Maintenance and Rehabilitation of Pavements and Technological Control

Proceedings of the Fifth International Conference
Park City, Utah, USA
8-10 August, 2007

Edited by

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Preface

The sustainable maintenance and rehabilitation of pavements is becoming a key challenge in many countries in 21st century. It is well known that road and airfield pavement is the backbone of the economic prosperity and public welfare. But, the sustainability challenges pavement builders and managers to respond creatively to new and dynamic problems of rehabilitating and maintaining pavements in the most environmentally friendly manner by lowering energy cost, reducing traffic noise, and minimizing air and water pollution.

With sustainability as the main theme the **MAIREPAV5** (**MAI**ntenance and **RE**habilitation of **PAV**ements and Technological Control) conference was organized at the Canyons Resort in Park City, Utah, USA by the University of Iowa, from August 8-10, 2007. This is the **5**th International Conference in the series of conferences organized to allow researchers, government agencies, consultants and contractors to exchange technological advancements and innovations of building and maintaining longer-lasting road and airfield pavement. The first conference was held in São Paulo, Brazil by Mackenzie University in 1999, the second in Auburn, USA by the University of Mississippi in 2001, the third in Guimarães, Portugal by University of Minho in 2003, and the fourth in Belfast, Northern Ireland by the University of Ulster in 2005.

This book consists of papers presented at the MAIREPAV5 conference. The book includes two keynote papers on FHWA pavement and materials program and importance of good construction on reducing maintenance costs and eighty-eight peer-reviewed papers. Each paper was reviewed by at least two experts from the International Organizing and Scientific Committee. The final revised manuscripts were then reviewed by the editors to ensure compliance with the recommendations and suggestion made by the reviewers. The book is organized into fifteen sections based on the order of the technical sessions presented at the conference: asphalt pavement materials, concrete pavement materials, pavement construction, asphalt pavement performance modeling, concrete pavement performance modeling, pavement economic analysis, asphalt pavement rehabilitation, concrete pavement rehabilitation and recycling, pavement evaluation, asphalt pavement recycling I, pavement noise and safety, pavement management, asphalt pavement recycling II, sustainable pavement materials, and pavement preservation.

We would like to recognize the co-sponsors of MAIREPAV5: International Society for Maintenance and Rehabilitation of Transportation Infrastructure (iSMARTi), Federal Highway Administration (FHWA), Transportation and Development Institute (T&DI) of American Society of Civil Engineers (ASCE), Transportation Research Board (TRB), Korean Society of Road Engineers (KSRE), and Public Policy Center (PPC) and Civil & Environmental Engineering Department of the University of Iowa. We would like to record our indebtedness to distinguished members of International Organizing and Scientific Committee who have peer-reviewed papers and guided us to the success of this conference. Finally, we would like to thank authors who convened in Park City, Utah from all over the world to share their knowledge and experiences in building and maintaining pavements and their invaluable contributions to this book.

It was our honor and privilege to host MAIREPAV5 and edit this book.

Hosin "David" Lee / M. Asghar Bhatti

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REHABILITATION ALTERNATIVES USING NEW ASPHALT RUBBER MIXTURES WITH BRAZILIAN MATERIALS

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Abstract: The Brazilian road network, which is predominantly composed by flexible pavements, has revealed a high rate of deterioration over the last decades. In addition, the heavy-load traffic and the age of the pavements have led one to predict a scenario of rapid deterioration, requiring rehabilitation alternatives to recover their quality. The use of crumb rubber from ground tires in bituminous mixtures for pavement rehabilitation has been used in last thirty years, especially in the USA. However, in Brazil, only a few experiments are known. Thus, the use of asphalt rubber mixtures requires a performance evaluation, trying to incorporate characteristics of local materials (bitumen and crumb rubber), as well as traffic and environmental conditions. The present study intends to develop mixture to improve the fatigue and permanent deformation resistance, taking Brazilian conditions into account. The new mixtures will be adopted as alternative rehabilitation techniques, in order to evaluate their influence in the improvement of the life span of existing pavements.

