Polymer modified bitumen for runways containing 60% recycled asphalt

C.P. Plug, A.H. de Bondt & F.R. Bijleveld
Strukton Civiel West bv / Ooms Producten bv, Scharwoude, Netherlands

G. van Uden
AsfaltNu, Culemborg, Netherlands

ABSTRACT: Polymer modified bitumen (PMB) with a high polymer content demonstrated its benefits for high bearing asphalt applications such as runways and taxiways at airports. Runway 18R/36L at Schiphol airport (Amsterdam) was constructed according to this principle in 2002. The asphalt construction for this runway consists of several layers of polymer modified asphalt (PMA). For major maintenance in 2021 about 600,000 m^2 of the runway and surrounding pavements were replaced with 150,000 tons of new asphalt containing 60% recycled asphalt (RAP) originating from the old PMA asphalt layers.

The use of RAP is common practice in the Netherlands, especially for base and bind layers. New techniques with the pre-treatment of RAP material makes it possible to use the RAP in surface courses as well without quality issues. Furthermore, several studies show that the use of RAP from the old PMA is beneficial for a new asphalt layer.

To maintain the high quality of the PMA containing RAP, strict requirements are needed for the PMB used. Because of changes in bitumen production and crude sources at refineries it has become more difficult to maintain the quality of such binders. For the mentioned project an extensive quality control of the PMB production has been established including selection of the virgin base binder. This quality control provides an optimal homogenous quality of the PMB for the entire project.

For the entire rehabilitation project approximately 3,000 tons of PMB was produced and successfully applied in the new asphalts pavements within a period of 13 weeks. This paper provides an advanced quality control methodology and demonstrates this for an actual runway project in the Netherlands.

KEY WORDS: Polymer modified bitumen, Recycled asphalt pavement, High bearing asphalt, Polymer modified asphalt.

1 INTRODUCTION

Since the early 1990s heavily polymer modified asphalt (PMA) is used at Amsterdam Airport Schiphol. Between 1990 and 2000 already over 400,000 tons of PMA has been applied in more than 20 different projects. Among these projects were new pavements like exits and aprons with full depth PMA, and reconstruction of runways and taxiways. Because of the good performances of these PMA pavements, it was decided in 2000 to specify the at that time new runway 18R/36L also with heavily modified PMA, which was completed in 2003. Major maintenance was carried out on runway 18R/36L in early 2021. For this the old PMA was removed and replaced with new PMA for the base and bind layers in which 60% of the old PMA was reused.

Recycling of asphalt is done on a large scale in the form of partial recycling (PR) in the Netherlands. The percentages of recycled asphalt (RAP) can be without any problems and with little effort up to 60-70% of RAP for asphalt base and binder layers with the use of a parallel drum asphalt mix plant. A high percentage of RAP is also possible for surface courses. Here the quality of the RAP is the restricting factor. The quality depends on the old asphalt layer (grading, type of stone and bitumen content) and the degree of contamination in this layer during milling. For example, by fractionating and sorting the asphalt granulate (according to characteristics such as type of crushed stone and bitumen content), its usability improves and higher percentages of recycling can be achieved (also in surface courses) for new asphalt. Furthermore, recent studies show that the use of old PMA asphalt granulate can even be beneficial for the new asphalt. In combination with a heavily modified PMB and a rejuvenator it was possible to meet the desired specifications for the new base and bind layers of runway 18R/36L at Amsterdam (Schiphol) airport.

To maintain the high quality of the PMA containing RAP, strict requirements are needed for the new PMB used. Because of changes in bitumen production and crude sources at refineries it has become more difficult to maintain the quality of such binders. In this paper the aspects of producing a high quality asphalt containing a high percentage of asphalt granulate will be discussed.

2 RUNWAY 18R/36L ‘POLDERBAAN’ AT SCHIPHOL

Runway 18R-36L ‘Polderbaan’ is the westernmost runway at Schiphol Airport. With 3800 meters, the Polderbaan is the airport's longest runway and has a width of 60 meters. The runway was built in the period 2001-2003 (the asphalt layers in 2002 for the main runway and taxi ways) and officially opened on 13 February 2003. The Runway 18R-36L is only used for takeoffs in a northerly direction or for landings from a northerly direction, because of noise regulations for the environment. For this reason there is no taxiway to the northern end of the runway. The number of flight movements from Runway 18R-36L were around 80,000 landings and 65,000 takeoffs in 2018.

