Thermal properties of asphalt concrete: A numerical and experimental study

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# Research outline

## Thermal properties of asphalt concrete
- Experimental measurements
- Numerical model of asphalt concrete

## Hydronic Pavement
- Numerical model of hydronic pavement
- Anti-icing of road surface in Östersund
## Research outline

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### Hydronic Pavement
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Thermal properties: Experimental measurements

- Transient Plane Source (TPS) method
Transient Plane Source (TPS) method

Five different sensor sizes of the TPS method are used to measure the thermal properties.
Thermal properties: Experimental measurements

- Transient Plane Source (TPS) method
  - Thermal conductivity of five different types of asphalt concretes

<table>
<thead>
<tr>
<th>Asphalt concrete type</th>
<th>ABT11</th>
<th>ABS11</th>
<th>AG22</th>
<th>ABS16</th>
<th>ABB22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity (W/m·K)</td>
<td>1.39</td>
<td>1.89</td>
<td>1.51</td>
<td>2.24</td>
<td>1.44</td>
</tr>
</tbody>
</table>
Thermal properties: Numerical simulation model

Gray circles: Aggregate
Blue circles: Air voids
White area: Binder
Thermal properties: Numerical simulation model

- Estimate the effective thermal conductivity
Thermal properties: Results

- Comparison between experimental measurement and numerical simulation

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<td>Numerical results (W/m·K)</td>
<td>1.29</td>
<td>2.02</td>
<td>1.47</td>
<td>2.07</td>
<td>1.41</td>
</tr>
<tr>
<td>Relative difference (%)</td>
<td>7.19</td>
<td>6.87</td>
<td>2.64</td>
<td>7.58</td>
<td>2.08</td>
</tr>
</tbody>
</table>
Thermal properties: Parametric study

- Parametric study was done using the numerical simulation model
  - Air void content
  - Aggregate type and gradation
  - Modified binder with graphite
  - Moisture effects
  - Maximum effects of saturation and freezing
Thermal properties: Conclusion

• A 1% air void content increase, resulted in approximately 3% reduction in the thermal conductivity of asphalt concrete

• Changing aggregate types from diabase (2.3 W/m·K) to quartzite (5 W/m·K) in a dense graded asphalt concrete results in 50% increase in thermal conductivity.

• The addition of 40% graphite (by mass) in the binder of the ABT11 sample results in 24% increase in the thermal conductivity values.

• Thermal conductivity of moisture-saturated asphalt concrete, is higher than that of the dry state. Also, the thermal conductivity in freezing state is higher than that in moisture-saturated conditions.
Thermal properties: Publications

Thermal properties of asphalt concrete: A numerical and experimental study
Raheb Mirzamad, Pär Johansson, Sotiris A. Grammatikos
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Highlights
- Determination of thermal properties by the Transient Plane Source method.
- Validation of a two-dimensional numerical model of asphalt concrete construction.
- Prediction of the thermal conductivity of asphalt concrete using finite elements.

Graphical Abstract

Abstract
The aim of this study is to investigate the effects of different design parameters of asphalt concrete and environmental conditions on the thermal properties (thermal conductivity, diffusivity, and volumetric heat capacity). A transient plane source (TPS) model was developed based on the Finite Element Method (FEM). The numerical model was validated by experimental results using the Transient Plane Source (TPS) method. The experimental results showed that an increase in the temperature gradient results in a decrease in the volumetric heat capacity. The experimental results were used to validate the numerical model. A comparison between the thermal properties obtained by the numerical model and the TPS method showed a relatively good agreement with a coefficient of determination of 0.98. The model was used to study the effect of the type of aggregates, aggregate grading, asphalt film thickness, and mix design as well as moisture and freezing conditions on the thermal properties of asphalt concrete.

Ice free roads using hydronic heating pavement with low temperature
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Chalmers University of Technology
Gothenburg, Sweden, 2017
Thanks for your attention!
Questions