EME – LONG LASTING STRUCTURAL ASPHALT

Trevor Distin
National Technology Manager, Boral Asphalt

Robert Vos
State Executive Officer – Queensland, Australian Asphalt Pavement Association

Summary
The paper describes the sustainable technology transfer of the French Enrobés à Module Élevé or EME which makes asphalt more sustainable by improving the structural strength of asphalt, providing pavements with a longer maintenance free in-service life. EME was developed in the late 1980’s as the need arose to build stronger road pavements to carry 13 tonne vehicle axle loads. The paper will report on the implementation and development of EME using local aggregates and binder in Australia. This includes the calibration of French mix design process using Australian performance based test methods and conditions and evaluation of the first EME field paving trial in Australia.

KEYWORDS: EME asphalt, EME2, performance based mix design, high modulus high fatigue asphalt.

1. Introduction
Enrobé à Module Élevé (EME) technology was developed in France in the late 1980’s in response to the need to build stronger and longer lasting pavements. The product has increased its engineering performance parameters during the development phase and is now denoted EME2. With development of EME2 its use was extended to airport pavements that could withstand the increased loading of the new A380 Airbus wide bodied jet aircraft.

France has made extensive use of EME2 on main routes as well as urban roads. This has permitted and improved cost-effective use of the road network with an increase in the permissible maximum axle loading on their road pavements to 13 tonnes as compared with Australia’s 9 tonnes. [1]

So what makes EME2 asphalt different from normal asphalt? EME2 is a structural asphalt which offers increased stiffness, fatigue and rut resistance properties over conventional unmodified asphalt base course mixes.

To achieve these performance enhancements, a very hard bitumen is used in the asphalt mixture at a higher binder content. As a result of the much-improved performance properties imparted to the asphalt, this allows:

• a significant reduction in the pavement thickness, or
• a substantial increase in the service life of the pavement for the equivalent layer thickness

The latter is of particular benefit to the road asset owner where strengthening of an existing distressed pavement is required in situations where there are height restrictions e.g. kerb and channel levels in urban areas, bridge crossings on motorways etc.

Study tours organised by the Australian Asphalt Pavement Association (AAPA) to South Africa in 2011 [2] and Europe in 2012 [3] revealed that EME2 had been successfully transferred and adopted in these regions.

EME2 is a standard product in the British Highways specifications [4] and is covered by the CEN specifications used across Europe. The introduction of EME2 technology into Australia was considered as an imperative by the local asphalt industry to improve the sustainability of flexible pavements, particularly in regions where high ambient temperatures require increased structural layer thickness to withstand increased traffic loading.
2. Principles behind EME2

The key principles [5] behind achieving improved performance in EME2 asphalt are:

- **Increased modulus.**
  This is achieved by increasing the stiffness of the bitumen. In Europe binder stiffness is measured by the needle penetration test at 25°C. The penetration of the bitumen used in EME2 is typically between 10 – 25 dmm compared with a value above 30 dmm for our hardest C600 grade bitumen.

- **Increasing fatigue life.**
  By increasing the binder content in the asphalt mix, the fatigue life is increased which helps counteract the high bitumen stiffness. Typical binder contents of EME2 are about 6% which are much higher than our dense graded structural asphalt which is about 4.5%.

- **Improved rut resistance.**
  This is achieved primarily through the high bitumen stiffness, which offsets the effect of the increase in bitumen content to help prevent rutting.

- **Improved moisture sensitivity.**
  By increasing the bitumen content, the film thickness of the binder coating on the aggregate is increased and the air voids in the mix are reduced.

- **Improved workability.**
  By increasing the binder content the workability of the mix is improved. This allows easier compaction during construction and renders an in-situ mix with lower air voids.

The above enhancements result in a significant improvement in the performance properties of EME2 over conventional dense graded structural asphalt.

Figure 1 shows the evolution of EME2 in France and how the change in binder stiffness and content impacted on the performance properties of asphalt.

