DECISION MODEL FOR THE USE OF POLYMER MODIFIED BINDERS IN ASPHALT CONCRETE FOR AIRFIELDS

By:
Maarten M.J. Jacobs, CROW
Marc J.A. Stet, KOAC•WMD
André A.A. Molenaar, Delft University

PRESENTED FOR THE 2002 FEDERAL AVIATION ADMINISTRATION AIRPORT TECHNOLOGY TRANSFER CONFERENCE

05/02

DECISION MODEL FOR THE USE OF POLYMER MODIFIED BINDERS IN ASPHALT CONCRETE FOR AIRFIELDS

By Maarten M.J. Jacobs, CROW, the Netherlands[1]
Marc J.A. Stet, KOAC•WMD, the Netherlands[2]
André A.A. Molenaar, Delft University, the Netherlands[3]

Introduction

The increasing wheel load and tire pressure raise the question whether it is still possible to build a pavement structure for airfields with a low maintenance regime. For this purpose polymer modified asphalt concrete (PMA) mixtures are becoming increasingly popular. PMA application is expected to cope with tough requirements.

In general the use of polymer modified binders (PMB's) can result in better performing asphalt concrete mixtures. The improvements can be found e.g. with respect to aging and/or resistance to permanent deformation and cracking. The bitumen suppliers offer a large amount of PMB's, which can be used for the maintenance of airfield runways. For the airfield authorities and its pavement consultants it is not easy to chose for the best performing PMB given a specific situation or application. In most cases the choice is made based on information supplied by the bitumen producer. This information is in general not uniform among the different suppliers because its often based on different type of tests or test conditions. In fact the problem can be separated in four parts:

1. it is hard to formulate uniform and measurable demands for PMB's and PMA's;
2. the performance of PMB's and PMA's are hard to determine and described;
3. a lack of methods to determine whether the offered PMB is delivered;
4. a lack of information about the appropriate weather conditions to handle the PMB's and PMA's properly.

For each project the available information from various suppliers must be evaluated again. Even for comparable projects! This takes a lot of valuable time. Besides that information and knowledge is lost due to the fact that no general descriptions of the PMB's are available. For this reason CROW started a working group to design a general guideline for the comparison of polymer modified products for airfields.

In this paper the approach of the working group is discussed as well as the model itself [1]. This approach is based on the experiences of Dutch, Danish, German, Belgian and French airfield authorities to find a more uniform and simplified model to chose for the most appropriate PMB for a specific situation. Also tests to determine the performance and the applicability of these products (compared to traditional penetration bitumen) are described.

In this paper first attention is paid to the requirements and characteristics of airfield pavements. After that the PMB's and PMA's are discussed as well as experiences of airfield

[1] PO Box 37, NL-6710 BA EDE, the Netherlands
Tel: +31 318 695300 ; Fax: +31 318 621112 ; E-mail: jacobs@crow.nl
[2] Schumanpark 43, NL-7336 AS APELDOORN, the Netherlands
Tel: +31 55 5433100; Fax: +31 55 5433111; E-mail: stet@koac-wmd.nl
[3] PO Box 5048, NL-2600 GA DELFT, the Netherlands
Tel: +31 15 2784812; Fax: +31 15 2783443; E-mail: a.a.a.molenaar@citg.tudelft.nl