The asphalt construction during construction consisted of three open graded polymer modified asphalt layers with a dense graded polymer modified asphalt on top. A (tar-based) antiskid layer was applied on top of this. The polymer modified bitumen used was a heavily modified PMB (Superpave PG 76-22; Sealoflex SFB 5-50 (HT)) to meet the tight tender specifications for rutting and reflective cracking (Nataraj et al, 2005), see table 1. The asphalt construction was laid on a foundation of sand and a cement treated base (CTB).

Table 1: Design PMA Specification in 2003.

Description	Test method	Specification
- Permanent deformation at 40°C - Mix viscosity	EN 12697-25, part B *3	max 1.0% *1 min 750 GPa.s *1, 5
- Permanent deformation at 60°C - Mix viscosity	EN 12697-25 part B *3	max 2.0% *1 min 500 GPa.s *1, 5
Resistance to reflection cracks		
ITS at 0°C	EN 12697-23	Min 3.15 MPa, Av-3.5 MPa *2
Toughness at 0°C	EN 12697-23 *4	Min 11.5 mm/mm^2 Av-14.0 mm/mm^2 *2

*1 Average 4 tests
*2 Average 6 tests
*3 Test conditions: σ_c = 0.00 MPa; σ_b = 0.40 MPa; T_1 = 0.2 s; T_0 = 0.8 s; N = 10,000; blok puls
*4 Force-displacement curve
*5 Mix viscosity from slope of deformation test

3 REUSE OF POLYMER MODIFIED ASPHALT

Since around the beginning of the 1980s, polymer modified asphalt (PMA) has been used successfully on many large and small projects worldwide. The application of PMA, the lifespan of an asphalt construction can be extended, often in combination with a reduction in thickness. PMA has also proven itself, among other things, in (porous) thin noise reducing layers (thin surfacing), which without polymer modification would have an unacceptably short lifespan; a thin surfacing would simply not have existed.

Because of environmental reasons nowadays, questions are being asked whether polymer modified asphalt can be reused as a partial polymer modified asphalt (PR) in new asphalt. Already at the end of the nineties of the last century, extensive research was done into this and the conclusion of this research was that by using PMA granulate, the underlay mixture would have more favorable properties and a higher resistance to permanent deformation than when using unmodified asphalt granulate. Recent research also shows that PMA can be reused without any problems. However, special attention must be paid to relatively fresh PMA granulate. This PMA must first be homogenized before with unmodified asphalt granulate before reuse in order to prevent problems during mixing. It should be borne in mind here that the milling of fresh PMA is of course a rarity and is normally not be done.

3.1 PMA granulate

The most common polymer modifications for a PMA are the SBS (Styrene-Butadiene-Styrene) polymer and the EVA (Ethylene-Vinyl-Acetate) polymer. Both polymers have specific properties and can be applied separately or combined in a PMA, depending on the desired properties and possible national specifications. Which polymer is applied can usually be characterized by means of an FTIR (Fourier Transform Infra-Red) analysis of the recovered bitumen (see figure 1).

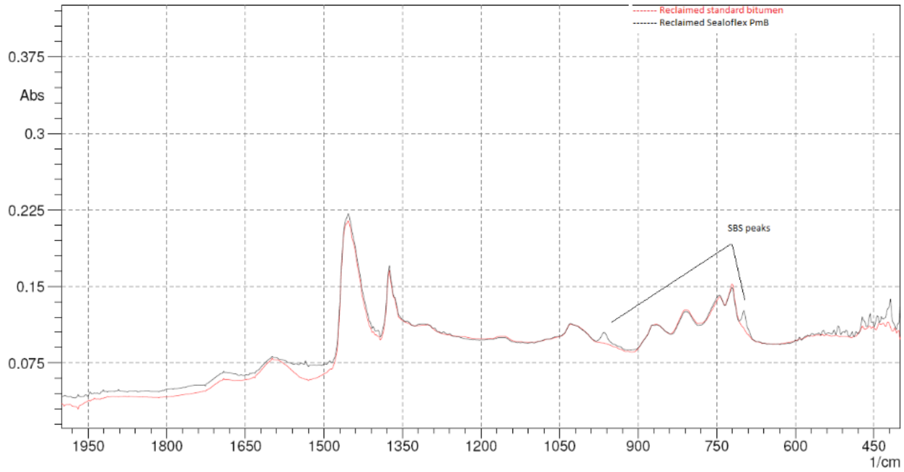


Figure 1: Example FTIR analysis of reclaimed binder from RAP (with and without PMB).

Depending on the age of the PMA, the effectiveness of the polymer will decrease over time. To what extent the effectiveness decreases depends, among other things, on the initial modification and the asphalt type. Under the influence of weather conditions a PMA will slowly age; this will also reduce the effectiveness of the polymer. As a result, the viscosity of the asphalt mixture will change and its workability will become comparable to non-modified asphalt.

