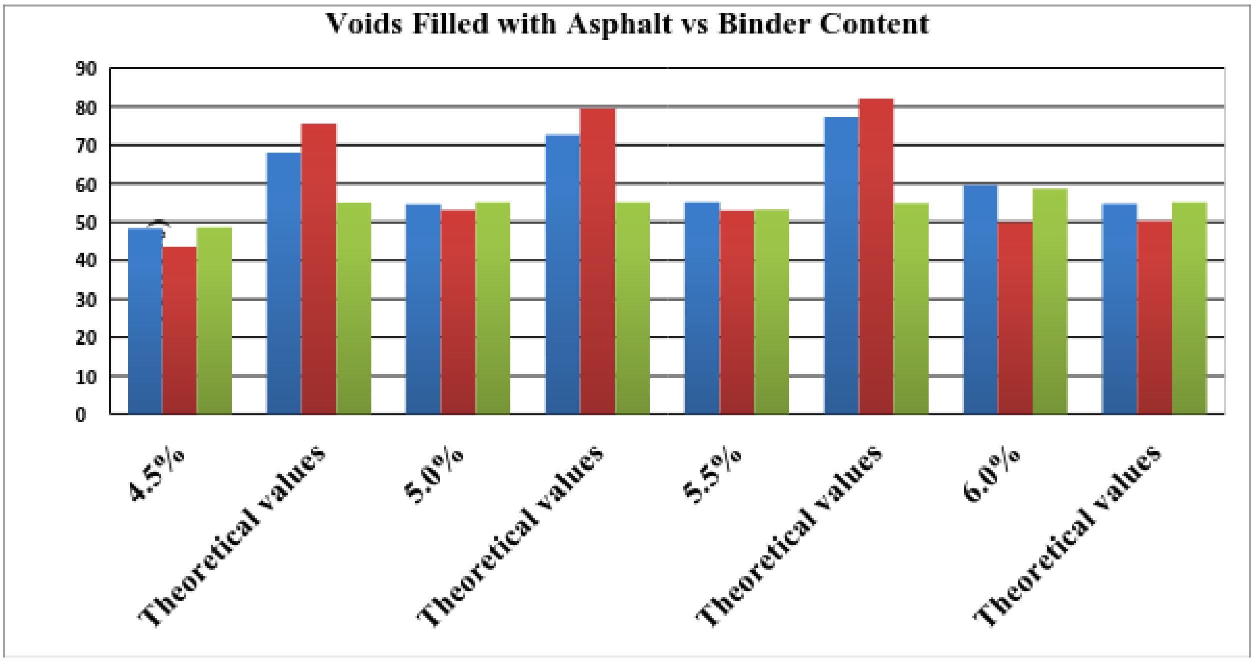

Figure 2: Voids filled with asphalt versus binder content.

The VFB for 60/70 Pen shows an increase in percentage with an increase in the binder content. This is concurrent with the finding of Saad and Ibtihal (2014) where the VFB values are 5.5%for 4.5% binder content, 79.4% for 5.0% binder content and 77.3% for 5.5% binder content. However, John et al. (1995) has a lower VFB of 54.7% for 6.0% binder content.

The VFB for Rubberized Asphalt for the current study increases with increase of binder content from 4.5% to 6.5%. However, the study shows that there is no significant increase of the VFB between 5.0% - 5.5% binder content.

The EA-2 Polymer Asphalt for both the current study and by John et al. (1995) shows un-even increase and decrease of the VFB values with increase in binder content.