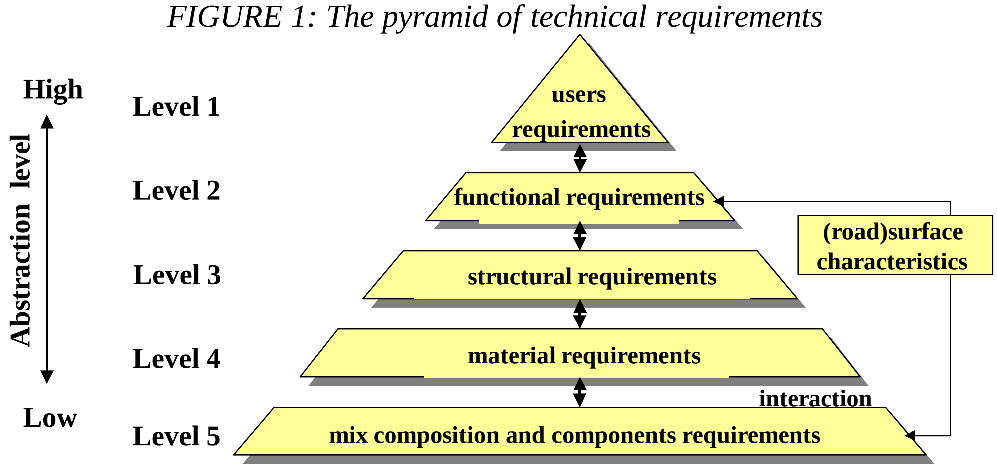
authorities with these products and finally a selection model for PMA's is introduced. It should be noted that in this paper the first preliminary results of the working group are presented. Only test procedures are indicated but no test results are given. These requirements are worked out in the working group in the first half of 2002.

Requirements and characteristics of airfield pavements

The present requirements for airfield pavements have been developed in the last decade. Based on knowledge and practical experiences these requirements developed into the present empirical requirements, which are related by practical standard tests. Practical tests, no matter how valuable in the construction process, only have limited value in the development of new products. A disadvantage of the old approach is the fact that new products and/or materials cannot be truly evaluated based on these practical tests. For airfield pavements an extra problem occurs: no risks can be taken with the use of new products because of the critical availability of the runway. Hence, to minimise risks on one hand and to introduce new materials like PMA's on the other hand, functional requirements are used more frequently. Based on these requirements technical characteristics are defined, both in the structural and durability field. The functional and technical characteristics are in most cases the basis for a contract between contractor and airfield authorities. In the rest of this paragraph attention will be paid to the development of functional requirements and characteristics of airfield pavements.

In the pyramid of technical requirements five different levels can be recognised (see figure 1):

FIGURE 1: The pyramid of technical requirements



1. requirements claimed by the user: safety, comfort, availability and sustainability of the surface of the pavement;
2. functional requirements. The user requirements are redefined in terms of measurable characteristics at the pavement surface e.g. longitudinal evenness, roughness and PCI-value (FOD potential);
3. structural requirements. The user defined requirements like availability and sustainability can be redefined in terms of the structural performance of the pavement. At this level the designer and constructor of the pavement are involved which should take into account the

structural performance of the complete pavement structure. In this level e.g. the bearing capacity (PCN-value) of the pavement is involved;
4. In case the structural requirements can not be met on level 3 material parameters like stiffness, fatigue, crack growth and permanent deformation characteristics can be determined in a laboratory for material taken from the pavement;
5. The last level can be used in case it is not possible to cover requirements on a higher level. At this level requirements are met with respect to the components of a material. Examples of these components are the asphalt concrete mix composition, the percentage air voids, aggregate size distribution and form, density etc.

In the functional approach the requirements of the users (this are the pilot and the passengers) are addressed at a level as high as possible in the technical pyramid. In most cases the requirements can be met using functional, structural and material characteristics of the pavement and its materials. Looking at airfield pavements in most cases the material characteristics like resistance to fatigue, temperature and reflection cracking and permanent deformation should be taken into account. In a model for the determination of the best PMA for a specific situation these material characteristics play an important role. This will be discussed in the next paragraphs, but first attention will be paid to the advantages and disadvantages of PMB's.

PMB's and PMA's

The performance of the asphalt concrete mixtures can be improved by using either polymer modified or chemical modified binders. The last types of binders are used less often than the PMB's and were therefore not discussed in this paper.

Using PMB's the performance of a mix can be improved without (drastically) changing the composition of the mix. Some PMB's improve one property of the mix without deterioration of other mix characteristics. This implies that the efficiency of an improvement of the mix properties depends also on the situation in which the modified mix is used. In table 1 the improvements of PMB's on the structural (level 3) and material (level 4) characteristics of PMA's are given.

TABLE 1: Influence of type of PMB's on the structural and material characteristics of an asphalt concrete mixture.