Important questions for the reusage of PMA asphalt granulate are: Can the old PMA asphalt granulate be rejuvenated to the functional level of a new asphalt mixture? Does it mix well with the new binder in the recycling process? or does it result in a 2-phase structure? Various validation projects in the Netherlands have provided answers to these questions. The results of these studies show that PMA asphalt granulate can be reused without any problems, even in Porous Asphalt surface courses (Bochove et al, 2021).

3.2 Case studies reuse of PMA

In 1997, research was carried out into the environmental aspects of old PMA ZOAB granulate (Tauw, 1998). This research showed that the emission of the PMA granulate was on the same level as of non-modified asphalt granulate. This is also to be expected, because the chemical structure of the polymers used (mostly EVA (ethylene vinyl acetate) or SBS (styrene butadiene styrene)) are not chemically different than the components of which bitumen consists.

Also in 1997, the laboratory of the Dutch Road Authorities conducted a research for highly stable asphalt mixture (AC base 22) using 40% old PMA Porous Asphalt granulate. The conclusion of this research was that by using PMA granulate, the mentioned base asphalt mixture had more favorable properties and a higher resistance against permanent deformation than when non-modified asphalt granulate was used (DWW, 1997).

In 2005, an improved version of the above mentioned AC base 22 with 40% PMA Porous Asphalt granulate was used on the Dutch motorway A12 (between Grijsoord-Waterberg). In this project the fresh new bitumen component was also replaced by a polymer modified bitumen. This asphalt mixture was examined intensively during production and processing and no problems were encountered during the implementation (Van Kleef, 2005).

A more recent European study (RECYPMA, 2013) also shows that PMA granulate is a valuable building material for reuse. In this 2-year European study, research was carried out on a laboratory scale into the possibilities of using PMA granulate. The research showed that PMA granulate still contains an active polymer content, which can be beneficial in new asphalt mixtures. For this the PMA granulate has to be properly homogenized and characterized in order to make (optimal) use of the benefits.

As stated reuse of PMA RAB is therefore not a problem, either in theory or in practice. However, special attention should be paid to ‘fresh’ PMA granulate that has been in the road for less than about 1 year. This PMA granulate may have properties (such as a high viscosity), as a result of which it cannot be mixed by a parallel drum mixing system that is often used in the Netherlands at temperatures of 120 to 130 °C. Such PMA granulate should therefore be homogenized with unmodified asphalt granulate beforehand. The latter is more of a practical problem than a reason why PMA granulate cannot be used in new asphalt.

Furthermore, laboratory tests according to the Dutch CE-marking systematic show that it can be beneficial to use PMA granulate. As can be seen in table 2, which show the results of 2 Dutch AC 16 surf 40/60 (40% asphalt granulate) mixtures with standard asphalt granulate and PMA granulate according to the Dutch standard RAW specifications 2015.

Table 2: Example effect PMA granulate on asphalt properties AC 16 surf 40/60 (40% RAP).

Asphalt properties	Standard RAP	PMA-granulate	Dimension
Water sensibility **ITSR**	98	103	%
Stiffness **S_{mix}**	7200	6970	MPa
Resistance against deformation ***f_c***	0.22	0.08	µm/m/s
Resistance against fatigue **ε_6**	132	213	µm/m

In particular, the fatigue resistance will increase by applying PMA granulate. A difficulty here is that it is often not known whether asphalt granulate has been modified (and to what extent). A homogeneous PMA granulate will therefore hardly ever be available. Preparing a type test for an asphalt mixture with PMA granulate is therefore only worthwhile if sufficient homogeneous PMA granulate of the same quality is also available for production. As for renovation of runway 18R/36L at Schiphol this was the case.

3.3 Polymer modified asphalt with high content of RAP

The use of polymer modified asphalt (PMA) is common in heavily loaded asphalt constructions such as runways. The advantages of a PMA is (depending on the polymer modification) that the asphalt lasts longer and/or can be applied in a thinner construction.

By combining a (heavily modified) PMA with 50-60% asphalt granulate (standard unmodified RAP) an asphalt can be produced with excellent properties in comparison with a conventional AC-binder/base asphalt mixture, making it possible to reduce the total layer thickness, resulting in a reduction of the overall Environmental Cost Indicator (lower ECI per m^2 of asphalt). By applying 50%-60% asphalt granulate, there are no special requirements for the asphalt granulate and this type of asphalt can be produced relatively easily at almost any asphalt plant with a parallel drum system.

