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RUTTING IN ASPHALT PAVEMENT WHICH AFFECTS THE FATIGUE SERVICE LIFE IN ASPHALT ROADS

Mr BN Ngxongo[*1] & Prof D Allopi[2]

[*1]Department of Civil Engineering, Durban University of Technology, P.O. Box 1334, Durban, 4000, South Africa

[2]Department of Surveying, Durban University of Technology, P.O. Box 1334, Durban, 4000, South Africa

ABSTRACT

Fatigue is a major mechanism resulting in flexible pavement distress. Pavement distress results into rutting which lead to structural failure in the asphaltic roads. This is due to axle load applied on the surface of flexible roads and cause permanent pavement deformation. Saad and Ammar (2015) states that the causes of rutting and fatigue in asphalt pavement are a result of accumulation of cracks, aging of binder, repeated axial loading and environmental conditions.

The asphalt surfaced roads in Butterworth experience permanent pavement deformation at the asphalt wearing course surface and this result in the decrease of the road service life.

The main aim of this research is to investigate the problems associated with rutting and improve the asphalt wearing course surface by selecting the most appropriate asphalt mix design from three selected mixes of unmodified and modified asphalt parameters.

These parameters are pure asphalt-60/70 (unmodified control mix design), rubberize asphalt of rubber crumbs blended with bitumen (modified asphalt) and AE-2 polymer modified asphalt (modified asphalt).

The objectives of this study were met throught the conduction of laboratory tests which comprised a total of 18 briquettes from the 3 mix design parameters, whereby six (6) briquettes of each mix design were used to test the fatigue resistance of asphalt and its characteristics, through the use of Marshall test and Dynamic creep test.

The main parameters that affected the rutting are the volumetric composition of the mix design. The asphalt mix compositions are the aggregate properties, bituminous binder properties, gradation and angularity of aggregate. The volumetric composition affects the voids in mix (VIM) and the stability of the final asphalt mix in place on the roads. The most effective asphalt mix design was rubberized asphalt. This is due to the properties of the rubber crumb binder to display good characteristics of high VIM and high stiffness thus resisting fatigue on the road. This extends the service life of asphalt roads and performs well under heavy traffic load

Keywords: *Rutting, deformation, asphalt, pavement*

I. INTRODUCTION

Rutting is one of the main distress mechanisms in flexible pavements. Ankit et al (2014)states that pavement, an advanced physical structure, is affected and also responds in multiple ways to the traffic loading and environmental conditions.

The flexible pavement in Butterworthexperiences permanent pavement deformation thus decreasing the road service life. It is the purpose of this research to improve the wearing course of asphaltic roads. The research has examined the causes of asphalt pavement failure.

The effects of permanent pavement deformation result in a decrease in the road's service life; and a compromise to traffic safety.

A study by Dondi et al, (2015) concluded that the main factors that influence hot mix asphalt performance are binder content, compaction, material grading, temperature and traffic loading. This is in line with this study which recognized that the main factors which contribute to the problems of asphalt fatigue are; poor binder content, aggregate gradation, traffic load and volumetric parameters (void in mix).

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

This research will attemptto determine the rutting resistance of both unmodified and polymer modified binders. In order to achieve this outcome, the generalized Dynamic Creep will be used to extend the deformation performance of both mixes on the Elastic Modulus graph. The unmodified bitumen will be compared with two other modified binders of rubber crumb and AE-2 polymer modified bitumen.

II. PROBLEM STATEMENT

Fatigue failure has been a huge problem in many roads in our country by not meeting the design service level. The study intends to investigate the background problem which causes asphalt pavement failure and improve the road performance through field and laboratory investigation.

There are mainly four layers on asphalt pavements. These layers are namely;

- Asphalt surfacing layer
- Base layer
- Sub-base layer
- Sub-grade layer

The materials which make up these layers are most likely to be bitumen, fine aggregates or coarse aggregates depending on the mix design.

It is the understanding of the researcher that several cracks occur in other layers of the pavement and have an effect on the asphaltic layer, however this research is limited to evaluating the rutting of the top asphaltic layer in order to extend the service life of asphalt roads.

It further stated by Tschegg et al (2011), that cracks develop due to tensile and shear stresses which are a resultof axial loading.

III. CAUSES OF RUTTING

According to Mahmoud et al (2015), the visco elastic behaviour of asphaltcontributes to the rutting of the asphalt surface. This is due to the bituminous constituents whereby at high temperatures are viscous and elastic at low temperatures thus causing visco elastic performance under intermediary conditions.