The EME2 being used in Australia is based on the latest version from France and the UK [6] where it is referred to as EME2.

![Figure 1: Evolution of EME2 in France [5]](image)

The advantages of EME2 of the hard and high binder content with low air voids can be linked to performance related design methods [7]. As illustrated in Figure 2 the high temperature / slow loading rate improvements of EME2 represents the improved load bearing properties of EME2 for the Queensland conditions.
The key to the success of EME2 is in the performance based testing regime employed to design the mix so that these performance outcomes are achieved. Unlike traditional asphalt mix designs, which are based on volumetric principles and historical gradings with limited performance testing, EME2 mixes are required to meet set engineering performance criteria. At the conclusion of the mix design testing process, the grading and bitumen content are an outcome rather than the target as per traditional specifications.

The mix design process [8] requires the execution of 5 performance tests to be carried out in 4 steps as shown in Figure 3.

Table 1 shows the relative performance properties of plant mixed EME2 and 20mm Dense Graded (DG20) asphalt produced with C600 bitumen. These results were obtained on the asphalt mixes placed on the demonstration trial reported on later in the paper.

Figure 2: Master Curves of EME2 vs Dense Graded Asphalt with alternate binders [7]

3. Design of EME2 mixture

Figure 3: EME2 mix design process
Table 1: Summary of performance test results on the plant mixes

<table>
<thead>
<tr>
<th>Performance Property</th>
<th>DG20</th>
<th>EME2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue @ 20°C, cycles to failure</td>
<td>40,000</td>
<td>270,000</td>
</tr>
<tr>
<td>Modulus @ 25°C</td>
<td>6.0 MPa</td>
<td>10.8 MPa</td>
</tr>
<tr>
<td>Rutting depth @ 60°C &amp; 60,000 passes</td>
<td>2.9 mm</td>
<td>1.2 mm</td>
</tr>
<tr>
<td>Tensile Strength Ratio and value</td>
<td>99%</td>
<td>101%</td>
</tr>
<tr>
<td></td>
<td>758kPa</td>
<td>1280kPa</td>
</tr>
</tbody>
</table>

4. Benefits of EME2 performance

EME2 offers the road asset owner potential economic, environmental and engineering benefits over conventional structural asphalt products through its improved performance properties. [8],[9]

4.1 Reduction in layer thickness

The increase in the modulus and fatigue properties of EME2 vis-a-vis dense graded asphalt provides a reduction in structural layer thickness for an equivalent load. Based on the Australian pavement design systems, it is estimated that the typical reduction will be about 30%. This reduction will increase as the ambient temperature of the region increases for a given loading condition. Using CIRCLY software to design a typical heavy-duty pavement in Queensland, we are able to replace a 250mm of DG20 layer with a 145mm thick EME2 layer. The design assumptions and calculations are shown in Figure 4.

4.2 Improved structural life

For the same thickness, the improved structural properties of EME2 will render a pavement with a longer life over dense graded asphalt. This means that less structural maintenance will be required during the design life of the pavement resulting in lower life cycle costs.
4.3 Increase in axle loading

Our flexible asphalt pavements are currently designed to be able to carry a dual tyre single axle load of 9 tonnes. [1] By replacing dense graded asphalt in the base course with EME2 in our heavy duty pavements, we will be able to carry heavier axle loads. In France they have been able to increase their axle load limits to 13 tonnes which allows them to:

- Reduce their cost of freight per tonne
- Render their goods more competitive for export

4.4 Reduction in construction costs

Use of EME2 can reduce construction costs of new pavements and rehabilitation of existing distressed pavements by:

- Eliminating the need to raise kerb and channels or maintain bridge deck clearances if strengthening of the pavement is required
- Eliminating the need to place a water proof seal under the wearing course because of its high impermeability to moisture ingress
- Less excavation required to construct new pavement because of reduced pavement thickness required for equivalent strength
- Reduced paving time required to lay thinner pavement layers for equivalent strength