Structural or material property	Type PMB	
	Plastomer	Elastomer
Sustainability of porous asphalt	0 to +	+
Resistance to permanent deformation	+++	+ to ++
Resistance to temperature cracking	- to ++	++
Resistance to fatigue cracking	- to ++	++
Resistance to reflection cracking	- to +	+

- = worse; 0 = identical; + = better; ++ = much better (compared to a mix with a standard penetration bitumen)

The use of PMA's is only functional and justified based on technological and economical grounds. The choice of a modification must always be made in relation to the position of the asphaltic layer within the pavement structure and the expected structural or functional failure mechanism. Based on the expected failure it can be decided to modify one or more asphalt concrete layers. In table 2 a number of situations are given in which the use of PMA's can lead to a better performance of the complete pavement.

TABLE 2: Application of PMA's in various asphalt concrete layers related to the desired improvement of this layer

Failure mechanism	Surface layer	Medium layer	Bottom layer
Permanent deformation:			
- subgrade	0	0	0
- subbase	0	0	0
- asphalt concrete layer	++	++	+
Occurrence of cracks:			
- fatigue at the bottom of the AC layer	0	0	++
- fatigue at the surface of the AC layer	+	0	0
- temperature changes in combination with hardening of the bitumen[1])	+	0	0
- reflection cracking	0	+	++
Sustainability			
- ravelling	+	0	0
- aging of the binder	+	0	0
- resistance to fuels and de-icing products	++	0	0

- = worse; 0 = identical; + = better; ++ = much better (compared to a mix with a standard penetration bitumen)

[1]) Temperature cracking can be prevented by using a bitumen, which is viscous enough at lower temperatures, does hardly age and has a high tensile strength. The low temperature cracking is caused by the base bitumen and not by the polymer modification. The polymer modification allows using the same or softer base bitumen, whereas the behaviour at higher temperatures will be equal or improves.

The decision model in general

For a univocal determination it is essential to define an approach with always an uniform set of tests to determine the material characteristics of the PMB's and PMA's. Also test descriptions and interpretation methods should be available. For this purpose the European standards proof valuable; they will officially be available in 2003. All tests concern the functional specifications of the mixes. In table 3 an overview of these tests are given. The relevance of these tests with respect to the material characteristics and the position of the modified mixes in the asphalt concrete layer are also mentioned.

TABLE 3: Relevant characteristics of asphalt concrete mixes in a the asphalt layer

Property of the PMA	Location in de AC layer		
	Top	Middle	Bottom
Macro texture	X		
Micro texture	X		
Porosity[1])	X		
Cohesive strength[1])	X		
Water sensitivity	X		
Visco-elastic properties	X	X	X
Resistance to permanent deformation	X	X	X
Crack resistance	X	X	X
Fatigue resistance			X

[1]) Relevant for porous mixes

In case process ability and recycling are important issues in the application of PMB's also extra conditions should be fulfilled. The extra conditions are gathered in table 4. In this table first the essential requirements with respect to recycling and process ability are mentioned, then the various topics which are concerned with the requirements and in the right column the PMA mix characteristics are mentioned which are relevant for the process ability and recycling.

TABLE 4: Extra conditions for the use of PMA's with respect to process ability and recycling

Essential requirement	Criterion	Characteristic value
Process ability	Compact ability	Gyratory compaction results; G-Black diagram
	Segregation sensitivity mineral aggregate	Homogeneity; Zero shear viscosity
	Segregation sensitivity bitumen	IR photoscopy
Recycling	Equal to 100% new asphalt concrete mix	Characteristics 100% new AC mix
	Controllable	Bitumen content; bitumen characteristics
Environmental load	Immersion into soil and air	Composition of PMB; Safety records producers
Occupational health situation workers	Exposure time	Dust and fume concentration
	Smell (maximum temperature)	

Remarks:
- The process ability of the mix depends on the dynamic viscosity of the mix. The supplier should provide information about this topic. The information about the viscosity should be determined with the rotation viscosimeter (for materials within one group) and the G-Black diagram (for various type of modifications).
- Recycling: The bitumen supplier should give information about the special attention that has to be paid to the recycling of his product without taken more environmental and constructive changes than necessary.
- Environmental claim: The supplier should give information about the volatility of the bitumen and a guideline for a safe use of the product.