Permanent pavement deformation is also caused by insufficient strength of the asphalt physical properties, unsatisfactory compaction of the road surface and inadequate pavement strength (Saad and Ibtihal 2014).

Amir et al (2012) states that rutting occurs due to repeated loading on the Hot Mix Asphalt (HMA) pavements. The degree and depth of rutting is also influenced by the external and internal factors of the pavement structure which are the thickness of the pavement, bitumen binder content, aggregate and mixture properties. According to Ghazi et al (2013), the fatigue life of pavement is affected by the different properties of the mixture, including the type and amount of binder used in the mixture, temperature and air voids.

The movement of cracks from the upper surface of an asphalt pavement to the bottom bituminous layer results from the aging of the top surface layer which is related to oxidation reaction on the bituminous layer.

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Suo (2012) states that one of the most problematic effects of asphalt pavement deformation which affects the service life of asphalt roads is the binder aging. He further states that aging results in stiffening the asphalt layer thus making it brittle. This will cause the pavement layer to have a potential of experiencing fatigue and thermal cracks to occur.

The mechanical properties which of asphalt mix design are the ability of aging to increase viscosity, softening point and complex modulus, while decreasing the penetration and phase angle.

Suoet al (2012), the speed of the moving load has a significant effect on elastic and plastic pavement response. The confinement effect of shoulders is found to be able to reduce pavement deflection. The effect of different load attributes, axle load, number of axles and number of wheels, as well as cross section attributes, subgradetypes and shoulder width, are investigated and found to be significant in flexible pavement response.

According to Ankit (2014), rutting can be divided into three stages namely;

a. Primary rutting

This refers to the development of predominantly densification of asphalt mix which is a result of compaction from traffic axial loading. Primary rutting affects rate of plastic deformation.

b. Secondary stage

In the secondary stage, the asphalt experience plastic shear and the rutting increases in smaller constant rate.

c. Tertiary stage

In the tertiary stage, the asphalt undergoes shear failure and the mix flows to brittle and cracks occur.

The tertiary state normally occurs as a result of maintenance and rehabilitation works.

IV. OBJECTIVES AND EXPECTED OUTCOMES

Due to pavement fatigue experienced in South African roads, the study intends to evaluate the problems associated with asphalt mix design and to improve the road performance in South African Roads.

V. GEOGRAPHIC LOCATION OF THE STUDY

The study will be conducted on the main road of Butterworth in the Eastern Cape which experience permanent deformation.

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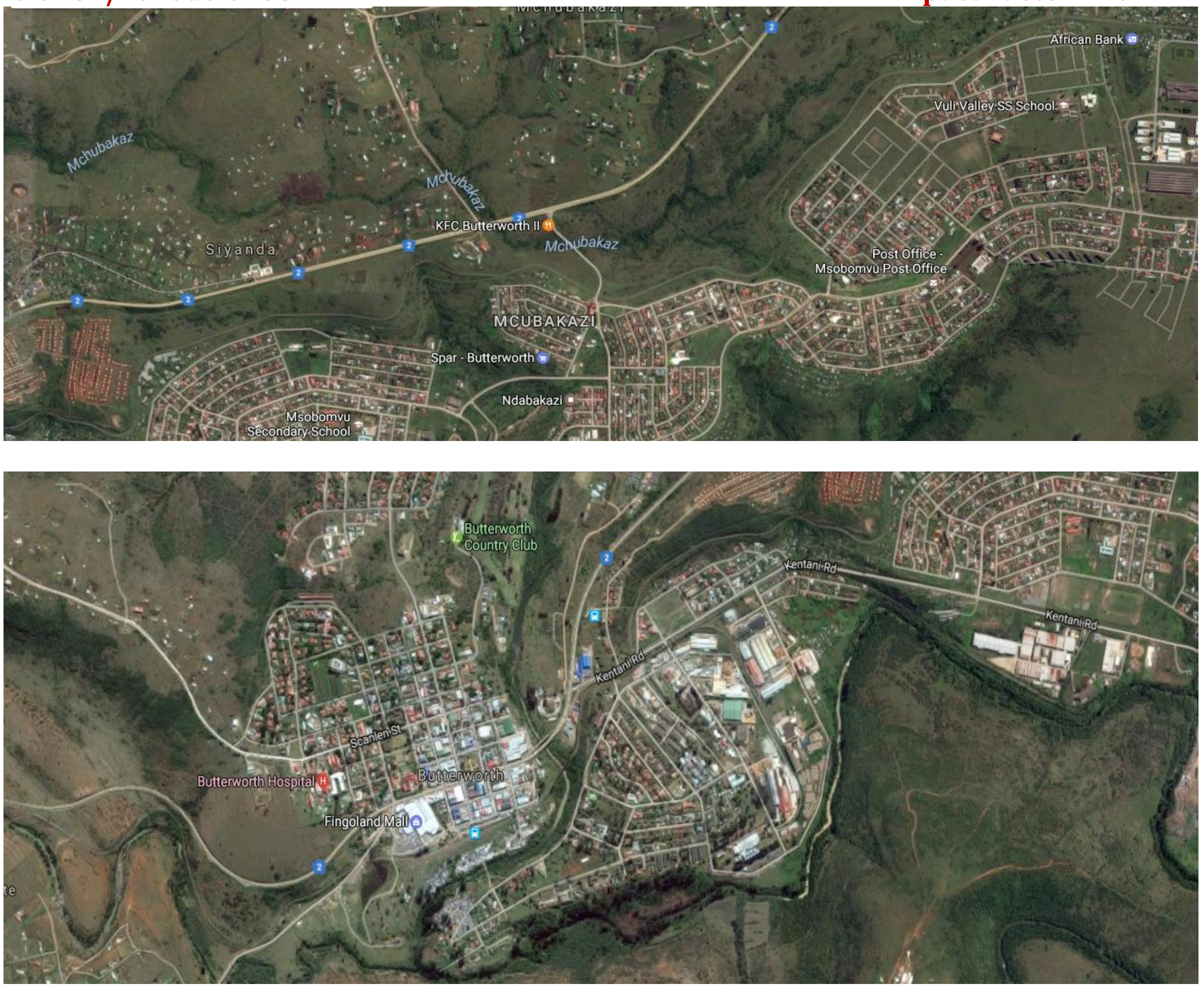

