The Use of Polymer Modified Bitumen in Road Paving

by En. Nur Izzi bin Md. Yusoff, Assoc. Prof. Dr Mohd Rosli bin Hainin and Prof. Gordon D. Airey

FOR several decades, it was widely accepted that the empirical method of blending different types of unmodified bitumens was the only way to improve the binder characteristics [1]. However, in recent years, the increase in traffic levels as well as tyre pressure, and the introduction of larger and heavier trucks, and new axle designs have added to the already severe demand of load and environment on the highway system, resulting in the need to enhance the performance of existing bituminous material [2]. These factors contribute to structural failures of road pavements such as rutting, cracking and potholes (Figure 1).

In Malaysia, these distresses have caused the Government millions of ringgit to repair and maintain the roads. Furthermore, a better understanding of the behaviours and characteristics of bitumen, coupled with greater development in technology, have allowed researchers and practitioners to examine the benefits of introducing additives and modifiers. As a result, modifiers such as fillers, extenders, polymers (natural and synthetic), fibres, oxidants and anti-oxidants, anti stripping agents and hydrocarbons, among others, are introduced to be mixed with bitumen [3].

Among them, polymer modified bitumen, normally abbreviated as PMB, is the most popular modifier used to improve the fundamental characteristics of unmodified bitumen as its characteristics are related to the performance of asphalt mixtures (or hot mix asphalt or asphaltic concrete). PMB is produced by mixing bitumen and polymer using a low or high shear mixer. Developing countries are using PMBs to build their infrastructures while developed countries are using them for maintenance. Their usage is continuously receiving great attention particularly in countries such as Europe, the United States, Canada and Australia.

Figure 1: (a) Rutting, (b) Cracking and (c) Pothole deformations

PMB was first used in Malaysia for the runways and taxiways of the Kuala Lumpur International Airport (KLIA) in 1996 to 1998. In addition, it was also used on selected sections of several federal roads on a trial basis. However, the local demand for it is less than 30,000 tonnes, which represents less than 1% of the total binders used in the country. This number is really low compared to other Asian countries which have a recorded usage of between 5% and 10% [4]. PMBs have made an important contribution to asphalt technology particularly in helping to promote mixtures with a better performance and increased life [5].

Table 1: Type of polymers and its examples [3]

TYPE OF POLYMER	EXAMPLES
Elastomers	styrene-butadiene-styrene (SBS), styrene-butadiene-rubber (SBR), styrene-isoprene-styrene (SIS), styrene-ethylene-butadiene-styrene (SEBS), ethylene-propylene-diene terpolymer (EPDM), isobutene-isoprene copolymer (IIR), natural rubber, crumb tyre rubber, recycled tyres, polybutadiene (PBD), polyisoprene, ethylene terpolymer (elastomeric and synthetic reactive)
Plastomers	ethylene vinyl acetate (EVA), ethylene methyl acrylate (EMA), ethylene butyl acrylate (EBA), atatic polypropylene (APP), polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS)
Combination	blend of rubber and plastomers

PMBs that have been used in road paving are usually divided into two groups, namely, elastomeric and plastomeric substances (Table 1). Approximately 75% of the PMBs used are classified as elastomeric modifiers, 15% as plastomeric modifiers while the remaining 10% being either rubber or miscellaneous modifiers. It is worth noting that elastomeric SBS PMB is the most widely used in road construction [2]. This particular PMB has received great attention due to its tremendous ability to improve the overall performance of the pavement. Their usage is expected to have a resistance to traffic at least four times greater compared to unmodified bitumens and extreme climatic conditions [6].

(To be continued on page 18)

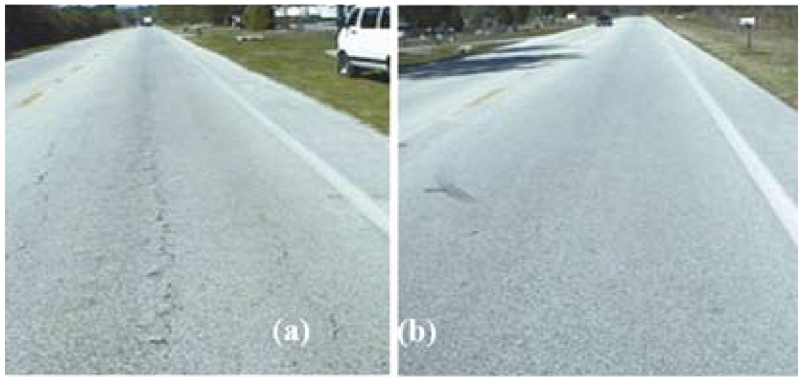

Figure 2: (a) Conventional Bitumen (Exhibits Cracking) and (b) Modified Bitumen (Without Cracking) [8]

The history, usage, test methods and specifications, as well as benefits of PMBs have been widely discussed by many researchers. In general, PMB provides better rheological or mechanical properties over a wide range of temperatures and loading frequency. The stiffness modulus and elasticity values of modified binders are significantly increased. Hence, they are more resistant to rutting, abrasion, cracking, fatigue, stripping, bleeding and ageing at high temperatures and brittle fracture at low temperatures [7]. However, a brittle failure is not particularly relevant in our country's climate. A stronger impact on these properties could be observed at intermediate temperatures. Figure 2 shows a comparison between unmodified bitumen and the PMB used in road construction. It is clearly observed that the latter provides better resistance to cracking deformation [8].

