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

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Introduction

This study compared the excess fuel consumption due to structural response (EFC_S)* with a pavement with no structural response, and also compared EFC_S with the effects of roughness and macrotexture on EFC*. EFC_S 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_S for a factorial of vehicles, traffic flows, speed distributions and climate regions typical of California.

*EFC: Additional fuel required to propel a vehicle compared to an "ideal" pavement (baseline pavement).

** Compared with IRI of 38 in/mi (0.6 m/km), MPD of 0.5 mm

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. The importance of EFC_S considering the interactions of structure, temperature, traffic speed and load have not been simulated.

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, verify the same models using the results of the field measurements with instrumented vehicles (currently underway).

Three models for calculating vehicle fuel consumption from rolling resistance

- **Oregon State University Model:** Uses the finite element method (FEM) and calculates energy dissipated in the pavement.
- **Michigan State University Model:** Uses axisymmetric FEM and calculates energy dissipated by the wheel at the bottom of the basin pushing against the side.
- **Massachusetts Institute of Technology Model:** Uses a beam model deflecting under the load and calculates energy dissipated by the wheel on the slope of the beam. Using a fast computation version of this model meant for network level analysis.

Regression model used for simulation from modeler's results:
For the OSU and MSU results

Dissipated energy (MJ) = $exp\left(a_1 + a_2\sqrt[3]{L} + a_3T + a_4v + a_5T\sqrt[3]{L} + a_6v\sqrt[3]{L}\right)$

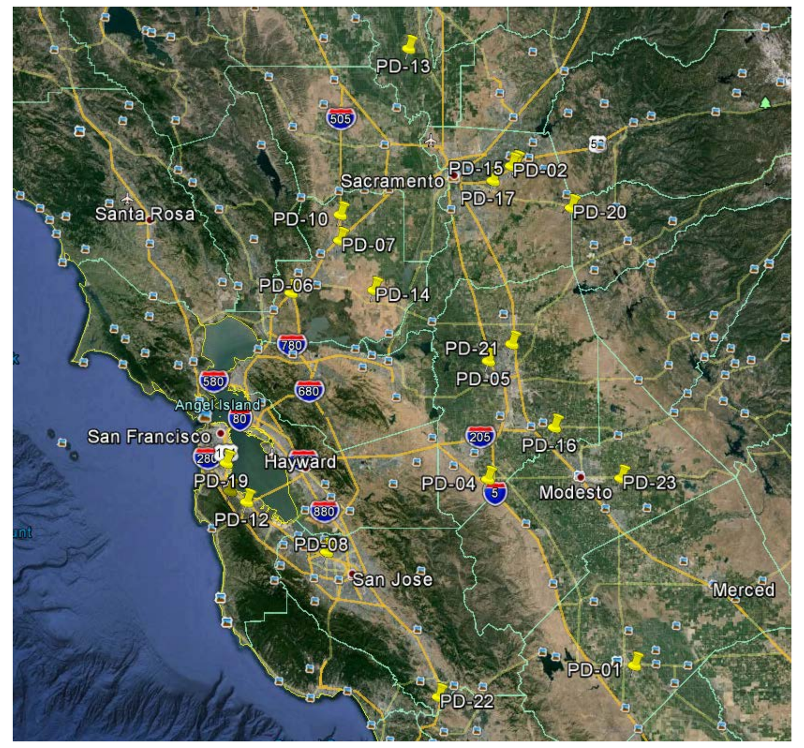
For the MIT results:

Dissipated energy (MJ) = $exp(a_1 + a_2\log(L) + a_3\log(T) + a_4\log(v))$

where L is the axle load (kN),
T is the pavement temperature at one-third depth (ºC) and
v is the speed (km/hr).