Based on the functional requirements of the mixture on level 2 the functional behaviour related pavement characteristics (level 3), mix characteristics (level 4) and type of mechanical test can be defined.

The decision model for PMB's and PMA's

To choose and select a specific type of PMA a methodology is developed, in which effects of the change in performance related characteristics of asphalt concrete mixes and these changes on the functionality of the pavement structure can be taken into account to determine the behaviour of the pavement structure. In this methodology it is possible to compare the behaviour of several mixtures to each other or with a reference mix. The model is an evaluation method in which an optimisation is accomplished by means of a relative approach. The basic components for the comparison are the results of the dynamic mechanical tests. Also it is possible to estimate some of the mechanical characteristics of the asphalt concrete mix on an analytical basis. Figure 2 presents the model.

Referring to the note A until L the following remarks can be made:

A. Based on experiences (empiricism and calculations) constructions of the pavement are selected and compared. Often not only the technical quality of a design determines the design: also the realisation and maintenance budget is important. The pavement structure itself is described in terms of characteristics of the subgrade, subbase, the number of asphalt concrete layers and their composition. In case of renovation the condition of the present pavement should be evaluated by means of:
   - Coring the pavement constructions to determine the present layer thicknesses and their composition;
   - FWD-measurements to determine the bearing capacity of the subgrade and present pavement structure;
   - Visual survey of the pavement to determine its damage pattern;
   - Expected traffic loading to check the construction design;
   - Evaluation of the evenness of the pavement for the milling and inlaying activities for a smooth and flat pavement surface;
   - Environmental research with respect to the re-use of the pavement in relation to the presence of tar.
B. Choice of the asphalt mixtures. Once the total thickness of the asphalt concrete layer is known, the thickness of the individual layers can be determined. Based on the maximum aggregate size in an AC mix, the optimum layer thickness can be calculated.
C. Choice of the modified layers. Based on the expected damage in the future, one or more AC layers can be modified with a PMB. In table 1 the influence is already given of a PMB of the functional characteristics of the final asphalt concrete. The designer chooses the character to be improved and then the type of modification.

