
DEVELOPMENT OF A PMB PRE-SELECTION METHOD FOR AIRFIELD PAVEMENTS

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ABSTRACT
Airport authorities are using more and more polymer modified bitumen in their pavements in order to increase the lifetime and reduce maintenance costs and operational disruptions. The choice of the right PMB for an application is always difficult. The association of bitumen suppliers in the Benelux (Belgium, the Netherlands and Luxemburg) has, for that reason, developed a pre-selection method for PMB. The input for the model is based on the depth of the layer in the structure, the kind of base (bound or unbound) and on the use of the pavement on an airport site (location). The test methods to characterise the binders are chosen in line with the expected future (European) specifications. Almost all members of Benelux Bitume have committed themselves to put the values of their own products, measured according to those test methods, on the Benelux Bitume website. By using this method, the possible choice for the PMB is limited to a few types, which meet the requirements that were inputted. These types can then be used for the optimization process of the asphalt mixture during the laboratory testing phase.

Keywords: Functional Specifications, Heavy-Duty Pavements, Mechanical Properties, Modified Binders

1. INTRODUCTION
Asphalt is an extremely complex but challenging and cost-effective material with a mix of viscous and elastic properties, which is caused by the presence of the bituminous binder. Improving one property means many times loosing on another property. A pavement owner expects from an asphalt pavement that it has the following properties, amongst others; a high resistance to rutting (implying a strong elastic behaviour at higher temperatures), that it can be laid without joints (implying sufficient viscous behaviour to balance shrinkage), a low tendency to cracking (implying also a sufficient level of viscous behaviour and healing properties) and a high resistance to fatigue (implying a sufficient level of self-healing properties and stiffness).

As mentioned, a number of these requirements are contradictory with one another. On the one hand the binder must be elastic to have a good resistance to permanent deformation and on the other hand it must be sufficiently viscous to allow shrinkage cracks not to occur. This viscosity/elasticity balance can be influenced to some extent by the choice of the crude oil and its processing. Only by adding suitable polymers this viscosity/elasticity balance can be improved dramatically.

Another aspect complicating the design of asphalt pavements (and the selection of the binder) is that the behaviour of the asphalt material depends on the way it is exposed to the load it has to carry. It matters if the layer involved is the top, the middle or the bottom layer of the pavement structure. Also the nature of the foundation (cement stabilized or not) is of big importance.

The growing axle loads and tyre pressures lead to the question if it is still possible to build durable airfield pavements (runways, shoulders, taxiways, platforms and aprons) with asphalt mixtures. In many countries PMA (polymer modified asphalt) is used to counter this issue with success. However, a lot of PMB’s are on the market to modify the mixtures that can be used for different applications such as airfield pavements. Those PMB’s are special products, which in many countries are not standardised. So the user has to rely on the information given by the supplier. As the given information is not always comparable with each other, there is a need for a common data-sheet to give the user the opportunity to make the choice for the right binder on the right place more easily.

Initiated by a request from the Dutch airfield authorities, Benelux Bitume, the association of bitumen suppliers in the Benelux (Belgium, the Netherlands and Luxemburg), developed a so-called binder pre-selection tool. This model has the purpose of assisting the airfield industry in choosing the most suitable binder for a specific application. It is as far as possible in agreement with the current trends in the European CEN discussions about binder specifications. Where necessary, experience from Benelux Bitume members with specific tests was added.

