USE OF ECO-FRIENDLY MATERIALS FOR A NEW CONCEPT OF ASPHALT PAVEMENTS FOR A SUSTAINABLE ENVIRONMENT

Accelerated testing of eco-innovative pavements

PSWNA Meeting
Warsaw, 30th March 2017

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TRL, United Kingdom

• Agenda
  – Introduction
  – Objectives
  – Methodology
  – Results
  – Conclusions
  – Notes and recommendations
Introduction

• APSE project – “Use of eco-friendly materials for a new concept of Asphalt Pavements for a Sustainable Environment”
• Aim of the project is to replace conventional pavement materials with eco-friendly materials

- Higher levels of closed-loop asphalt recycling
- Effective use of C&D recycled material
- Partial substitution of bitumen with bio-products
- In a single pavement structure
• Project objectives
  Task 3.3: Accelerated testing of the APSE concept pavement
  1. Provide a clear indication of how the APSE materials might perform in actual highways
  2. Key linkage between laboratory scale tests (WP2) and road-scale trials (WP5)
  3. “Upscale” the APSE concept materials to plant mixed materials
  4. Monitor the performances of APSE trial materials compared to their conventional alternatives

• Task 3.3 (WP3) Methodology:
Objectives

• Test the properties of Construction and Demolition (C&D) recycled aggregates
• Compare the performances between:
  – Conventional limestone sub-base
  – The C&D alternative
• Followed recognised process in the UK’s Specification for Highway Works (SHW)
  – Clauses 802.12-18
• Determine the need for a control limestone sub-base in accelerated pavement trafficking trials

Methodology

• Trial took place at CEMEX’s Wickwar Quarry over one day (April 18th 2016)
• Trial area was located directly on the limestone bedrock, so a regulating layer (150mm) of limestone Type 1 subbase was placed and compacted to provide a level area for the trial
• Two 60 m sections were constructed side by side and were 3.6m wide
1) Sub-base trial

Recycled aggregate surface showing high fines content (above) and contrast with limestone subbase (below)

Trafficking

- The mean vertical deformation to be measured after trafficking equivalent to 1000 equivalent standard axles

- The SHW states that the material is acceptable as unbound subbase if the mean vertical deformation (after 1000 equivalent standard axles) is less than 30 mm.
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1) Sub-base trial

Trafficking results

- The mean vertical deformation for both materials is less than half this value, with no individual measurements exceeding 30 mm.
- The deformations for the recycled aggregates were significantly lower than for the limestone.

<table>
<thead>
<tr>
<th>Chainage</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recycled</td>
</tr>
<tr>
<td></td>
<td>Offside WP</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
</tr>
</tbody>
</table>

Average each wheel track: 7.6 (Recycled); 12.2 (Limestone)
Overall average: 9.9 (Recycled); 14.0 (Limestone)

Laboratory test results

- C&D gradation distribution

- Moisture content as-received = 5%.
Laboratory test results

1) Sub-base trial

- C&D recycled aggregates meet almost all requirements set out in SHW
  - CBR = 19% (>30% req. in SHW) due to the high fines content
- Frost heave – Not required since the PTF is enclosed and will never be subject to sub-zero temperatures.
  - Note: Recycled aggregates can be susceptible to frost heave if they contain a high proportion of fines and materials with high water absorption
- Each source of C&D recycled aggregates should be assessed for its own suitability, particularly with regards to fines content.
  - High fines content should be avoided for aggregates used outside due to the susceptibility to moisture

Conclusions

1) Sub-base trial

- On the basis of the trafficking trial and the laboratory test results, the recycled aggregate was deemed suitable for use as unbound subbase in the PTF trial, and control sections of limestone subbase were therefore not required
24/03/2017

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2) Machine lay trial mixtures in the PTF

APSE trial pavement sections

- Design thickness
  - 150mm asphalt (40mm surface, 110mm binder course and base course layers)
  - 225mm C&D sub-base
  - Subgrade CBR 3-3.5%
- Instrumentation (asphalt strain gauges and thermocouples)

