Green Asphalt? What’s that?

Opening Thoughts

- Road construction budgets are a popular position for short term cuts
- In most mature and even in growing economies there is a distinct shift from construction of new roads to renovation, overpaves and seals
- Almost all countries have severe net consumption of road infrastructure in the past 2 decades
- High bitumen prices and regional shortages
- Higher focus on „green manufacturing” and sustainable use of resources
- HIGH NEED FOR INGENUITY

Background

- Specification: Zusätzliche technische Vertragsbedingungen und Richtlinien für Straßenbaumanbeiten in Hamburg (ZTV-St-Hmb)

Widening of upper RAP limits over time

<table>
<thead>
<tr>
<th>Year</th>
<th>Base Course</th>
<th>Binder Course</th>
<th>HiMa Binder Courses</th>
<th>Wearing Courses</th>
<th>Stone Mastic Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>25% 50% 50%</td>
<td>0% 20% 20%</td>
<td>0% 0% 0%</td>
<td>0% 0%</td>
<td>0% 0%</td>
</tr>
<tr>
<td>1992</td>
<td>90% 60% 60%</td>
<td>50% 50% 50%</td>
<td>30% 30% 30%</td>
<td>30% 30%</td>
<td>30% 30%</td>
</tr>
<tr>
<td>1996</td>
<td>90% 60% 60%</td>
<td>50% 50% 50%</td>
<td>30% 30% 30%</td>
<td>30% 30%</td>
<td>30% 30%</td>
</tr>
<tr>
<td>2005</td>
<td>90% 60% 60%</td>
<td>50% 50% 50%</td>
<td>30% 30% 30%</td>
<td>30% 30%</td>
<td>30% 30%</td>
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<tr>
<td>2007</td>
<td>90% 60% 60%</td>
<td>50% 50% 50%</td>
<td>30% 30% 30%</td>
<td>30% 30%</td>
<td>30% 30%</td>
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<tr>
<td>2009</td>
<td>90% 60% 60%</td>
<td>50% 50% 50%</td>
<td>30% 30% 30%</td>
<td>30% 30%</td>
<td>30% 30%</td>
</tr>
<tr>
<td>2012</td>
<td>90% 60% 60%</td>
<td>50% 50% 50%</td>
<td>30% 30% 30%</td>
<td>30% 30%</td>
<td>30% 30%</td>
</tr>
</tbody>
</table>

Value of raw materials inside RAP

- RAP contains
  - Bitumen
  - Filler
  - Sand
  - Coarse aggregates

- At addition levels of below 15-20% designers most often ignore the bitumen properties of the binder inside the RA

A closer look at RAP

Typical base course 0/22 mm AC

<table>
<thead>
<tr>
<th>Content by mass</th>
<th>Content by €€€€€</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen</td>
<td>~ 4.0 %</td>
</tr>
<tr>
<td>Filler</td>
<td>~ 8.0 %</td>
</tr>
<tr>
<td>Sand</td>
<td>~ 33,5 %</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>~ 55,0 %</td>
</tr>
<tr>
<td>% Mass</td>
<td></td>
</tr>
<tr>
<td>% Cost</td>
<td></td>
</tr>
</tbody>
</table>
If roads are built according to this construction principle it is always creating value to mill the layers separately!

**Aggregates in RAP**

- Binder Course
- Base Course
- Wearing Course

**Moisture is limiting use of RAP**

- The majority of plants do not have RAP heaters.
- They use cold feed RAP addition to pugmills or elevators.
- Most specs allow up to 30% of RAP, at least in the lesser mix qualities.
- Most plants only manage addition of 15% RAP.
- Moisture, "eats heat"!
- Spontaneous expansion is a problem especially in batch plants.
  - Moisture in RAP is always a concern especially in baghouses.

**Temperature of virgin aggregate**

- Required temperature for heated aggregates in °C for addition of dry RAP at levels up to 10 and 40%.

**Moisture cont.**

<table>
<thead>
<tr>
<th>Water content in RAP [%]</th>
<th>Temperature correction in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>0.2</td>
<td>8</td>
</tr>
<tr>
<td>0.3</td>
<td>6</td>
</tr>
<tr>
<td>0.4</td>
<td>4</td>
</tr>
<tr>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>0.6</td>
<td>0</td>
</tr>
</tbody>
</table>

- Amount of temperature increase needed to correct for water content in RAP.
- The grey background marks the area that is considered critical for most plants.

**Analysis and controls**

- Mandatory items:
  - Analysis of RA (1 sample per 500mt of RA)
  - Homogenisation of RA
  - When necessary; adjustment of grading curve with virgin minerals
  - Compactibility identical to "normal" mix
  - Additional proof of performance if R&B of RA > 70°C
  - Absolute Homogenity of the mix
  - In Germany and other European countries it is standard requirement that any hot mix containing RA must perform identical or better than a "virgin" mix.