4.5 Environmental benefits

By replacing DG20 asphalt with a product, which will last longer or reduce the thickness of the asphalt pavement for the same traffic loading, EME2 offers the following environmental benefits:

- Savings in the consumption of non-renewable raw materials like bitumen and aggregates, and the associated reduction in transport and energy usage
- Requires less expensive structural maintenance and related disruptions to traffic
- Potential to carry heavier axle loadings thus reducing GHG emissions per tonne/km of freight
- Render the pavement less susceptible to changes in temperature brought about by extreme climatic events

5. Implementation of EME2 in Australia

In 2012 Austroads commissioned ARRB to undertake an explorative study on the potential to transfer EME2 technology to Australia. [10] This report provided the basis for the transfer of EME2 into Australia.

To facilitate the successful transfer of EME2 technology into Australia, an industry EME2 task team was formed in early 2013. The task team comprised members of both Austroads and AAPA organisations. Through the collaborative efforts of all task team participants various projects were identified to ensure the successful implementation of local EME2.

One such project was funded under the Austroads program and supported in-kind by AAPA members. The project was aimed at developing mix design guidelines for EME2 and setting appropriate performance criteria using Australian test methods. A second project, funded by the Queensland Department of Transport and Main Roads (DTMR), was aimed at developing guidelines for the structural design of pavements containing EME2. DTMR were also committed to developing a supplementary specification for implementation by mid 2014, which would allow EME2 to be used on their projects.

In order to achieve these project goals, the translation of the French mix design requirements to appropriate Australian criteria were needed to be established by conducting parallel testing of a number of mixes in both France and Australia. This was an essential task to conduct because the French test methods and climatic conditions are very different to Australia. The key differences between the EME2 performance test methods and conditions for the two countries are summarised in Table 2.

To this end local companies have had mix designs developed in France using Australian materials. These were later tested in Australia using local performance tests and environmental conditions. In
addition, materials for an existing French EME2 mix with known performance was shipped to Australia and tested at ARRB’s laboratory to serve as a benchmark for locally designed mixes.

Table 2: EME2 test methods

<table>
<thead>
<tr>
<th>Property</th>
<th>French</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Gyro angle 0.85° loading 600 kPa</td>
<td>Gyro angle 2 - 3° loading 240kPa</td>
</tr>
<tr>
<td>Moisture</td>
<td>Duriez test 10% air voids</td>
<td>TSR test 8% air voids</td>
</tr>
<tr>
<td>sensitivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rut resistance</td>
<td>Large wheel 60,000 passes @ 50°C</td>
<td>Small wheel 10,000 passes @ 60°C</td>
</tr>
<tr>
<td>Modulus</td>
<td>Direct tensile 15°C @ 10Hz</td>
<td>Indirect tensile 25°C @ 10Hz</td>
</tr>
<tr>
<td></td>
<td>Trapezoidal beam 10°C @ 25Hz</td>
<td>4 point beam 20°C @ 25Hz</td>
</tr>
</tbody>
</table>

6. Development of local EME2 binder and asphalt mix

Key to the successful implementation of EME2 was the availability of locally produced bitumen which would meet the 15/25 penetration grade binder and EME2 mix performance requirements. The low penetration (15 – 25 dmm) and relatively low softening point (<72°C) binder were key to achieving high modulus and rut resistant properties of the asphalt, whilst the high binder content in the mix would ensure the high fatigue and low moisture susceptibility properties would be achieved.

To this end extensive local performance testing was done on French produced EME2 asphalt to establish equivalent performance parameters for our climatic and test conditions.

A binder suitable for EME2 is not simply one that is much harder than the typical Australian C600 binder. If also has to balance hardness with toughness to allow for increased fatigue resistance. Figure 5 is a plot of the Colas France database of bitumen & RAP based mixes [11]. Only certain binders will allow the mix to meet the upper right quadrant engineering property requirements of EME2.