INTRODUCTION

The most common pavement rehabilitation policy used in Brazil comprises the application of an additional layer of asphalt mixture on the old pavement. Nevertheless, after a few years of service, the pavement exhibits substantial fatigue cracking, rutting and mainly crack propagation due to the reflective cracking. This rehabilitation strategy does not provide long-term rehabilitation solution. In order to solve the Brazilian overlays problems, researchers are searching for long-term and economically viable rehabilitation alternatives using modified binder such as asphalt rubber.

This paper presents the results of a research on the technical study of the use of asphalt rubber, in which Brazilian asphalt cement and crumb rubber materials were used to produce the modified binder. This study also evaluates the asphalt rubber mixtures performance produced by the terminal and continuous blending processes, through fatigue, permanent deformation and crack propagation resistance. For a comparative study, a conventional mixture was used.

The experimental study involved four components: (i) characterization of crumb rubber and asphalt rubber; (ii) characterization of the aggregates and mix gradation; (iii) evaluation of fatigue and permanent deformation properties of mixtures; (iv) evaluation of crack propagation.

MATERIALS

The rubber from scrap tires used in this study to produce asphalt rubber by continuous and terminal blend process was obtained from ambient grinding. Ambient describes the temperature of the rubber or tire as it is being size reduced. Rubber particles produced in the granulation process generally have a cut surface shape, rough in texture, with similar dimensions on the cut edges (RRI, 2005).

Three binders which were used in this study to produce the bituminous mixes:

- ***Conventional* binder (BB)** – the conventional asphalt which has been applied in most pavements in Brazil and which is classified by viscosity, as CAP-20;
- ***Asphalt rubber continuous* blend (BBbB)** – in order to obtain the required properties of asphalt rubber produced with a continuous blend process, a previous study was conducted to choose the better blend conditions that resulted as follows: (i) 90 minutes of digestion time; (ii) 180 ºC of temperature of blend; (iii) 21% rubber content by weight;
- ***Asphalt rubber terminal* blend (BB15)** – the terminal blend asphalt containing 15% of rubber and produced in Brazil.

The mixtures were prepared with the same granite aggregate with the gradations presented in Figure 1. The gradations studied follow specifications according to:

- Dense-grade reference Brazilian mixture with the conventional asphalt BB (CAP-20), denominated in this research as **BBB**;
- Dense mixture with asphalt rubber BB15 –specified in accordance with mix type IV of "The Asphalt Handbook Manual Series nº 4", named **IBB15**;
- Gap graded mixture with asphalt rubber BBbB specified in accordance with Caltrans ARHM-GG mix (asphalt rubber hot mix gap graded), called **CBBbB**.

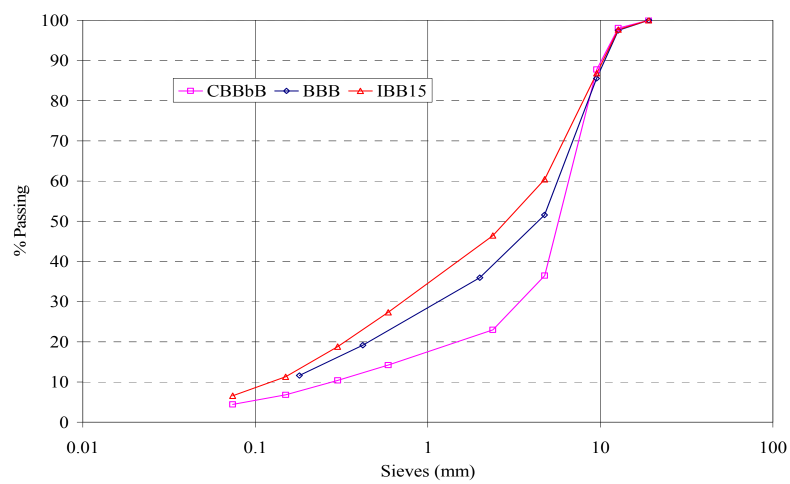

Figure 1 – Gradation curves of the mixtures

Marshall Method was used to determine the optimum binder content of the mixtures. The Marshall properties and the optimum binder content for each mixture are presented in Table 1. The specimens prepared in laboratory to fatigue and permanent deformation tests were compacted in slabs through the use of a cylinder with vibration over the bituminous mixture to achieve the apparent density of the asphalt hot mixes defined in the design.