<table>
<thead>
<tr>
<th>Section</th>
<th>40mm</th>
<th>110mm</th>
<th>225mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBCS</td>
<td>TBCS</td>
<td>TBCS</td>
<td>TBCS</td>
</tr>
<tr>
<td>APSE binderbase layer</td>
<td>Conventional binderbase layer</td>
<td>APSE binderbase layer</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>Subgrade</td>
<td>Subgrade</td>
<td>Subgrade</td>
</tr>
</tbody>
</table>

BISAR Analysis under 50kN
Deflection = 0.85mm
Strain = 280 microstrain
Design traffic N = 110,000 standard axles

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Construction

- Test pit area = 12m x 10m
- Preparation of subgrade – 15th June 2016
- Sections 1 and 2 completed – 5th July
- Sections 3 and 4 completed – 3rd October

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Foundation preparation
- Weakened subgrade 3-3.5% CBR
- C&D recycled sub-base
- Quality control
  - MEXE cone penetrometer testing
  - Sub-base Light Weight Deflectometer (LWD) 35-90MPa

Asphalt materials and properties
- APSE binder course / base asphalt mixtures contained 25% RAP
- APSE binder course modified with the addition of bio-flux (2.5% of 4.7% binder content)
- APSE surfacing contained lignin-modified binder (shear blended in plant in Spain)

<table>
<thead>
<tr>
<th>Course</th>
<th>Material type</th>
<th>Date of production</th>
<th>Penetration (0.1 mm)</th>
<th>Softening point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APSE base-binder</td>
<td>Asphalt concrete 20 mm dense; 40/60 straight-run bitumen; bio-flux; 25% RAP</td>
<td>5th July 2016</td>
<td>21</td>
<td>60.2</td>
</tr>
<tr>
<td>Conventional base-binder</td>
<td>Asphalt concrete 20 mm dense; 40/60 straight-run bitumen</td>
<td>5th July 2016</td>
<td>19</td>
<td>65.4</td>
</tr>
<tr>
<td>APSE surfacing</td>
<td>Asphalt concrete 10 mm close-graded; lignin-modified binder</td>
<td>3rd October 2016</td>
<td>19</td>
<td>70.6</td>
</tr>
</tbody>
</table>

Asphalt binder content = 4.7-5.7%
2) Machine lay trial mixtures in the PTF

Asphalt paving process

(a) Delivery of asphalt to the PTF
(b) Paving Section 1 base-binder course
(c) Conventional surface course
(d) APSE surface course

Instrumentation
- Asphalt strain gauges
  - 6 strain gauges in each section
  - Located along centreline
- Thermocouples
  - Air, surface, 40mm, 90mm and 140mm
Pavement characterisation

- Pavement uniformity
  - Ground Penetration Survey (GPR) post construction

- Layer stiffness
  - Falling Weight Deflectometer (FWD) post construction and throughout trafficking

- Pavement instrumentation - initial tests were aimed to determine;
  1. response of the gauges under the FWD load and the PTF trafficking, and
  2. early life performance of the pavement

<table>
<thead>
<tr>
<th>Gauge reference</th>
<th>Section 1</th>
<th>Section 2</th>
<th>Section 3</th>
<th>Section 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>NO</td>
<td>YES</td>
<td>*YES</td>
<td>YES</td>
</tr>
<tr>
<td>3</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>4</td>
<td>NO</td>
<td>*YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>5</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>6</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

Pavement Test Facility

- Super-single wheel loading 40-65 kN
- Wheel speed 15 km/h
- Indexed wheel loading distribution
- Ambient temperature conditions

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PTF testing and data acquisition

- Initial trafficking (approx. 10,000 passes) at 40 kN and then increased to 50 kN
- Higher PTF wheel loads applied in latter stages (55, 60, 65 kN) to:
  - complete trafficking within given timeframe
  - to assess pavement performance under unrealistic loading
- FWD testing performed prior to each load increase
- Data recorded intermittently
  - Horizontal asphalt strains at ambient temperatures
  - Temperature data
  - Rutting measurements
  - Cracking monitored
  - Surface wear or deterioration