Figure 1: Geographic representation of Butterworth (Extracted from Google maps)

VI. SIGNIFICANCE OF THE STUDY

The experience of permanent pavement deformation and rutting in Butterworth roads will be used as a reference with other South African roads which experiences rutting and pavement deformation in the asphalt wearing course surface.

VII. MATERIAL AND RESEARCH METHODOLOGY

The main aim of the research is to improve the asphalt wearing course surface. This will be determined by the selection of the most suitable asphalt mix design from three selected asphalt mix design parameters;

- Pure asphalt 60/70 Pen (unmodified control mix design).
- Rubberize asphalt of rubber crumbs blended with bitumen (modified asphalt).
- And AE-2 polymer modified asphalt.

In order to meet the objectives of this study a total of 18 briquettes from the 3 mix design parameters, whereby six (6) briquettes of each mix design will be used to test the fatigue resistance of asphalt and its characteristics, through the use of Marshall Test method.

VIII. FACTORS AFFECTING RUTTING

Table 1 Factors affecting asphalt mixture durability

General Category	Specific Factors
Environment	Temperature Moisture
Mixture composition	Aggregate properties Binder Properties Gradation Volumetric Properties
Drainage	Surface Subsurface
Construction	Weather conditions Segregation Compaction Joints Layer bond

IX. ENVIRONMENT

The climatic condition to which a pavement is subjected affects both the materials selection and the layer thickness determination in order for asphalt roads to sustain a longer service life span. This is a result of the temperature to affect the rutting resistance, structural stiffness, and cracking resistance of asphalt mixtures.

High daily and yearly temperature instabilitiescausestresses in the surface materials which may cause cracksin the asphalt layer as the material volume changes.

Ankit et al (2014) explains that temperature is an effect of thermal cracking in asphalt pavement in the form of single or repetitive thermal cycles of warm or cool temperatures.

Moisture may damage the asphalt aggregate bond thus results in the weakening of the bond through adhesive failure at the interface and cohesive failure within the asphalt aggregate.

There are three ways that moisture may damage asphalt concrete mixtures.

- Loss of cohesion within the asphalt binder
- Loss of adhesion between the asphalt binder and the aggregate
- Aggregate degradation particularly when freezing occurs in the mixture.

X. MIXTURE COMPOSITION

a. Aggregate properties

The aggregates must be resistant to degradation during production and under traffic loading. This characteristic will be determined by the degradation of small size coarse aggregate by abrasion and impact.

XI. DRAINAGE

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.

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XII. CONSTRUCTION

Materials which are used in the construction of pavements are initially selected according to their availability, cost, and quality. The quality is evaluated in terms of the material's efficiency in distributingthe load over the underlying layers, its ability to resist weathering, and its long-term performance characteristics.

Underwood et al, (2012) state that, the materials placed in the pavement must be able to resist the effects of moisture, aging, traffic and environmental loading. This includes the asphalt surface.