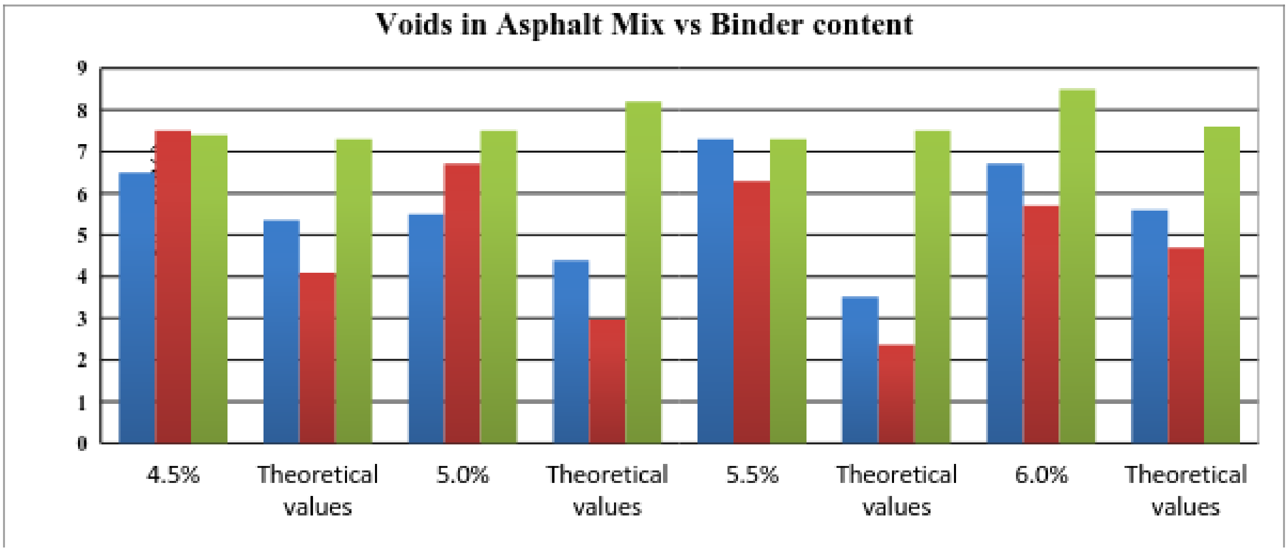

Figure 3: Voids in asphalt mix versus binder content.

The amount of air voids in an asphalt mix plays a significant role in determining the lifespan of asphalt pavement.

The 60/70 Pen and Rubberized asphalt for both the current study and literature by John et al. (1995) shows un-even increase and decrease of the void values with increase in binder content where the binder content is between 4.5% to 6.0%.

The AE-2 Polymer asphalt shows a constant value with no increase or decrease in the void value between 4.5% binder to 6.0%. This is concurrent with literature from John et al. (1995).