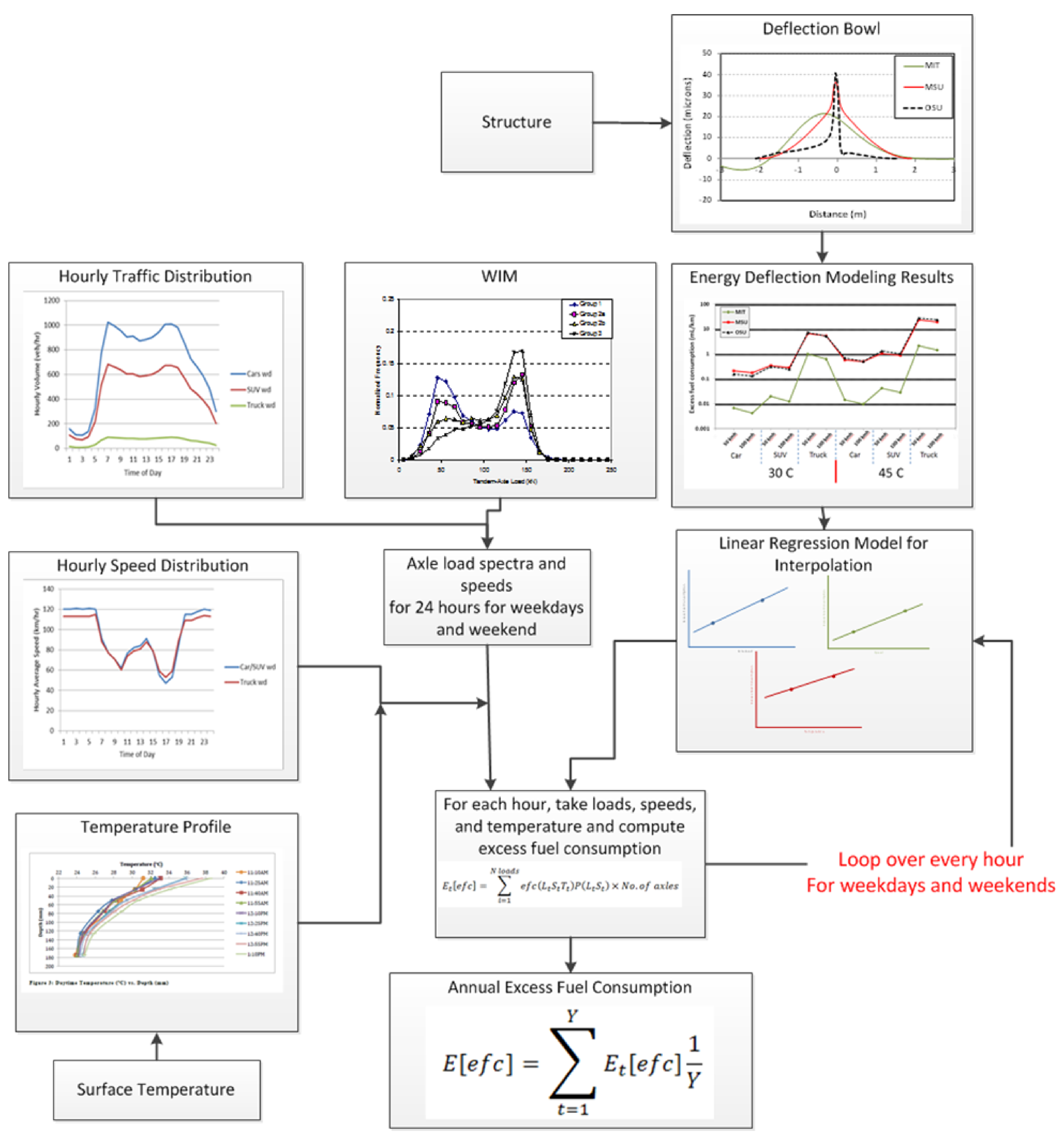
Pavement Test Sections

- 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



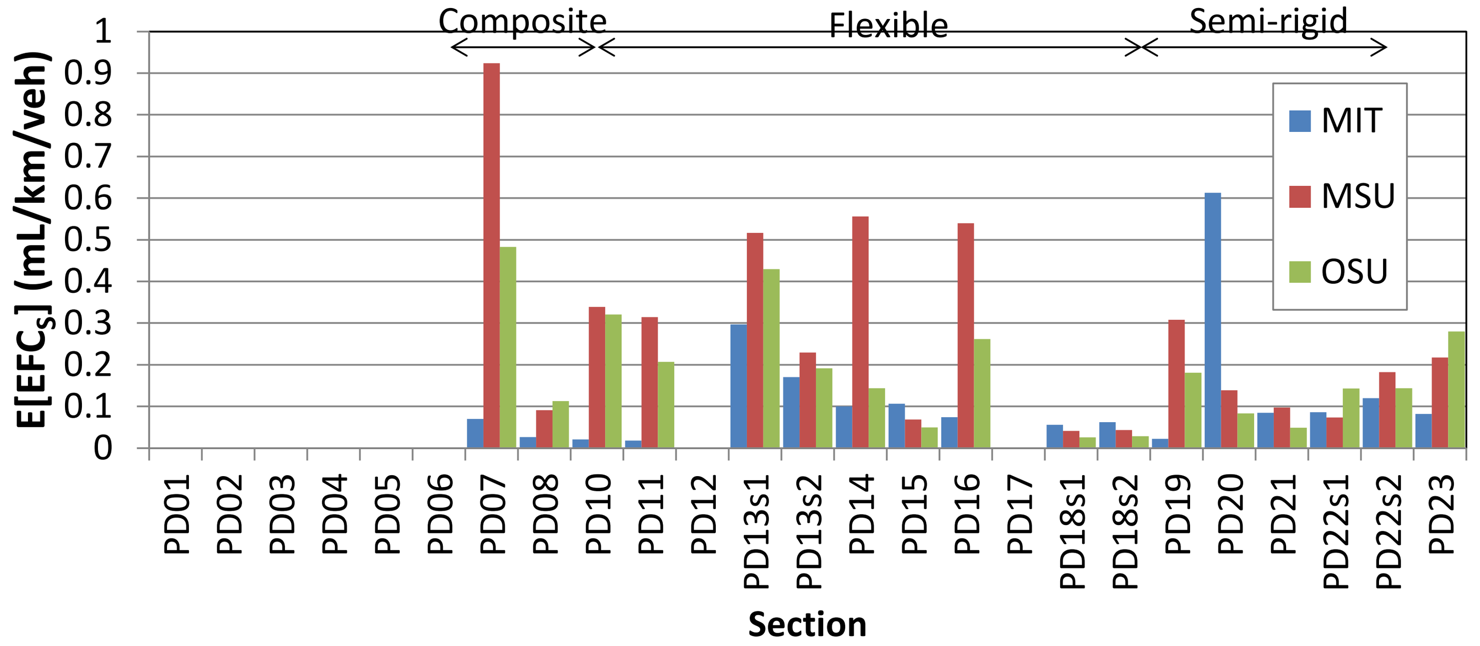
*** assumed to have no EFCs for preliminary comparison