The binder pre-selection model, which is presented in this paper, gives the designer and the airfield owner the opportunity to evaluate the choice of a conventional binder versus a polymer modified binder. Also the PMB’s from different origins can easily be compared in the evaluation phase. It also allows the airfield owner to limit the effort in the labour and cost intensive asphalt mixture testing phase for the final selection. Almost all Benelux Bitume members agreed that they will report the properties of there binders in accordance with the list of test conditions.
2. BACKGROUND
An important reason to choose for a PMA on an airfield, is the expectance (and fact) that the risk of failure is less with a PMA. Due to the specific characteristics of a PMB, the user expects a better resistance to ageing, a higher resistance to fatigue, permanent deformation and cracking. That means that the higher costs of a PMA are paid back with a longer lifetime and less maintenance. Remarkable is the current lack of consistence in practice in the choice of the modified binder. SBS, as well as EVA, PE or a combination of these are chosen for base as well as wearing courses. In the Netherlands, the mixture is often optimised by a traditional Marshall study. After having defined the optimum binder content, the conventional binder is replaced by the polymer modified binder, taking into account the difference in density of the two binders. After this study, several tests are done on the mixture (void content, indirect tensile characteristics and resistance to permanent deformation under cyclic loading). The requirements of the tests are put into the tender documents. It is certainly a practical way of choosing a PMA, but does it give the right binder and the right mixture for the given application? The drawback is that the asphalt mixture testing takes a lot of effort, since for every bitumen which is in the selection process, the entire set of asphalt tests needs to be performed. Also the duration of such a process is a problem, since during the tendering process the asphalt producer does not have the time for this. Benelux Bitume, as a binder industry, cannot give solutions to test the mixture. However, assistance can be given via offering a tool to pre-select some binders based on performance related requirements.

To define the requirements mentioned above, the findings of the Eurobitume Workshop in Luxemburg 1999 were utilized. The conclusions of the Workshop were that the following performance requirements for the pavement are important: permanent deformation (rutting), fatigue, reflective cracking, surface cracking, thermal cracking and bearing capacity. In the same workshop, the discussion was about the characteristics of the binder that are (maybe) related to those requirements, or binder characteristics that influence the performance of the pavement (see table below).

<table>
<thead>
<tr>
<th>Requirement for pavement</th>
<th>Binder characteristic</th>
<th>Test equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent deformation (rutting)</td>
<td>Rheological (viscosity, G', δ)</td>
<td>DSR</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Failure</td>
<td>None</td>
</tr>
<tr>
<td>Reflective cracking</td>
<td>Force-ductility</td>
<td>Ductilometer</td>
</tr>
<tr>
<td>Surface cracking</td>
<td>Ageing (long and short term)</td>
<td>e.g. RTFOT/PAV</td>
</tr>
<tr>
<td>Thermal cracking</td>
<td>Rheological + failure combination</td>
<td>DSR, BBR, DTT</td>
</tr>
<tr>
<td>Bearing capacity</td>
<td>Rheological (complex modulus)</td>
<td>DSR</td>
</tr>
</tbody>
</table>

For airfield cases additional requirements are needed:
- loss of stones at the surface (Foreign Object Damage for jet engines)
- resistance to chemical agents (deicing and jet fuel spillage)

When the work of CEN-TC336 WG1 is analyzed, it can be seen that a lot of these so-called new test methods shown in the table, are accepted as future standardised European test methods for PMB.

3. PRE-SELECTION METHOD: BITUMEN INPUT DATA
The method is called a pre-selection method because the outcome of this method is not a single binder which is the best for that application. Certainly not, the outcome of this method is a small selection of binders of whom it is believed that, by using them in an appropriate asphalt mixture, the mixture will meet the requirements asked for by the user. Therefore, almost all members of Benelux Bitume committed themselves to give to the customer the information asked for in the method. That means that all the binders will be characterised at least in the way which is described below.

The following criteria were used when selecting the requirements (test methods): test procedure as accurate (= performance related) as possible, a minimum number of tests per damage criterion and directly usable in up-to-date laboratories.

3.1 Rutting (Permanent deformation)
It is obvious that information on the binder related to the behaviour of the pavement with regard to rutting (defined as permanent deformation within the asphalt layers) is needed. In order to check the degree/level of polymer modification, the ratio storage modulus/complex modulus is determined by means of the DSR. This at a temperature of 50°C and a frequency of 1.59 Hz. To characterize the resistance to permanent deformation, the Zero Shear Viscosity at 40°C and 60°C measured with the creep method is used. This parameter has shown to have a good correlation with the slope of the so-called dynamic creep curves of asphalt mixtures (sometimes called the mixture viscosity). Since the latter parameter is inputted in rut predictions, it is thought that a good link is created between a bitumen property and the corresponding asphalt performance in the pavement.
3.2 Reflective cracking
Due to the heavy loads, on airfield pavements in areas with weak soils often cement treated bases are used. Although these bases are notched, reflective cracking is still a design issue. This characteristic is taken into account by the force-ductility test method. Micro-mechanical simulations have shown that the strain at fracture and the energy measured during the test (until fracture) are the dominant bitumen parameters. This because the PMB must enable the mixture to follow the slow displacements of the underlying crack/notch without cracking. This at a relatively low temperature.