Table 1 – Mixture properties for continuous blend mixtures

Mixture Properties	**BBB**	**IBB15**	**CBBbB**
Binder name	BB	BB15	BBbB
Air voids (%)	4,0	5,0	6,0
VMA* (%)	13,9	17,6	19,0
Stability (N)	12141	11190	12176
Flow (0,01 cm)	4,85	39,0	35,0
Density (g/cm^3)	2,45	2,37	2,39
Optimum asphalt content (%)	5,5	7,0	8,0

*VMA - Voids in Mineral Aggregate

MECHANICAL BEHAVIOUR

Figure 2 presents the values of complex modulus for all the mixes studied obtained in the four point bending test conducted at 20 ºC. The values do not show significant differences in the modulus of asphalt rubber mixtures produced by terminal blend and continuous blend. The resilient modulus for the conventional mixture is greater than the other mixtures.

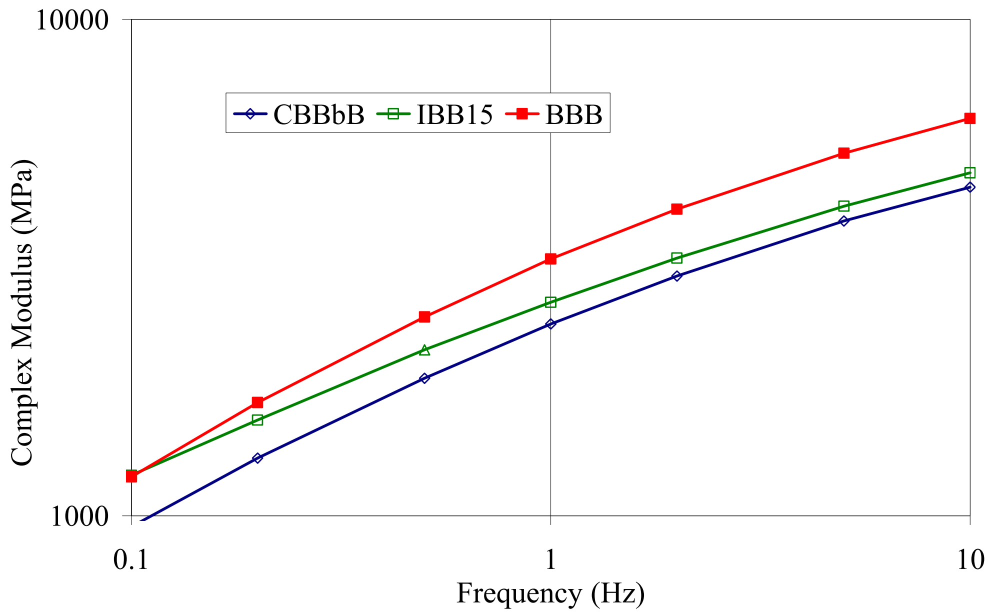

Figure 2 – Complex modulus

Figure 3 shows the fatigue life curves for the mixtures obtained in four point bending tests conducted at 20 ºC and 10 Hz. The IBB15 mixture, produced with terminal blend binder, presents the highest fatigue life, followed by the continuous blend mixture. All mixtures with asphalt rubber presented longer fatigue life than the conventional one. It is important to stand that the IBB15 has more than 10 times fatigue life than the conventional mixture. Although the IBB15 has lower binder content than CBBbB, that mixture presents a longer fatigue life, what means the asphalt rubber IBB15 has better performance than the other ones.