Recently, waste or recycled PMB is used to reduce modification cost, lower energy consumption and solve environmental problems. For instance, it is roughly estimated that over 2.8 million or approximately 57,391 tonnes of scrap tyres are generated each year in Malaysia. Of these, over 60% are unused and being placed in stockpiles [9]. Crumb rubber-modified bitumen (CRMB) therefore offers a beneficial solution to this problem. Clemson University had conducted a study which showed that between 500 to 2,000 scrap tyres can be used in each lane mile (1 mile = 1.609km) of pavement depending on the application selected. This means that for a one-mile section of a four-lane highway, between 2,000 and 8,000 tyres can be recycled to create a longer lasting road [8].

It is well known that the biggest culprit to a pavement's failure is water. The News Straits Times [4] reported that a high annual rainfall of more than 2,000mm per year in our country often results in flood. Water allows moisture to seep through and saturate the gravel base, leaving the pavement vulnerable to heavier vehicles. As a result, roads tend to deteriorate faster. Therefore, the use of PMB in an asphalt mixture can improve durability by improving its resistance to water damage.

Today, different types of polymers are commercially available; however, there is no universal type of polymers and the selection should be made according to the specific needs [10]. The level of modification depends on factors such as polymer characteristics, polymer content or percentage, and the nature of unmodified bitumens. PMBs with a similar polymer content and prepared with identical penetration grade bitumens but obtained from different sources can yield different microstructures and characteristics. Studies conducted by many researchers deduced that the use of PMBs improves the deficiencies and overall performance of a flexible pavement.

(To be continued on page 20)

Despite such achievements, many challenges remain. A major concern that is related to PMBs is their proverbial lack of morphological stability during long storage. For example, separation between the polymer-rich phase and asphaltene-rich phase occurs in the elastomeric substances (e.g. SBS, SBR) compared to the plastomeric substances (e.g. EVA) [11]. A considerable effort has been undertaken to improve its storage stability and compatibility including the use of phosphorous and polyphosphorous acid, carbon black, anhydride (maleic and succinic), sulphur, various straight chain dicarboxylic acids, stabilisers and reactive polymers.

The blending process of the polymeric substance with bitumens can be destroyed by very high temperature during mixing, or by being kept at a high temperature for a long period of time after mixing. The binder storage times should be kept as short as possible, otherwise, deterioration of the polymer may take place. The ideal mixing process would involve the lowest possible temperature for the shortest possible time (compatible with a complete incorporation of the polymer into the bitumen) both from an economic standpoint and to minimise any changes in the bitumen and/or polymer resulting from thermal effects. The incorporation of the polymer also means the mixing tank operation for bitumens need to be altered to fulfil its special requirements.

Even though these modifiers can improve a binder's performance, they can also increase the cost of a binder between 30% and 100% and boost the overall cost of the asphalt mixture between 10% and 40% [12]. Ponniah and Kennepohl [13] showed that the lifecycle cost is ineffective if its cost is more than 100% of unmodified bitumens. The initial higher cost needs to be overcome even though it is widely understood that it lasts longer and saves on repair costs. Studies showed that the use of PMB could result in net savings of up to 20% over a 20-year period. This savings could possibly increase up to 45% if user costs and accidents are taken into account [6].

In summary, the advantages of PMBs outnumber its disadvantages. Quality roads will tremendously reduce the rate of fatality or accidents. Moreover, the government could save millions of ringgit on maintenance and rehabilitation works. Perceptively, the employment of sustainable materials including PMBs in road paving is becoming essential because every road user deserves and needs better roads for numerous purposes. ■

REFERENCES:

[1] Reubush, S.D. "Effects of Storage on the Linear Viscoelastic Response of Polymer Modified Asphalt at Intermediate to High Temperature", MSc thesis, the Virginia Polytechnic Institute and State University, Virginia, 1999.

[2] G.D. Airey. "Rheological Properties of Styrene Butadiene Styrene Polymer Modified Road Bitumens." Fuel, vol. 82, pp. 1709–1719. 2003.

[3] J. Read and D. Whiteoak. The Shell Bitumen Handbook 5th Edition. London: Thomas Telford Ltd, 2003, pp. 61–90.

[4] News Straits Times. "Better and Safer Road for All". pp. 15, June 22, 2010.

[5] R. Taylor and G.D. Airey. "Polymer Modified Bitumens Part One: Background and History". Asphalt Professional. Issue 34, pp. 11–16, 2008.

[6] C. Lenoble and N.C. Nahas. "Dynamic Rheology and Hot Mix Performance of Polymer Modified Asphalt." Journal of the Association of Asphalt Paving Technologists, vol. 63, pp. 450–480, 1994.

[7] F. Bonemazzi, V. Braga, R. Corrieri, C. Giavarini and F. Sartori. "Characteristics of Polymers and Polymer-Modified Binders." Transportation Research Record, vol. 1535, pp. 36–47, 1996.

[8] Internet: http://www.clemson.edu/ces/arts/benefitsofRA.html (Dec. 2, 2010).

[9] S.K. Thiruvangodan. "Waste Tyre Management in Malaysia." PhD thesis, Universiti Putra Malaysia, Malaysia, 2006.

[10] X. Lu, U. Isacsson and J. Ekblad. "Rheological Characteristics of SEBS, EVA, and EBA Polymer Modified Bitumens". Materials and Structures, vol. 32, pp 131–139, 1999.

[11] Asphalt Academy. Technical Guideline: The Use of Modified Bituminous Binders in Road Construction (TG 1), 2nd Edition. South Africa, 2007.

[12] T. Kuennen. "Polymer Modified Asphalt Comes of Age." Better Roads, vol. 75, 2005.

[13] J. Ponniah and G. Kennepohl. "Polymer-Modified Asphalt Pavements in Ontario: Performance and Cost-Effectiveness." Transportation Research Record, vol. 1545, pp. 151–160, 1996.