In September 2012, this so called hybrid asphalt was applied for the first time on a large scale on the newly constructed road section of the Dutch A4 motorway near Steenbergen. By applying this type of asphalt mixture 50 mm thickness of asphalt was saved on this project (based on structural calculations). So in addition to reusing material, savings were also made on new raw materials (Plug et al, 2020).

The same method can be performed with PMA asphalt granulate. The properties of the new asphalt will then also benefit from the polymer modification in the PMA asphalt granulate. An important factor here is that the PMA asphalt granulate is of a consistent quality (from the same source with the same modification). Only then can the added value of the PMA asphalt granulate be included in construction calculations.

4 RUNWAY 18R/36L REHABILITATION PROJECT

A total of approximately 1,400,000 m^2 of PMA asphalt granulate was selectively milled from the runway and connecting areas after removing the antiskid layer, representing approximately 130,000 tons of asphalt. The asphalt that was selectively milled was partially crushed on site and from there transported to the asphalt plant so that it could be reused for in the new asphalt. For the new asphalt a heavily modified PMB was selected with improved workability at lower application temperatures (Sealoflex SFB 5-90 LT) with the in table 3 given properties. Added to the PMB was a chemical ‘low temperature’ additive to achieve improved wetting of the crushed stones and asphalt aggregate during mixing resulting in an overall beter workability during paving.

Table 3: Properties selected polymer modified binder

Properties	test	Specification	Unit
Penetration	EN 1426	80-120	mm x 0.1
Softening point R&B	EN 1427	≥ 85	°C
Elastic recovery	EN 13398	≥ 90	%
Force ductility at 5 °C	EN 13589	≥ 5.0	J
MSCR $J_{NR,3.2\ kPa}$ at 60 °C	EN 16659	≤ 0.1	1/kPa

With the selected PMB a new PMA asphalt for base and bind layers was produced with 60% of the old RAB from the runway in combination with a rejuvenating agent (Anova) to meet the tight tender specifications within a period of 13 weeks without any problems. The properties (according to the Dutch CE-marking systematic) of the used PMA mixtures have been summarized in table 4.

Table 4: PMA asphalt properties with 60% PMA RAP (Dutch CE type test).

Asphalt properties 60% PMA RAP	Dense PMA	Open PMA	Dimension
Stiffness $\mathbf{S_{mix}}$	4014	4401	MPa
Resistance against deformation $\boldsymbol{f_c}$	0.05	0.05	µm/m/s
Resistance against fatigue $\boldsymbol{\varepsilon_6}$	291	268	µm/m

In comparison with the properties of the PMA mixtures without RAP (see Table 5), the stiffness of the latter mixtures is lower and the fatigue is higher. Without RAP, the stiffness (around 2800 MPa) is close to the minimum design stiffness, and with PMA RAP the stiffness (around 4000 MPa) is further away from the minimum. The fatigue with PMA RAP is lower than without RAP, but higher than with standard RAP (without polymer modification). However, the fatigue level is high enough because of the total construction on top of a CTB foundation.

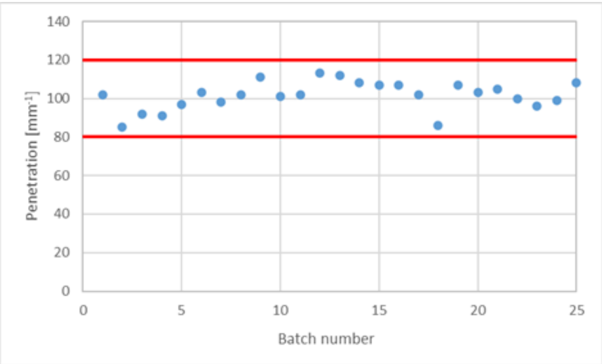
Table 5: PMA asphalt properties without RAP (Dutch CE type test).

Asphalt properties	Dense PMA	Open PMA	Dimension
Stiffness $\mathbf{S_{mix}}$	2767	2767	MPa
Resistance against deformation $\boldsymbol{f_c}$	0.15	0.05	µm/m/s
Resistance against fatigue $\boldsymbol{\varepsilon_6}$	362	336	µm/m

As surface layer a special developed porous friction course (without RAP) was applied (FlightFlex) by the contractor (Santvoort, 2021) without the need of a conventional antiskid layer. Because of the strict regulation for antiskid performance, recycled asphalt could for this project not be used in this layer. Begin May 2021 the rehabilitation project was finished and the runway was put back into operation.