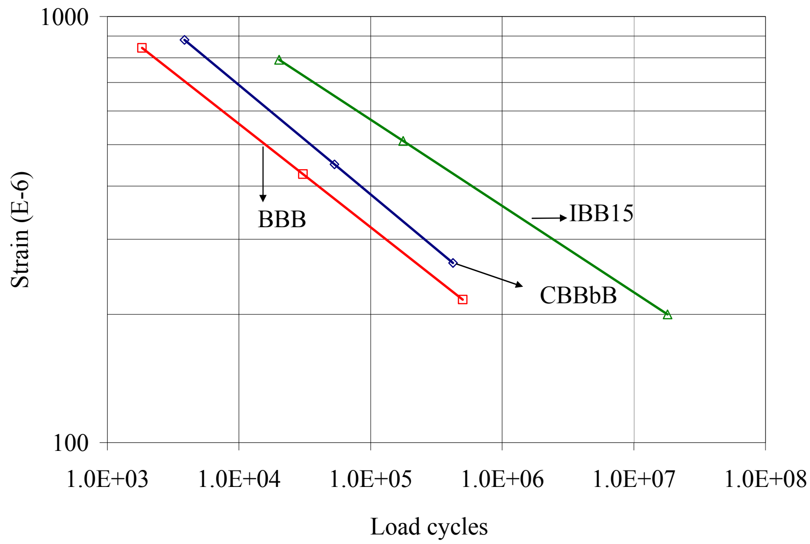

Figure 3 – Fatigue life

The permanent deformation evaluated using the repetitive simple shear test at constant height is presented in Figure 4 what indicates that the terminal blend mixture IBB15 has better performance than the other mixtures. The use of asphalt rubber mixtures improves the permanent resistance because all of them present superior results if compared with the conventional mixture.

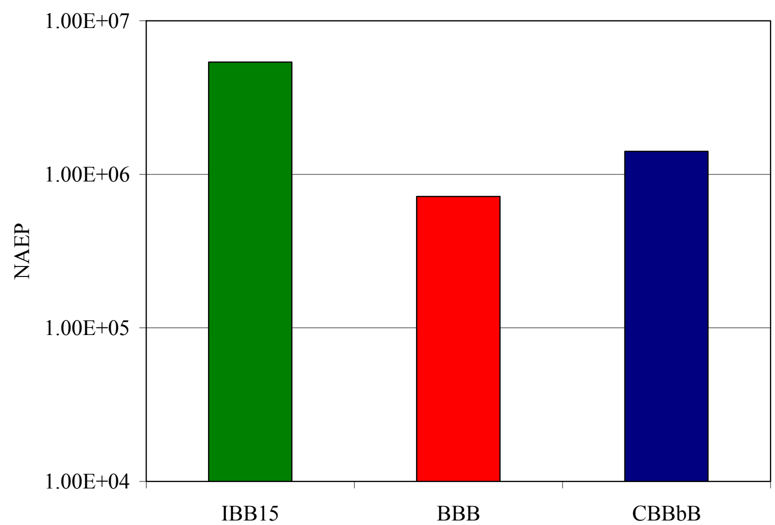

Figure 4 – Permanent deformation results

CRACKING REFLECTION

The main application for the mixes studied in this work is their use in pavement overlays where they will be subjected to the cracking propagation due to the cracks of the existing pavements. This phenomenon named cracking reflection is the main distress for pavement overlays and it can be evaluated using the mechanistic-empirical based overlay design method for reflective cracking proposed by Sousa et al. (2002), where both conventional and asphalt rubber mixes were taken into account in the developed method.

In the present work, the mixes studied will be applied in the design method to evaluate their ability to resist to cracking reflection. Although the design method has been developed for some specific conventional and asphalt rubber mixes, the method was used with the same adjustment factors (for aging, temperature and field) for these three studied mixes.

The application of the design method requires the calculation of the von Mises strain deviator given by:

$$\varepsilon_{VM}\ (1x10^{-6}) = a * [Overlay\ \ thickness\ \ (m)]^b \tag{1}$$

For the von Mises strain deviator calculation, a typical Brazilian pavement was defined, for medium traffic, as defined in Table 2. The bituminous mixtures properties for inclusion in the reflective cracking model (fatigue laws evaluated in four point bending tests and stiffness modulus) are defined in Table 3. The application of the design method for the defined pavement and for these three mixtures allows to define the influence of the overlay thickness as function of the design traffic (Figure 5). Therefore it can be concluded that, only for heavy traffic, the studied asphalt rubber mixes can have a thickness reduction compared with the overlay thickness for conventional mixtures. The reduction is only visible for the mixture IBB15.