Figure 5: Hard bitumen sources vs Modulus & Fatigue Resistance [10]

Once the binder supplier for the project, SAMI, was confident that they could produce a binder that would meet the French EME2 requirements using local aggregates, aggregates from project contractor, Boral’s Whinstanes and West Burleigh plants were sent to Colas’ international laboratory in Paris for testing. Following 6 months of performance testing Colas were able to formulate a mix design using SAMI’s 15/25 EME2 grade binder and the local aggregates. Figure 6 below provides some understanding of the different viscosity band of the EME binder when compared the usual Australian C class of binders.
7. First EME2 asphalt demonstration project in Australia

The execution of the first EME2 demonstration project in Australia took place on 15 February 2014 on the access road to Boral’s asphalt plant at Whinstanes in Brisbane. The key challenge for the project was to validate that Boral could manufacture and pave EME2 using local aggregates and SAMI’s binder, which was designed in accordance with the French EME2 specifications.

Boral had approached Brisbane City Council during late 2013 with a proposal to upgrade the access road to their Whinstanes asphalt plant using EME2. DTMR and ARRB were invited to be involved to assist
with the experimental design, data collection and to provide the industry with the confidence that EME2 could be successfully transferred to Australia using local materials that would perform under our climatic and traffic conditions. Under the auspices of AAPA, a series of meetings took place involving all the aforementioned stakeholders to ensure that all the necessary steps were taken for a successful project outcome.

The final decision was to construct a pavement with two different mixes and layer thickness

- 100mm layer of EME2 (315 tonnes) and
- 150mm layer of DG20 (350 tonnes) with C600 bitumen.

This provided ideal conditions to compare the in-service performance properties of EME2 against the standard asphalt base course under measurable traffic, climatic and foundation conditions.

7.1 Manufacturing and paving EME2

On the manufacturing side extra care was taken to ensure that the EME2 mix could be consistently produced to meet the target grading and binder content. The EME2 mix design required a higher proportion of crushed sand and fines than what would normally be used in base course asphalt mixes. The mix contained no natural sand or hydrated lime.

Trial mixes were produced at the plant using standard bitumen to ensure that they could achieve the design volumetric targets. On the day of the trial the gradings of the raw materials in the stockpiles were checked to ensure that they had not changed. To ensure that the special EME2 binder would not be contaminated in the plant, SAMI supplied a surrogate load, which was used to flush out the storage tank prior to manufacturing the EME2 asphalt.

During manufacture of the asphalt, close control was kept on the bitumen and aggregate hot bin temperatures to ensure that the final mix was dispatched into the tippers above 180°C.

![Figure 8: Placing of strain gauges in the pavement prior to paving EME2](image)

As part of the broader involvement of ARRB in the project, an AAPA sponsored weather station, and engineering performance measuring devices were included.

The construction of the demonstration project involved the removal of the existing distressed asphalt pavement to accommodate road widening, temperature monitoring and varying layer thickness. The project also involved the installation of strain gauges and a weather station to monitor and record in situ pavement temperatures.

Standard paving and compaction equipment was used to place both the DG20 and EME2 material. A section of the EME2 was also gritted to evaluate the skid resistance of the surface in the event that it would be left open to traffic before the application of a 30mm DG10 wearing course.

Despite concerns that they would struggle to achieve in situ density given the high viscosity of the binder (6000 Pa.s @ 60°C), the EME2 compacted very easily with the vibratory 7 tonne tandem steel wheeled roller and 9 tonne vibratory PTR. This was also aided by the close proximity of the site to the mixing plant, layer thickness and high ambient temperature which was above 30°C.
8. The way forward

The test data collected from the demonstration project and the French produced EME2 asphalt mixes will be used by ARRB to develop a specification framework with equivalent performance test methods and requirements.

