Assessment of stiffness and fatigue tests in Portugal

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Outline

1. Introduction
2. Conditions Used on the Study
3. Discussion of Results
4. Conclusions
Objectives

► Asphalt mixtures applied in construction works on the Portuguese national motorways network are often subjected to a “performance based” type of quality control.

► Stiffness modulus and fatigue laws established with samples prepared in the laboratory and by 4pb tests, are usually used as a reference for behaviour/quality control analysis of the samples coming from the construction site. This procedure, besides a real world representation problem also raises a question on results compatibility when coming from different equipments.

► This study is a first step to address the second problem
Methodology

► Compare results from a performance characterization in laboratory (stiffness and fatigue) using a traditional base course mixture carried out in three different laboratories in Portugal, owning three different 4pb equipments (labeled “1”, “2” and “3”), all of them with an extensive participation on asphalt mixtures quality control processes during the last decade.

Motivation

► Will the discussion of the results help to understand if the differences found make it necessary to produce a new orientation for Portuguese performance assessment of asphalt mixtures?

► Which limitations must be known or be present when dealing with this kind of procedure.
Equipments

► One of the equipments is of the hydraulic “Cox” type with the horizontal translation freedom at the supports established with ball bearings.

► A second equipment is a Cooper Technology equipment, which uses servo pneumatic technology and a digital data acquisition and control system.

► A third equipment is a self made design. The requirements for the translation and rotation freedoms at the supports are fulfilled by “rollers” (bearings) used between the beam and the supports and a lubricant is also used to minimize friction. The clamping is achieved by pneumatic actuators with a constant force.
Asphalt Mixture

- Limestone aggregates
- Aggregates blend: 5% of limestone filler; 41.5% of 0/5 (mm); 23.5% of 5/15 (mm) and 30.0% of 15/25 (mm)

- 50/70 penetration bitumen; 4.2% of bitumen content
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Samples

► Prismatic beams (435x65x50 mm³)

► Bulk specific gravity (kg/m³) average and four variability indicators for the three sets of beams, one for each laboratory:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>2383</td>
<td>2381</td>
<td>2384</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>6,8</td>
<td>10,6</td>
<td>11,1</td>
</tr>
<tr>
<td>Max value</td>
<td>2395</td>
<td>2397</td>
<td>2400</td>
</tr>
<tr>
<td>Min value</td>
<td>2372</td>
<td>2353</td>
<td>2360</td>
</tr>
<tr>
<td>Variation coefficient</td>
<td>0,29%</td>
<td>0,45%</td>
<td>0,46%</td>
</tr>
</tbody>
</table>

Test Conditions

Stiffness Modulus

- Temperatures
  - 20°C and 40°C

- Frequencies
  - 1, 2, 4, 6, 8 and 10 Hz

- Controlled Strain
  - 100 μm/m (sinusoidal form: 50/-50 μm/m)

Fatigue

- Temperatures
  - 20°C

- Frequency
  - 10 Hz

- Controlled Strain
  - 200, 500 and 900 (μm/m)

2. Conditions Used on the Study
3. Discussion of Results
A tolerance of at least 15% should be considered when analyzing stiffness modulus results at relatively low test temperatures (around 20ºC)

When using high test temperatures (over 30ºC) for the same purpose the whole process should be accomplish by the same laboratory and figures should be seen as relative and not absolute

<table>
<thead>
<tr>
<th>Temperat. (°C)</th>
<th>Frequency (Hz)</th>
<th>Δ 1−2 (%)</th>
<th>Δ 3−2 (%)</th>
<th>Δ 1−3 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>6</td>
<td>15</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>12</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10</td>
<td>13</td>
<td>-3</td>
</tr>
<tr>
<td>40</td>
<td>6</td>
<td>65</td>
<td>63</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>48</td>
<td>63</td>
<td>-9</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>30</td>
<td>71</td>
<td>-24</td>
</tr>
</tbody>
</table>
Fatigue

For longer 4pb tests and temperatures around 20ºC, the differences among calibrated equipments are not significant in terms of fatigue results for this type of asphalt mixtures.

3. Discussion of Results

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_5$ ($\mu$m/m)</td>
<td>261</td>
<td>298</td>
<td>276</td>
</tr>
<tr>
<td>$\varepsilon_6$ ($\mu$m/m)</td>
<td>161</td>
<td>172</td>
<td>152</td>
</tr>
<tr>
<td>$\varepsilon_7$ ($\mu$m/m)</td>
<td>99</td>
<td>99</td>
<td>84</td>
</tr>
</tbody>
</table>
Final Remarks

► When performing the deformation characterization of an asphalt mixture (stiffness modulus) by the use of a 4 pb equipment, the type of equipment may have influence in the results.

► When addressing quality control using relatively low test (service) temperatures (around 20°C) determination of the stiffness modulus could be made by any type of 4pb equipment but, the test “set conditions” used to obtain the reference values must be known in order to minimize discrepancies. Even doing this, an acceptance coefficient related to the reference values must be defined and this study has lead to a figure of +/- 15%.
Final Remarks_2

► For 20ºC and for fatigue characterization, it can be said that any of the three 4pb equipment performing similar “set conditions” will provide similar results.

► When addressing quality control using relatively high test (service) temperatures (over 30ºC but more around 40ºC) the whole process should be accomplished exactly by the same type of 4pb equipment and stiffness modulus figures should be seen as relative and not absolute.

► Fatigue characterization at high test (service) temperatures is not a quality control issue, at least for Portuguese technology.
Final Remarks_3

► This study have had constrains that lead to limitations on the inferences.

► This is at most an alert just to underline, on the one hand, the need for a more careful interpretation of the quality control results when using performance tests, namely when using 4pb equipments, and, on the other hand, the importance of establishing a periodic cross evaluation and calibration of the equipments used for that purpose in order to minimize discrepancies.
Thank you