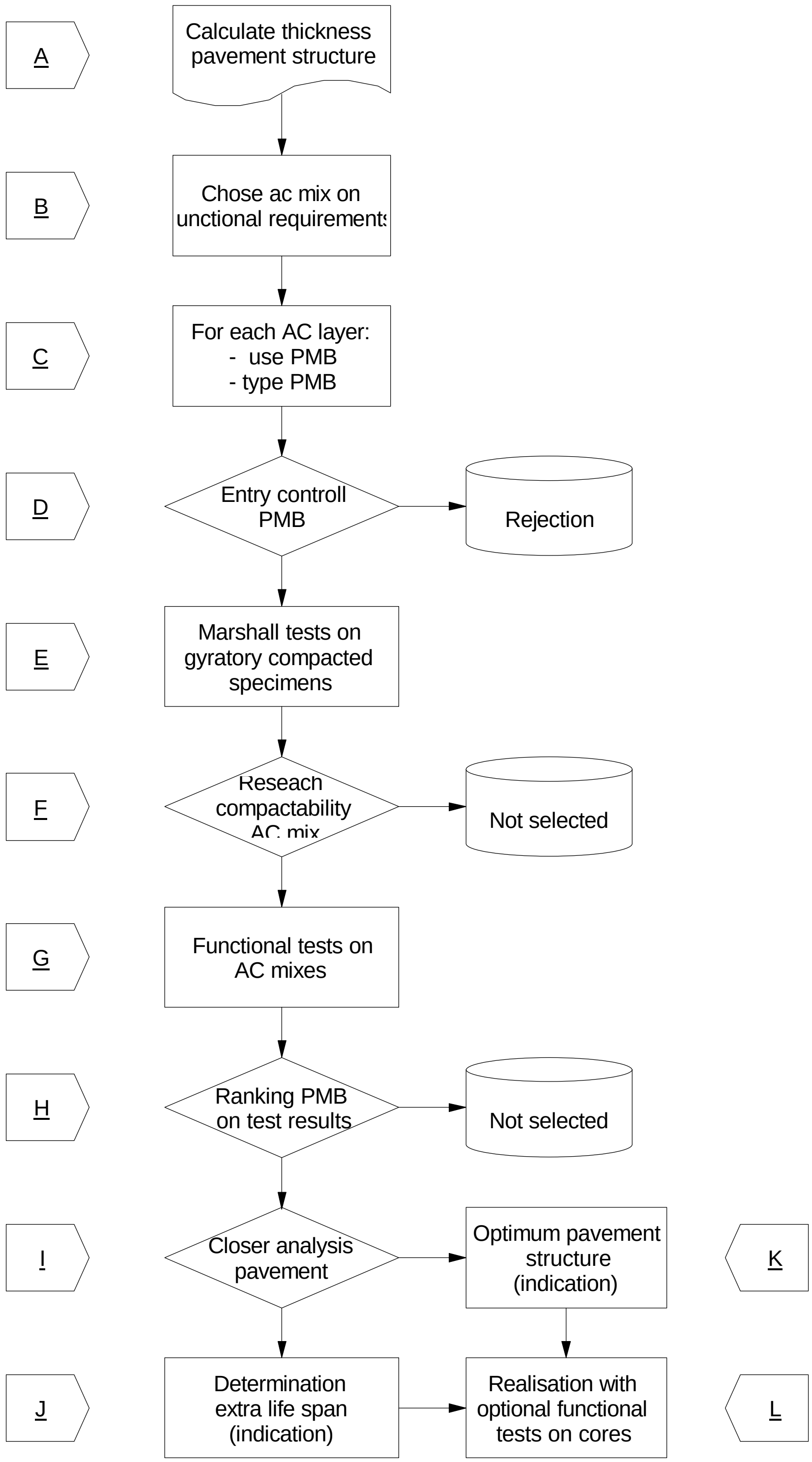


FIGURE 2: Schematisation of the PMB and PMA selection model

D. Check on the quality of the supplied PMB. Once the type of PMB (elastomer, plastomer, multi grade) is chosen the suppliers are asked for information about their products. The selection of the PMB should be based on the rheologic characteristics of the material. In this rheological characterisation a "finger print" of the PMB is determined. A supplier should make an information sheet containing this fingerprint of the PMB in which tests are performed under uniform applied circumstances. An example of a list of test for this finger print is:

- Density;
- Viscosity at 135, 150 and 170°C;
- Penetration;
- Temperature Ring and Ball;
- Penetration Index (PI);
- G-Black-diagram;
- Mastercurves of the bitumen stiffness in relation to the loading time (or frequency);
- A certificate of the origin;
- A Occupational Health and Safety Act in which it is stated that the modification causes no environmental risk during manufacturing and re-use;
- A sample.

Also other tests can be used e.g. infra red (IR) tests, GPC (gas chromatography) or NMR (nuclear magnetic resonance). Special care should be taken with IR and GPC especially for aged PMB's. Only the NMR method determines under all circumstances the correct amount of modification in a PMB.

Based on the complete set of characteristics a first selection of the PMB is made. This choice can for example be based on the mastercurve and/or G-Black-diagram. Finally a selected number of PMB's are entered to be tested in the next phases.

E. The determination of the mix composition is based on the Marshall characteristics on gyratory compacted specimens. In these tests penetration bitumen is used instead of the PMB. Based on this procedure the amount of bitumen is determined. After this the penetration bitumen is replaced (in the same mass percentages) by the PMB's, which are preselected.

F. The number of gyrations to achieve a compaction degree of 98% (with a certain mix composition at a compaction temperature given by the supplier) gives information about the compactibility of the mix. The compactibility can also be determined at lower temperatures in order to get information about problems that can occur in practice under bad weather circumstances (rain and wind).

G. The mechanical behaviour of the PMA's is determined by means of functional mechanical tests. These tests are also carried out on a mix with penetration bitumen, which serve as reference for comparison. The functional tests are related to damages, which occur in practice. In this way the fundamental reological characteristics related to loading time and temperature are established. In table 5 the functional tests are given. It is advised to perform these tests at least in threefold.