3.3 Thermal cracking (low temperature)
Since there are spots on airfield pavements (e.g. shoulders) where the bitumen is not “massaged” during its long service-life, even in moderate climates low-temperature cracking is an issue. By means of the BBR this phenomenon is adressed. As a selection criterion the critical temperature has been chosen (lowest value of LST or LmT).

3.4 Loss of aggregates (FOD)
This is an interaction issue between aggregate and binder. To measure the resistance to loss of aggregates, a high frequency test has been selected: the Plate Shock Test after a curing period of 30 days at 70°C.

3.5 Structural contribution (bearing capacity)
In order to assess the effect of the PMB on the bearing capacity of the entire pavement structure, the modulus of the bitumen is tested at intermediate temperature (15 °C) and frequency (1.59 Hz). This value can be inputted in the well-known equations, which relate binder modulus with mixture modulus.

3.6 Resistance to chemical agents
This surface characteristic is tested by putting a sample of the compacted asphalt mixture in a chemical agent during a certain period and afterwards brushing the surface. The loss of material is measured in accordance with draft CEN-standard 12697-43.

3.7 Ageing (durability)
Most of the tests are done on new binders (except the Plate Shock and the resistance to chemical agents). To be sure that the characteristics of the binder in the mixture after laying are comparable with those of the new binder, three tests (each covering an important damage phenomenon) are also done after ageing with the Modified Rolling Flask at 163°C. The choice for the MRF test is based on the fact that it gives (in one go) enough aged binder to perform the three mentioned tests. Also important is the fact that on airfields in the Benelux only continuously graded mixtures are used, for which the ageing during production and laying already covers the major part of the entire potential ageing.

By using this procedure it is believed that “balanced” PMB’s are rewarded. In other words, the bitumen modification treatment should result in PMB’s which have a good resistance to rutting, reflective cracking and low temperature cracking all along the pavement service-life.

4.PRE-SELECTION METHOD: GENERATION OF BITUMEN INPUT DATA
The values for the bitumen characteristics are generated and inputted into the system by the producer of the binder. That means that every producer has the possibility to include PMB products, with brand names and with the required characteristics (note that the method is put on the website www.beneluxbitume.be).

5.PRE-SELECTION METHOD: BITUMEN QUALITY CLASSES
The requirements for the binder have been divided into three classes. That means that for each characteristic that is considered important, the customer can choose for one of the three classes. The reason to have three classes is that it enables the customer to enhance the behaviour of the binder for one or more characteristics and also to make the differences between different PMB’s very clear. Note that the values put forward for the division between the classes are based on actual knowledge and experience and could be changed in future.

Also the possibility to include some conventional (unmodified) binders is available.

6.PRE-SELECTION METHOD: HOW IT WORKS
The PMB pre-selection model is a tool that can be used by the airfield operator and the consultant during the pavement design and binder selection process. The database provided by Benelux Bitume consists of a number of PMB’s, with the specific binder properties measured according to a well defined set of performance related test methods. The binders range from conventional bitumen to highly polymer modified. The binder selection is carried out in relation to the condition to which the binder will be exposed during its service life. Taken into consideration are the following aspects:

- mechanical speed of the load, vertical position in the pavement
- road base type of road base, bound or unbound
- environment temperature conditions, potential chemical attack
The case can be entered by the designer or the airfield owner himself via a worksheet in which he/she can give his/her preferences and personal experiences based on local conditions of the specific airfield.

The input given by the pavement designer/airfield owner is based on the foreseen use of each specific asphalt layer in the structure. First, information is acquired on the location and use (platform, taxiway, runway, runway-head, runway shoulders, de-icing platform, service road). For platforms e.g. the asphalt mixture to be used should have a good resistance to static loads and have improved fuel resistance. For runways the resistance to stone loss will be one of the main criteria. The next step is to select the vertical position of the asphalt layer in the pavement structure (wearing course, binder or base layer) and indicate the type of road base (bound or unbound). For bound bases the resistance to reflective cracking will be an additional requirement.