According to Saad and Ammar (2015),the construction procedure can affect the pavement life and also increase the maintenance cost.

XIII. PREDICTION OF ASPHALT RUTTING

Taheret al (2011) highlights the different factors that affect rut depth of asphalt mix, namely: vehicle speed, vehicle axle load, thickness of pavement and temperature as well as material properties of asphalt mix.

Saad and Ammar (2015) state thatmodified asphalt remainsas anticipated to be one of the utmostsignificantresolutions for pavement distress.

XIV. CONCLUSIONS

The laboratory results indicated that the asphalt mixture composition affects the stability of asphalt roads to withstand traffic loading. The most effective asphalt mix design was rubberized asphalt. This is due to the properties of the rubber crumb binder to display good characteristics of high VIM and high stiffness thus resisting fatigue on the road. This extends the service life of asphalt roads and performs well under heavy traffic load.

The furthermostsignificantelements responsible for surface distress are age of the pavement, average annual daily traffic and the type of traffic that result in axial loading on the pavement surface. This is in line with Saad and Ammar (2015)who agrees with Audrius and Migle (2013) who states that the causes of rutting and fatigue in asphalt pavement are a result of accumulation of cracks, aging of binder, repeated axial loading and environmental conditions.

The permanent strain of pavement is measured as a function of rutting.

The structural properties of asphalt pavements are affected by the evironmental factors and this is responsible for the deterioration of the pavement.

XV. RECOMMENDATIONS

It is recommended that further reseach should be consided in the following aspects in order to maximize the conclusive factors affecting the rutting of asphalt pavement. These topics are;

- Temperatures
- Solar radiation measurements
- Moisture movement
- Freezing and thawing in pavement layers
- Effect of seasonal variations.

REFERENCES

1. *Amir G, Ehsan J, Yunus N, Zahra A, and Mahmood, K. (2012), Effect of Aggregate Gradation on Rutting of Asphalt Pavements, vol.53, pp.440-449.*
2. *Audrius V and Migle P (2013), Evaluation of Time Loading Influence on Asphalt Pavement Rutting. Procedia Engineering 57 (2013) 1205 – 1212, 11th International Conference on Modern Building Materials, Structures and Techniques, MBMST 2013*
3. *Ankit G, Praveen K and Rajat R (2014), Critical Review of Flexible Pavement Performance Models. KSCE Journal of Civil Engineering (2014) 18(1):142-148*
4. *Dondi G, MazzottaF, Simone A, Vignali V, Sangiorgi C, and Lantieri C (2015), Evaluation of different short term aging procedures with neat, warm and modified binders, Construction and Building Materials 106 (2016) 282–289.* www.elsevier.com/locate/conbuildmat
5. *Ghazi G. Al-Khateeb, Khalid A. Ghuzlan (2013), The combined effect of loading frequency, temperature, and stress level on the fatigue life of asphalt paving mixtures using the IDT test configuration, International Journal of Fatigue 59 (2014) 254–261.*
6. *Mahmoud A, Shams N, Mohammad M, and Mohammad H.M (2015), A study on fatigue modelling of hot mix asphalt mixtures based on the viscoelastic continuum damage properties of asphalt binder, Construction and Building Materials 106 (2016) 243–252.* www.elsevier.com/locate/conbuildmat
7. *Saad I.S and Ammar K.A (2015), Fatigue Life Assessment of Modified Asphalt Concrete, International Journal of Scientific Research in Knowledge, 3(2), pp. 030-041, 2015*
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. *Saad I.S and Samer M.S (2014), Contribution of Crumb Rubber in the Aging Process of Asphalt Concrete, International Journal of Scientific Research in Knowledge, 2(9), pp. 404-415, 2014*
10. *Suo Z, Wong W.G, Luo X.H and Tian B (2012), Evaluation of fatigue crack behavior in asphalt concrete pavements with different polymer modifiers. Construction and Building Materials 27 (2012) 117–125*
11. *Tschegg E.K, Jamek M and Lugmayr R (2011), Fatigue crack growth in asphalt and asphalt-interfaces, Engineering Fracture Mechanics 78 (2011) 1044–1054.* www.elsevier.com/locate/engfracmech
12. *Taher, B.M, Mohamed, R.K, and Mahrez, A. (2011), A review on fatigue and rutting performance of asphalt mixes. Scientific Research and Essays Vol. 6(4), pp. 670-682.* www.academicjournals.org/SRE
13. *Underwood B.S (2012), A continuum damage model for asphalt cement and asphalt mastic fatigue, International Journal of Fatigue 82 (2016) 387–401.* www.elsevier.com/locate/ijfatigue