Table 2 – Pavement used for cracking reflection evaluation

	Thickness (m)	Stiffness (MPa)
Bituminous layer	0.125	3000
Granular layer	0.35	250
Subgrade		100

Table 3 – Fatigue laws used for cracking reflection evaluation

Mix	Fatigue law	Stiffness @ 10Hz, 20 ºC (MPa)
CBBbB	$1{,}15 \times 10^{15} \times (1/\varepsilon)^{3{,}896}$	4600
BBB	$2{,}15 \times 10^{15} \times (1/\varepsilon)^{4{,}124}$	6300
IBB15	$4{,}15 \times 10^{18} \times (1/\varepsilon)^{4{,}938}$	4900

CONCLUSIONS

The laboratory tests results indicated that Brazilian asphalt rubber materials are adequate for rehabilitating pavements with success. The values of the stiffness modulus of asphalt rubber mixtures presented no important differences, regardless the binder source (terminal blend or continuous blend). On the other hand, the stiffness modulus for the conventional mixture presents higher values than the other mixtures, which allows the pavement to exhibit lower strain levels.

The fatigue life curves showed that the IBB15 mixture, produced with terminal blend binder obtained the highest fatigue life and that the asphalt rubber mixtures presented better fatigue life than the conventional mixture.

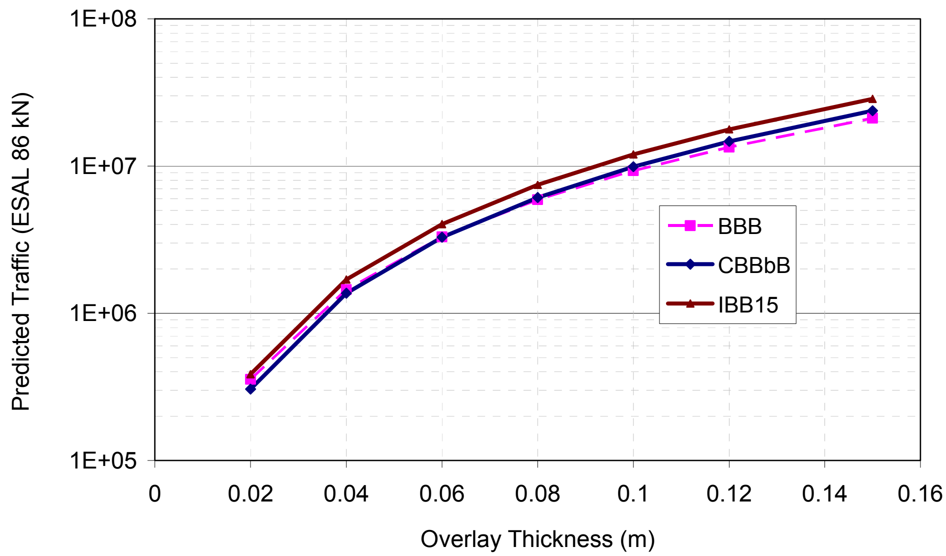

Figure 5 – Overlay thickness considering the cracking reflection

In the same way, permanent deformation test indicates that the terminal blend mixture IBB15 has better performance among the mixtures studied. In addition, the use of asphalt rubber mixtures improves the permanent resistance. The mixture with better performance was the IBB15 mixture, i.e. using the Asphalt Institute gradation with 15% of the asphalt rubber from terminal blend process.

The behavior of the studied mixtures for cracking reflection allows conclude a slight overlay thickness reduction when asphalt rubber mixtures are used, especially when the studied terminal blend mixture is used.

ACKNOWLEDGEMENTS

The fourth author was supported by the Programme Alban, the European Union Programme of High Level Scholarships for Latin America, scholarship nº E04D040507BR between 2004 and 2006. Current, the fourth author is supported by CNPQ (Conselho Nacional de Desenvolvimento Científico e Tecnológico).

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