The required information related to the asphalt pavement (i.e. bound or unbound foundation layer, asphalt wearing course, asphalt binder or base layer and location/use) is entered in the model (using scroll-bars). This includes the selection of the relevant conventional binder; in this case 50/70 bitumen. The first column of the model is showing now for each “performance” aspect the required bitumen class as being the opinion of Benelux Bitume for a big general airport. The second column represents the preferences as given in by the designer/airfield owner for his specific application. To indicate the different classes use is made of colour codes: yellow for class A, green for class B and red for class C. The weight factors are shown in the coloured boxes. If the user does not agree with one or more of the weight factors for the different performance criteria, it is possible to enter new weight factors (which are considered more relevant for the specific project conditions) by changing the values in the “Input own Preference” worksheet (see figure 2). Based on these user-defined weight factors, the colour of the boxes will indicate the minimum required bitumen class for each performance criterion.

For each class the values for the different properties are included in the model and shown on the right part of the screen. The actual bitumen (pre-)selection involves comparison of the properties of the available bituminous binders with these values. It should be noted that class C is not necessarily always a highly modified bitumen. For example, very soft Penetration Grade bitumen belongs probably to class C for resistance to reflective cracking. The properties of a binder not available in the Benelux Bitume database can be entered in the third column of the model (denoted as free input). The colour of the box indicates to which class the binder belongs for a certain performance criterion. Comparison with the colours of the first (or second) column shows directly whether the binder complies with all requirements. The properties of a binder selected from the database are shown in the fourth column. Again, the colours of the boxes can be used to assess whether the binder complies with all requirements. The outcome of this exercise is preferably a limited number of bituminous binders that comply with the demands (or in fact the weight factors, since a weight factor between 1 and 24 implies that the requirement is considered not important, a factor between 25 and 49 is represented by class A, between 50 and 74 by class B and between 75 and 100 by class C). These binders should be included in the next selection step (for example asphalt mixture testing). However, since the requirements can be conflicting, it can also be that no binder fulfils all requirements. In that case the weight factors need to be reconsidered (in fact via a change of the composition of the pavement) or a new PMB needs to be developed.
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Figure 2 The “Input own Preference” worksheet which can be adapted to specific local situations

7. PRE-SELECTION METHOD: EXAMPLE

The procedure is illustrated with an example: bitumen selection for a wearing course of a taxiway on a cement bounded sub base. The “bitumen specification” as proposed by Benelux Bitume is shown in the first column of the screen print. It can be seen that for this situation resistance to reflective cracking, resistance to rutting and to stone loss are considered to be important performance criteria. With respect to these criteria the selected bitumen should belong to either class B or C. However, in this case the user decides that resistance to reflective cracking is less important and reduces the weight factor to 60. As shown in the second column of figure 1 this corresponds to a class B binder. The user had already entered in the column ‘conventional bitumen’ the properties of the 50/70 binder by choosing it from the conventional binder selection window. It can be seen that this binder does not meet the requirement for resistance to rutting (class A instead of class B). The properties of another binder that is selected from the database (PMB CCC) are listed in the fourth column. This binder meets all requirements and can be included in the next selection step.

8. CONCLUSION

Benelux Bitume has developed a bitumen pre-selection model for airfield pavements, which can be used by asphalt mixture designers to ease the optimization process of the asphalt mixture.

The database of the model is put on the website of Benelux Bitume (www.beneluxbitume.be) and consists of a number of PMB’s with their specific binder properties, established according to a well-defined set of performance related test methods.

The model input given by the pavement designer is based on the final use of the asphalt. Firstly, information is required on the location and use (e.g. apron, taxiway, runway, runway-head, shoulders, deicing platform). The next step is to select a position (depth) in the pavement (asphalt wearing course, asphalt binder course or base course) and indicate the type of base layer (bound/unbound).

Based on the input from the designer the model will propose a set of performance related minimum requirements for the binder. The designer can decide to agree or modify the specifications based on specific local conditions. By selecting binders from the database the designer can compare the properties of the binders available on the market with the recommendations. In this way the model can be used to efficiently pre-select suitable PMB’s for the application.