Comparison between various bituminous binders modified with crumb tyre rubber

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Materials

- **Bitumen**
  - PG 64-16 LOW % asphaltenes
  - PG 64-22 HIGH % asphaltenes

- **Crumb rubber** (powder)
  - High shear mixer with RPM control (duplex head)
  - 70
  - 1.E+04
  - 1

- **Temperature control with Hot plate method**
  - TR-MAB Bf
  - 58
  - 50
  - 1.2
  - 20
  - 40
  - 80
  - 1.E-05
  - 90
  - 1.E+03
  - 0.8
  - 0.6
  - 40
  - 1.E+02
  - 0.4
  - 60
  - 64
  - 1.E-05
  - 50
  - 90
  - -28
  - 70
  - 1.E+01
  - 30

Furthermore,

- **Oil extender 7.5% commercial used to produce SBS - MB**
  - Base binder (with or without oil) 85%
  - Crumb tyre rubber 15%
  - TR-MAB 85%

Blending protocol

- **High shear mixer with RPM control (duplex head)**
- **Temperature control with Hot plate method**

<table>
<thead>
<tr>
<th>Base binder (85%)</th>
<th>Oil [15%]</th>
<th>binder size</th>
<th>total weight</th>
<th>mixing time</th>
<th>mixing speed</th>
<th>mixing temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR-MAB A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR-MAB Af</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR-MAB B</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TR-MAB Bf</td>
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</tbody>
</table>

- Required amount of bitumen was heated at 180°C
- High shear mixing up to 2000 rpm was applied for first 10 minutes while firstly the oil extender than the rubber later was fed into the binder.
- Time was allowed for the temperature to settle at 180°C.
- Once the temperature reached 180°C, blending time was noted and mixing undertaken at 1000 rpm for one hour.

**Performance temperature range (°C)**

- Higher PG > 0
- Lower PG < 0

Binder characterization: Physical, chemical, rheological and by performance

- **Base binders**

<table>
<thead>
<tr>
<th>binder A</th>
<th>binder Af</th>
<th>binder B</th>
<th>binder Bf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration</td>
<td>42 mm</td>
<td>136 mm</td>
<td>54 mm</td>
</tr>
<tr>
<td>Softening Point</td>
<td>51°C</td>
<td>39.8°C</td>
<td>52.2°C</td>
</tr>
<tr>
<td>Fasius breaking point</td>
<td>0°C</td>
<td>-14°C</td>
<td>-2°C</td>
</tr>
<tr>
<td>Ductility</td>
<td>&gt;1000 mm</td>
<td>&gt;1000 mm</td>
<td>&gt;1000 mm</td>
</tr>
<tr>
<td>Asphaltenes Content</td>
<td>3.4%</td>
<td>3.4%</td>
<td>16.7%</td>
</tr>
</tbody>
</table>

- **Rotational viscosity (Pa.s)**
  - @ 100°C: 3.86, 1.57, 5.13, 2.14
  - @ 135°C: 0.40, 0.20, 0.45, 0.23
  - @ 180°C: 0.12, 0.07, 0.19, 0.13

**Oil extender effect**

- Characteristics show that the oil extender affects the base binder by softening it and thereby enhancing its temperature properties.
- Physical properties: lower Fasius breaking decrease in softening point and reduced viscosity.
- Rheology: Black diagrams show that even if the base binder contains 5% of the oil extender, the base binder’s performance is not changed significantly.
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**Tyre Rubber – Modified Asphalt Binders**

- **Performance:** All the TR-MABs have got a better performance temperature range in comparison with the base binders. TR-MABs obtained from the binder with higher asphaltenes content show higher PG and higher increase of performance B compared with the base.
- **Rheology:** Comparing the TR-MABs and the commercial original bitumens, the polymer network effect is clearly noticeable from the black diagrams that demonstrate the typical signs of modification with an extender. It is obvious that the addition of an extender does not change the gel point. From a comparison between the TR-MABs, it is possible to notice that the modified binders obtained using the higher asphaltenes content binders are an average either higher G' values, lower elastic (lower phase angles,) and higher storage moduli.

**Storage stability analysis:** R&B, PDA and DMA

Conclusions

The results have indicated that all the modified binders have a considerable improvement in terms of their rheological, physical and performance properties compared to the original base bitumens. However, fundamental differences have been found between the different binders.

- TR-MABs obtained from base binder B (higher asphaltenes content), seems to be a better product showing higher viscosity, but better performance grade, lower temperature and frequency susceptibility and better storage stability.
- The addition of the oil extender in the TR-MABs softens the modified binders and also reduces their performance range. The overall effect of adding the oil extender is the same whether it is added totally to the base binder or used as a component in the production of TR-MABs. The gel point of the material remain the same because the asphaltenes content does not change.
- Furthermore, the addition of 7.5% in weight of oil extender in the base binder appears to have a general detrimental effect on the modification in terms of the materials stability. This fact is much more evident on the bitumen with low asphaltenes content.
- It is impossible to produce a high performance TR-MAB. In order to get a good storage stability, the best level of modification and an acceptable level of viscosity, it is mandatory to preliminary assess the chemical composition of the bitumen and on this base increasing, or not, the aromatization content of the base by adding a relative quantity of oil extender.