For the determination of fuels (kerosene) and de-icing fluids special tests should be performed. An example of this test could be a brush test [2] on specimens that are immersed in that fluid for a specified number of time. A number of PMA-characteristics can be estimated using the volumetric compositions of the mix and the mechanical information about the PMB. In this way the research costs can be reduced. For the determination of the relationship between the stiffness of the bitumen and the mix several nomographs (e.g. Bonnaure et al.[3]) can be used. The estimation of the crack growth parameters A and n in Paris' law can be based on the approach of Jacobs et.al [4].

H. Based on the priorities of the improved characteristics per layer, the best performing PMB can be chosen. In case layer thickness reduction is intended the determined material characteristics can be used in the layer thickness optimisation.
It is advised to verify the material characteristics in practice. This can be accomplished by means of tests on cored specimens from the road.

TABLE 5: Tests to determine the functional characteristics of AC mixes

Functional character	Test
Stiffness	Bending (2-, 3- or 4-point bending) or tensile test
Resistance to fatigue in bottom layers	Dynamic bending or tensile test
Resistance to permanent deformation in surface layers	Dynamic triaxial test
Resistance to temperature cracking in top layers	Static Semi Circular Bending (SCB) test on notched specimens
Resistance to permanent deformation in bottom and binder layers	Dynamic triaxial test
Resistance to ravelling and chemicals	Brush test or SCB test on specimens with no notch
Resistance to reflective cracking in bottom layers	Static Semi Circular Bending (SCB) test on notched specimens

Findings

Application of polymer modified asphalt (PMA) is becoming increasingly popular in the construction and rehabilitation of airport pavement structures. Today, a variety of (polymer) modified bitumen (PMB) products are available on the market. For the application of most of these special products, the end users have to rely on the information provided by the suppliers. Because this subject is rather complex, airfield pavement authorities and consulting agencies have a difficult task in selecting the type of modified asphalt.
CROW, the Information and Technology Centre for Transport and Infrastructure in the Netherlands, is performing a research program to improve the possibility to choose for the correct PMB and to increase the applicability of PMB's in airfield pavements. This research program was started in 1999 and runs until 2002. The formal task is to describe a system to choose and apply PMB's for airfield pavements. In the research team airfield authorities, researchers and PMB-suppliers are working together. To solve these problems experiences in The Netherlands and surrounding countries are investigated and taken into account. Finally the work should result in a practical guide for the choice of PMB's, depending on the local situation and circumstances.
The key task for the working group is to provide pavement designers a method for selecting polymer modified asphalt for a given application. In addition, the working group was asked to formulate recommendations for tests which can be used for an adequate quality control. The working group has chosen a two-step approach. First, experiences of a number of national and international airport authorities were gathered by means of a questionnaire. The questionnaire provides insight in the current motivation for the use of PMA's and PMB's, their application and

performance. It became apparent that the PMA can not only improve the structural performance of the pavement, but also the functional life span of the pavement. A case study is performed to explain the proposed procedures by use of an example from practice. A frame work is presented to facilitate the review of products and the investigation of the requirements to be set. A system of existing test procedures and methods is provided to determine whether the polymer modified asphalt complies with the requirements. The characteristic values of the PMA in the various tests will be determined in the next stage of the working plan.

References

1. CROW, Information and Technology Centre for Transport and Infrastructure, "*Applicability of polymer modified asphalt concrete mixes for airfields*", Ed. M.J.A. Stet, November 2001, Ede (the Netherlands).
2. Buijs J. and van Buël T., "*Chemical Resistance Asphalt Concrete*", MSc-thesis Hogeschool 's-Hertogenbosch, (the Netherlands), June 2001.
3. Bonnaure F.P., Gest G., Gravoir A. and Ugé P., "*A New Method of Predicting the Stiffness of Asphalt Paving Mixtures*", Proceedings of the Association of Asphalt Paving Technologists (AAPT), Vol.46, pp. 64-105.
4. Jacobs M.M.J., Hopman P.C. and Molenaar A.A.A., "*Application of Fracture Mechanics Principles to Analyse Cracking in Asphalt Concrete*" Proceedings AAPT 1996, Vol.65, pp.1-39

Key words
Polymer modified bitumen (PMB), Polymer modified asphalt concrete (PMA), functional dynamic tests, finger print PMB, airfield pavements.