**Emissions**

- The majority of plants do not have RAP heaters. Their RAP capacity is limited by:
  - Heat transfer capacity.
  - Plants with conventional RAP heaters have also limits.
  - Bitumen quality of final mix / need for rejuvenation.
  - High RAP mix needs to be paved at conventional mix temperatures or even higher. In conventional RAP heating drums this almost always leads to emission problems.
RA heating drums have been designed in the past 20 years with a target of up to 50-60% RA in mixes.
Specifications in most countries only allow much lower limits.
If such a drum exists, the only way to push RA %age is to:
- Turn up the heat
- Lower the throughput/time
- Use warm mix technology
The first two alternatives will expose the RA to high temperature and cause significant increase of carbon based emissions and deteriorate the binder inside RA.
Measurements in Germany show that emissions from conventional RA drums become critical at mix temperatures >145 °C.

No damaged bitumen
- No contact to flame
High Efficiency
- Counter Flow Principle
- Hot air is returned
- Low temp. heat exchange
Low emissions
- Indirect Warming
- Mixed gases
New generation RAP heater
- Mixed RAP (15 °C)
- Hot RAP (045 °C)
- No damaged bitumen
- High Efficiency
- Low emissions
- Mixing chamber
- Burner
- Hot air recycling

With high RAP contents it is absolutely necessary to fully melt the binder contained in RAP prior to and during mixing.
- Binder must blend with virgin bitumen and/or rejuvenants and other additives
- Addition of virgin aggregate must be fully coated
- Indicative temp target: Bitumen becomes pumpable at approx. 70-80 °C above the softening point R&B. This should be the indicative temp. for efficient commingling.
- This is especially important if RAP binder is unmodified and „modification while mixing“ by addition of highly modified virgin binder is planned.
Resulting mix temp. after 40 Seconds mixing approx. 170 degr. C
How to check commingling

25% RAP, mixed with light coloured virgin aggregate. The visible difference in colour of the batches can be used to assess a mixing time to achieve good commingling of RAP binder with virgin binder.

A closer look at the binder

• The 4 mechanisms of binder ageing
  - Oxidation
    Reaction of bitumen with oxygen
  - Volatilisation
    Evaporation of lighter binder constituents
  - Polymerisation
    Combination of like molecules to form larger molecules, resulting in progressive binder hardening
  - Separation
    Removal of bitumen constituents in selective absorption by some porous mineral aggregates

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Adjustment of binders

In almost all countries of the globe it is best practice to use soft virgin binders to accommodate the aged binders in RAP

• In many countries softer binder grades are capped at PEN 100
• Germany limits softer binders to one grade softer than tendered
• Even with much softer bitumen the „blending in the mixer“ ends at 50-60% RA
• With very high RA content the binder quality needs to be readjusted with rejuvenators

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Trial with 50% RAP and 6.5% rejuvenator

Built September 30 1993
BV Nosdorf-Zweedorf 2,5 km 7,0 m wide

approx. 300 trucks/day since 1993
No rutting, no cracking
Adjustment of binders

- Following the above logic the full recycling method was devised
- Rejuvenation to readjust the binder
- Addition of Sasobit to ensure Warm Mix effect for
  - Manufacturing within clean air act limitations
  - Modify asphalt to more deformation resistance
  - Get supreme Workability

Paving a wearing course with >90% RAP

- This mix design normally fails around 12000 cycles!
- 8mm SMA expected to have 3.5 mm
- Warm Asphalt!

Hamburg Wheel Tracking result 3.9mm deformation after 20000 cycles
Paving a wearing course with > 90 % RAP; key data

- R&B of recovered binder after paving 2010: 64 °C
  - Second inspection January 2012: 64,7 °C
- TSRST measured in 2010: -21,7 °C
  - Second inspection January 2012: -22 °C
- Hamburg wheel tracking test 2010: 3,9 mm track depth
- Permanent deformation index (compressive oscillating test on Marshall specimen) according to TP Asphalt-StB is resulting in measurements of $\varepsilon_w$ between 5,7 and 6,3 x $10^{-4}$ o/oo
  - Expected for this kind of asphalt is a value around 14 x $10^{-4}$ o/oo
- Visual inspection of project in 2012 confirms measurements

Summary

- Project is performing well after two years. Confirms findings of other older private projects built with different mix designs
  - Performance after two winters with temperatures below -10 °C and two summers with maximum temperatures > 35 °C suggest further good performance in Hamburg climate conditions
  - So far the performance is equal to or better than a wearing course built with new materials.
  - State of Hamburg will do more projects
  - Other German states are building likewise reference projects
  - Solution where technical performance and ecologic benefit meet in an economically very viable solution

The End

- Thank you for your attention!

Questions?