Preliminary Results of Simulation of Annual Excess Fuel Consumption from Pavement Structural Responses for California Test Sections

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Introduction
This study compared the effects of excess fuel consumption (EFCs),* with a pavement with no structural response as well as with the effects of roughness and macrotexture on EFC. EFC was calculated using three different models for a factorial including 17 asphalt surfaced pavement field sections on the California state highway network with different structure types that were characterized for their viscoelastic properties. The results of the modeling were used to simulate annual EFC for a factorial of vehicles, traffic flows, speed distributions and climate regions. For the MIT results:

Roughness and Macrotexture Simulation Results:

- No clear trend between structures (flexible, semi-rigid, composite)
- Temperature (climate regions) generally more important than speed (urban vs rural) across typical ranges of both for California
- Load very important, reflected in sensitivity of EFCS ml/km/veh across all vehicles to % trucks
- No clear trend between structures (flexible, semi-rigid, composite)

Recommendations
- Improve modeling for the concrete pavements, consider multiple layers in rubberized AC
- Calibration should focus on the most sensitive variables: (pavement structure, wheel load, temperature, and speed)
- Consider possible interaction of roughness and structural responses.
- Check the EFC models by including the rough sections in the field sensitivity analysis

Acknowledgements
This work is part of Caltrans participation in the Miriam (Models for rolling resistance in Road Infrastructure Asset Management system) project which is being performed by a consortium of European national highway research laboratories, Caltrans, the UCPRC and the FHWA.

Problem Statement and Study Goals
The structural response energy dissipation models have not been compared with each other for the range of pavement types, vehicles and climates in California, or validated with comprehensive field data.

Goals
- Compare different pavement structural response energy dissipation models and the results they provide for estimated excess fuel consumption (EFC) for a range of California pavements, vehicles and climates using well characterized and documented field test sections.
- If warranted by the results of the first goal, to verify the same models using the results of the field measurements on the same sections with instrumented vehicles.

Pavement Test Sections
- Jointed plain concrete with and without dowels
- Continuously reinforced concrete
- Asphalt pavement with and without rubberized surfaces and open-graded surfaces and a range of thicknesses, older and newer asphalt
- Composite pavement
- Semi-rigid pavement

The ideal pavement was defined as:
- Structural response: no energy and fuel consumed by structural response
- Roughness: IRI of 38 inches/mile (0.6 m/km), approximately the smoothest pavement
- Macrotexture: MPD of 0.5 mm, typical of new dense graded asphalt mixes

Three Models for calculating vehicle fuel consumption from rolling resistance

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSU Model</td>
<td>A model developed at Oregon State University (OSU) which uses the finite element method (FEM) and calculates energy dissipated in the pavement.</td>
</tr>
<tr>
<td>MSU Model</td>
<td>The model developed at MSU by Zaabar and Chatti which uses axisymmetric FEM and calculates energy dissipated by the wheel at the bottom of the basin pushing against the side.</td>
</tr>
<tr>
<td>MIT Model</td>
<td>The model developed at MIT by Louhghalam et al. which assumes a beam deflecting under the load and calculates energy dissipated by the wheel on the slope of the beam.</td>
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</tbody>
</table>

For the OSU and MIT results:

Results of the highway network with different structure types that were asphalt surfaced pavement field sections on the California state modeling were used to simulate annual EFCS for a factorial of pavements, vehicles and climates using well characterized and excess fuel consumption (EFC) for a range of California dissipation models and the results they provide for estimated structural response for sections with IRI about 90 in/mi.

For factorial of climate regions and traffic across 1.7 sections analyzed:
- Temperature (climate regions) generally more important than speed (urban vs rural) across typical ranges of both for California
- Load very important, reflected in sensitivity of EFCS ml/km/veh across all vehicles to % trucks
- No clear trend between structures (flexible, semi-rigid, composite)

Conclusions and Recommendations
- General modeling conclusions:
  - Some major differences between modeling approaches
  - Not clear which one will best match field results
- For 17 sections analyzed:
  - Structural response excess fuel consumption (EFCS) ranges from 0.03 to 0.92 ml/km/veh, with 50% of sections between 0.08 to 0.26 ml/km/veh for OSU
  - Highly sensitive to model used
- Three models are not consistent across sections
  - Roughness and macrotexture EFCS are from 0.15 to 3.45 ml/km/veh
  - Sections selected based on IRI and MPD
  - Roughness about 10 times more important than texture
  - Roughness + macrotexture about 10 times greater than structural response for sections with IRI about 90 in/mi

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