Results

- After 151,032 PTF wheel passes (0.54 million standard axles), no sign of damage observed
- This includes:
  - a) PTF loading at much higher and unrealistic loads (>55 kN)
  - b) narrowing the wheel load distribution from ±450 mm to ±135 mm either side of the centerline
Results

- Little or no increase in rutting after 0.5 msa
- Slight increase in Section 1:
  - Due to extreme PTF loading (65 kN)
  - Narrowing of loading distribution
  - Much less failure threshold (10mm)
- No sign of cracking
- No significant changes in FWD deflections

Rutting results

3) Machine lay trial mixtures in the PTF
3) Accelerated testing trial
3) Accelerated testing trial

**Rutting results**
- Averaged across each section

![Rutting results graph]

**Asphalt strain results**
- Strains averaged over 10 readings
- After initial increase (0.1 msa), strains gradually reduce and ‘plateau’
  - Changes in strain follow changes in asphalt temperature (90mm)
- Little or no changes due to:
  - PTF loading (40-65 kN)
  - Narrowing of wheel loading distribution
3) Accelerated testing trial

Asphalt strain results

Temperature changes

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Laboratory test results

4) Laboratory testing

- Samples cored from each section showed:
  - % Air voids (BS EN 12697-8)
    - 3.6-6.4% conventional binder course (BC)
    - 4.0-8.6% APSE BC
  - Indirect Tensile Stiffness Modulus (BS EN 13108-20)
    - Conv. BC stiffness 35% higher than APSE BC

Laboratory test results

- Samples cored from each section showed:
  - Indirect Tensile Stiffness Ratio (BS EN 12697-12)
  - ITS values for control and APSE mixtures > 70% (good resistance to moisture damage)
Conclusions

• Pavement performance
  1. No signs of deterioration in the surface course
  2. Rutting: Minimal rutting observed
     a. Section 1 slightly higher due to unrealistic PTF wheel loading
     b. Sections 2, 3, and 4 had ≤3mm rutting measured
  3. No visible signs of cracking
  4. FWD results showed no change in structural condition
  5. Number of passes x5 higher than design life

• Pavement response
  1. Horizontal asphalt strain measurements recorded at ambient temperatures
     a. Peak values inherently associated with temp. changes
  2. All four trial sections showed an increase in horizontal asphalt strain, then stabilized and gradually decreased
     a. Data showed no change in structural condition
     b. Results are indicative of ‘long life behaviour’
Conclusions

• Material properties
  1. Laboratory testing showed that:
     a. Materials complied with the specification for grading and binder content
     b. The APSE base-binder mixture showed a lower softening point than the conventional binder
     c. The lignin-modified binder showed a higher softening point that the conventional which is in line with what would be expected of a Polymer Modified Binder (PMB)

• The trials demonstrated that the novel and recycled materials used in this trial can perform satisfactorily in road pavements provided that: (a) they are constructed to specification, and (b) laid by experienced site operatives

• APSE materials should perform equally well in on-road trials in Spain and Poland as:
  – Spanish pavement structure is similar to that of the UK (On-road trials to take place in Spring/Summer 2017)
  – Polish structure will be for a lower-specification road, and subject to less traffic
Notes & Recommendations

• Recycled aggregates from C&D sources
  – Can be finer grained and therefore particularly susceptible to moisture
  – If too fine, this source should be rejected

• Asphalt manufacturers should undertake laboratory workability testing on proposed APSE mixtures before proceeding to full-scale mixing
  – to ensure that they are comfortable with the resultant stiffness of the mixtures

• In regards to the RAP, removing the need to superheat the virgin aggregates fraction, the RAP would need to be relatively dry.
  – Some additional heat may be required where moisture is present in the RAP to drive off the excess

• There is no substitute for local knowledge. Mixture designs should be adapted to match local constituents and climatic conditions

Thank you
Any questions?