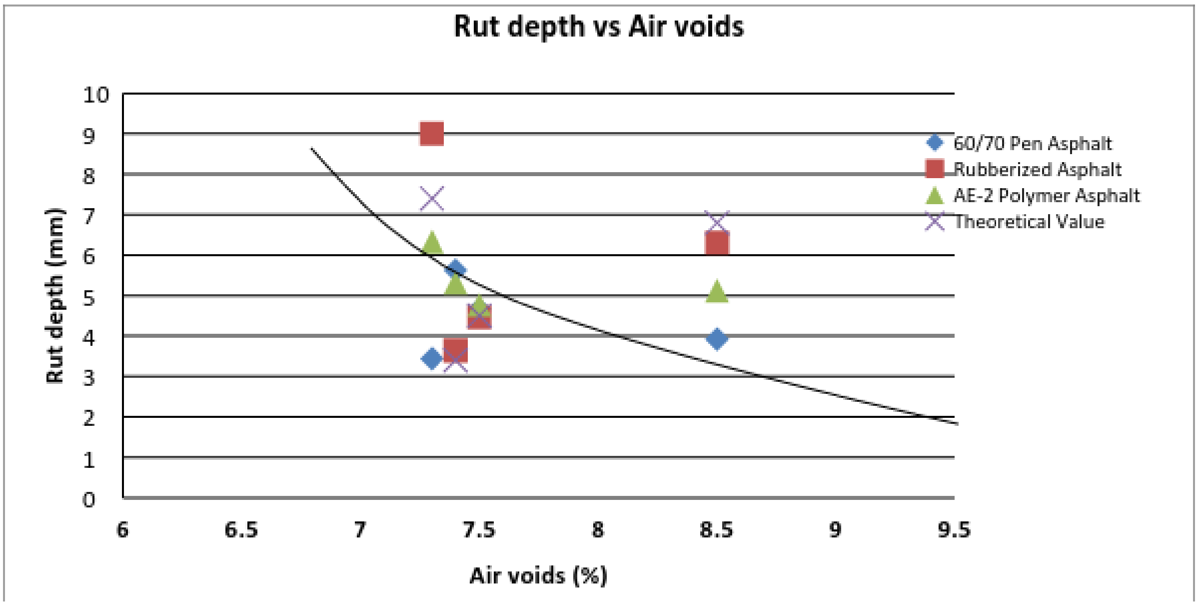

Figure 4: Permanent Deformation Properties of Asphalt Concrete Mixtures

In the above figure 4, it is evidence that rubberized asphalt have a high void at 5.5% where the air voids is 9.0%. This is in line with Rabbira 2002) who states that where the air void at 5.5% is 7.4%. This represents a reduction in the asphalt durability.

The rubber crumb binder has a more durable capability as compared to 60/70Pen and EA-2 HMA. Anochie-Boateng et al (2010) indicates that modified asphalt is twice as effective as unmodified pure asphalt.

8. CONCLUSIONS

The air voids are essential in the mix design to prevent pavement from flushing, shoving, and rutting.
Air voids may be increased or decreased by lowering or raising the binder content.

The current study indicates that the durability of asphalt pavement is affected by air void in related to the VIM. A 5.5% binder content is the recommended binder content for asphalt mixes.

9. RECOMMENDATIONS

It is recommended that in order to increase the VMA the binder content in the asphalt mix must be lowered; this principle is also applicable in the gradation of aggregates. In order to maximize the quantity of VMA, the binder content must be reduced.

This effect may not be entirely from the effect of gradation, but nevertheless it has one of the stronger effects on VMA. Reducing binder content to the lower end of the specification will maximize the amount of VMA which can be obtained.

The voids in asphalt mixture are directly related to density, thus it is necessary to closely control the density in order to ensure that the voids stay within acceptable range.

10. REFERENCES

[1]. Amir G, Ehsan J, Yunus N, Zahra A and Mahmood K (2012), Effect of aggregate gradation on rutting of asphalt pavement. Procedia – Social Behavioural Sciences 53 (2012) pg. 440 – 449.

[2]. Anochie-Boateng J, Denneman E, O'Connell J, Mturi G and Ventura D (2010), Hot mix asphalt testing for the South African pavement design method. Proceedings of the 29th Southern African Transport Conference (SATC 2010).
[3]. Cross, S.A., Adu-Osei, A., and Hainin, M.R. (1999), Effect of gradation on performance of asphalt mixtures, Paper presented at 78th annual meeting of the Transportation Research Board, Washington D.C.
[4]. John T.H, John A.D, Bor-Wen T, and Carl L.M (1995), Fatigue performance of asphalt concrete mixes and its relationship to asphalt concrete pavement performance in California.
[5]. Kassir A.F (2009) Fractional Chemical Composition of Asphalt as a Function of Its Durability.
[6]. Orhan A, Hanifi B, and Ersin O (2015), Durability of concrete made by partial replacement of fine aggregate by colemanite and barite and cement by ashes of corn stalk, wheat straw and sunflower stalk ashes, Construction and Building Materials 106 (2016) 253–263. www.elsevier.com/locate/conbuildmat
[7]. Rabbira Garba (2002) Permanent Deformation Properties ofAsphalt Concrete Mixtures
[8]. Saad I.S and Ibtihal M.L (2014), Impact of Asphalt Additives on Rutting Resistance of Asphalt Concrete, International Journal of Scientific Research in Knowledge, 2(3), pp. 151-159, 2014. *saadisasarsam@coeng.uobaghdad.edu.iq*
[9]. Zaumanis M, Rajib B, Mallick B and Frank R (2016), 100% hot mix asphalt recycling: challenges and benefits. 6th Transport Research Arena April 18-21, 2016
[10]. Zhi Suo and Wing Gun Wong (2009), Analysis of fatigue crack growth behaviour in asphalt concrete material in wearing course, Construction and Building Materials 23 (2009) 462–468. *www.elsevier.com/locate/conbuildmat*