5 QUALITY CONTROL POLYMER MODIFIED BITUMEN

Because of the high amount of PMA asphalt granulate of 60% in the new asphalt mixture strict requirements were needed for the PMB used. Because of changes in bitumen production and crude sources at refineries it has become more difficult to maintain the quality of such binders (Nahar, 2021). In order to guarantee the quality of the PMB to be produced, it is important to know the characteristics of the base bitumen. Deviations in the quality of the base bitumen can have major effects on the properties of the PMB. This is especially the case for specific applications with a high recycled asphalt content. For the production of the specific PMB (Sealoflex SFB 5-90 LT) bitumen from 1 refinery was selected. In the following graphs the variation in properties is given for the relevant specific properties during the production of the PMB.



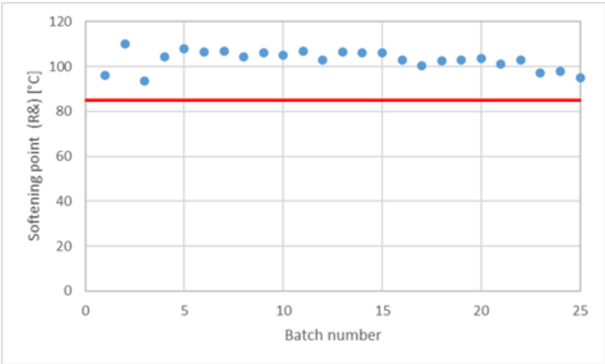
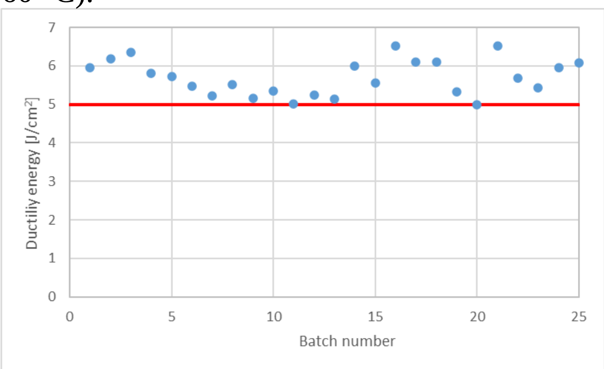


Figure 2 and 3: Obtained penetration and softening point of the produced PMB for the different batches.

As can be seen from the figure 2 and 3 the obtained conventional properties (penetration and softening point) were within tight limits, which were stricter than the European standard for PMBs (European spec EN 14023). This was also the case for the functional properties for cracking (force ductility energy $E_{0.20\text{-}0.40m}$ at 5 °C) and rutting (MSCR $J_{nr,3.5\ kPa}$ and $R\%_{3.5\ kPa}$ at 60 °C).



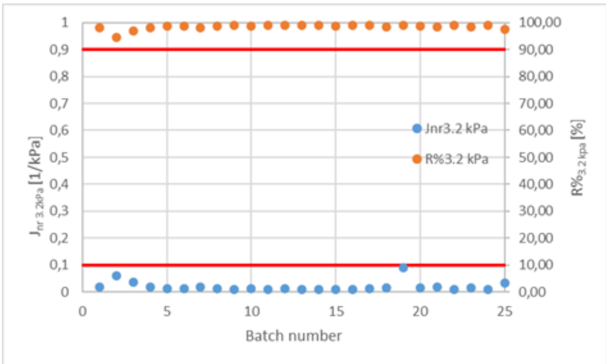


Figure 4 and 5: Obtained force ductility energy ($E_{0.2\text{-}0.4m}$) at 5 °C and MSCR $J_{nr,3.5\ kPa}$ and $R\%_{3.5\ kPa}$ at 60 °C.

6 CONCLUSIONS

Asphalt with a high percentage of asphalt granulate (RAP) can be used without any problems in heavily loaded constructions such as at airports (runways and taxiways) and motorways. For a good result, the quality of the asphalt granulate is very important, especially with high percentages RAB.

Polymer modified asphalt (PMA) can be reused without any problems, often improving the properties of the newly produced asphalt pavement. To be beneficial the PMA asphalt granulate has to be from the same source (same quality) and homogeneous.

The advantage of using (PMA) RAP compared to a PMA without RAP is that the stiffness of the asphalt mixture is increased compared to a 100% new PMA asphalt. This prevents the stiffness from falling below the design stiffness. The fatigue of the asphalt increases with PMA RAP compared to standard unmodified RAP. However, it is less than with a 100% new PMA mixture. For asphalt layers on a CTB this was within the specifications.

The runway rehabilitation project at Amsterdam Schiphol airport shows that PMA asphalt granulate also can be used for heavy duty run- and taxiways in such a way that the old materials of the runway could be reused in the new runway (so called horizontal recycling). Based on long-term experience with high percentages of RAP in heavy duty roads in the Netherlands, it is expected that this application of high percentage RAP will also be successful for runways.

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