A draft specification has been developed and will be published once ratified by Austroads. This will enable local laboratories to conduct mix designs for EME2 using Australian performance test methods. The intention is to be in a position to have a national EME2 specification by the end of 2014.

With the single agreed mix design process with performance requirements, road asset users across Australia will be able to incorporate EME2 in their procurement specifications for use in their road network.

Given that EME2 mix design process is performance based, the material properties can be used directly in the pavement design analysis. ARRB will continue to monitor the in situ performance of the EME2 by conducting FWD testing on the demonstration project. This information will be used to develop pavement design criteria to provide confidence in the use of EME2 under local conditions.

The potential future use of EME2 in pavements will be as alternates on major high load projects. Feasibly, these could include any pavement strengthening requirements, new design-build-operate projects such as near Toowoomba, airport runways and port areas. The high stability of EME2 also makes it a more viable option for highly loaded industrial pavements, aircraft parking/standing zones and for container stacking areas. The high performance improvement that can be imparted through pavement strengthening with reduced thickness can be used as a selective pavement upgrade option. This is particularly relevant for routes with higher freight use or increased axle loads where national and state routes are upgraded for economic reasons.

9. Conclusions and recommendations

This paper maps out the journey that has been undertaken to successfully transfer “EME2 - long lasting structural asphalt” technology from France for use in Australia using local materials. Whilst still at an early stage of the journey, our successes to date include:

- Design EME2 asphalt mixes using locally produced bitumen and aggregates which comply with French specifications
- Manufacture and pave EME2 on a local road project in Brisbane
- Developed a performance based mix design framework using Australian test methods which is planned to be published by Austroads at the end of 2014

As a consequence of the above achievements, we have paved the way for the implementation and use of EME2 on our road network. EME2 offers road asset owners real economic and long lasting engineering benefits over conventional structural asphalt products. These include improved performance by replacing DG20 asphalt with a product, which will last longer for the same thickness or will reduce the thickness of their asphalt pavements for the same traffic loading. EME2 also has the following environmental benefits:
• Savings in the consumption of non-renewable raw materials and the associated reduction in transport and energy,
• Requires less expensive structural maintenance and related disruptions to traffic,
• Potential to carry heavier axle loadings thus reducing GHG emissions per tonne/km of freight
• Render the pavement less susceptible to changes in temperature brought about by extreme climatic events

To quantify the benefits in financial terms by substituting long lasting EME2 for dense graded asphalt on all projects across Australia, this could render a potential materials savings of 1.5 million tonnes per annum. The value of this reduction in asphalt usage is estimated at $225 million.

Acknowledgements

The authors would like to acknowledge the support of the following organisations without which we would not have been able to achieve the successful transfer of EME2 technology to Australia. They are AAPA, ARRB, Queensland DTMR, Austroads, Brisbane City Council, SAMI, Colas and Boral.

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Authors

Trevor Distin
Joined Boral in 2009 as the National Technology Manager for their asphalt and spray sealing business. Prior to that he held positions as Executive Director of Southern African Bitumen Association, Marketing Director for Colas Southern Africa, Bitumen Technical Services Manager for Mobil Oil South Africa. He started his working career in the Roads Department of the Cape Town City Council. Has over 30 years experience in bituminous materials testing, manufacture and construction. Currently serves on Austroads Asphalt and Bitumen Surfacings working groups and on the AAPA board. Holds a Masters Diploma in Technology (Civil) and Bachelors Degree in Commerce.

Robert Vos
Joined AAPA in 2000, working with the industry and government to improve the performance of bituminous products and pavements in Queensland. 14 years with a State Road Authority in South Africa and 10 years as the Technical Director to the Southern African Bitumen Association. Has Civil Engineering degree and is a member of the UK and South African Institutions of Civil Engineers, a South African Professional Engineer and a UK Chartered Engineer.