Excess Fuel Consumption Simulation Approach

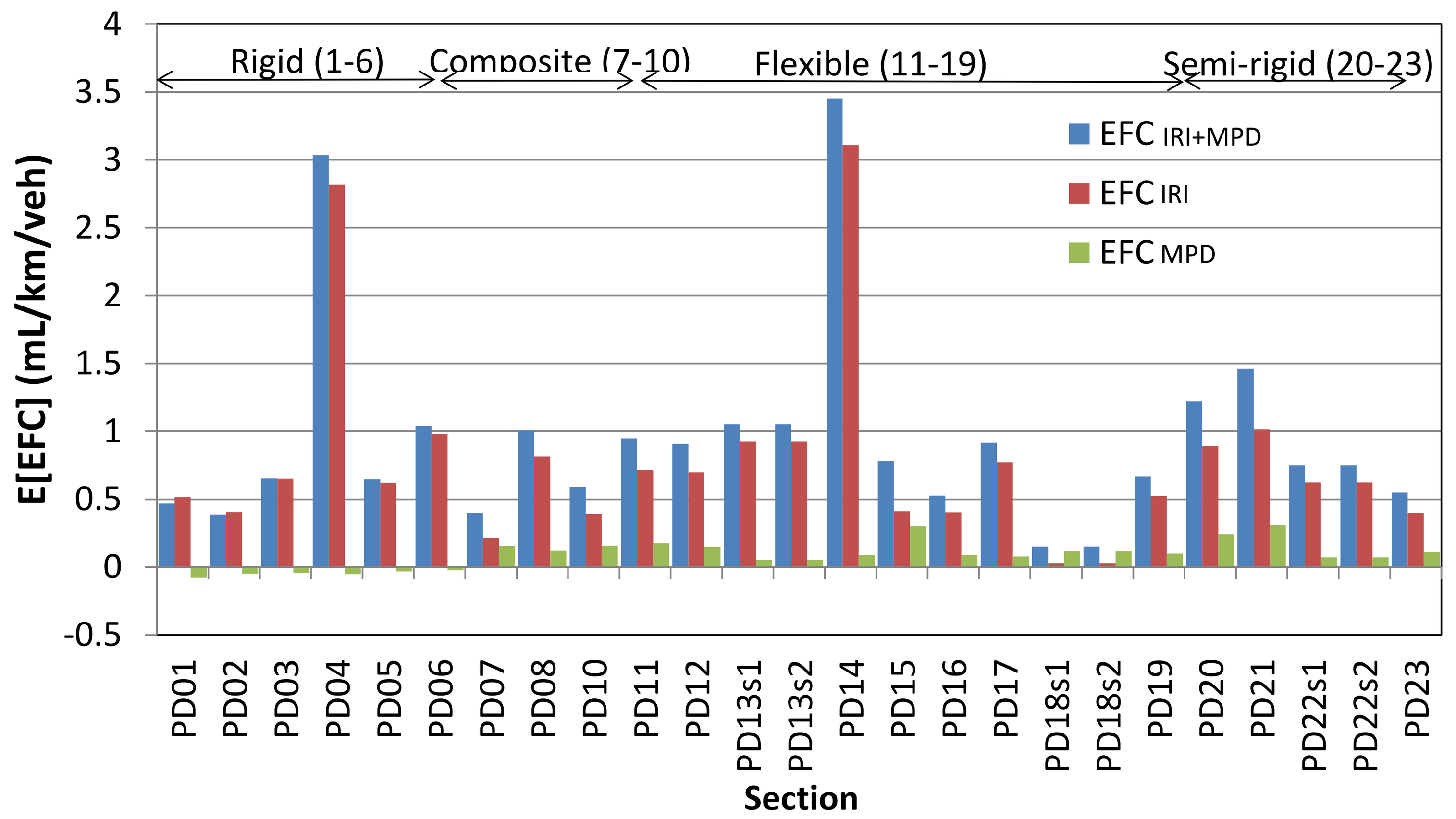


Results

Structural Response Simulation Results by section traffic/climate (avg ml/km/veh EFC_S)



Roughness (R) and Macrotexture (M) Simulation Results by Section
Specific Data relative to 38 in/mi and 0.5 mm (avg ml/km/veh EFC)



Conclusions and Recommendations

- For 17 sections analyzed
  - Structural response excess fuel consumption (EFC_S) 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 dependent on model usedo
    - Three models are not consistent across sections
  - Roughness and macrotexture $EFC_{R\&M}$ from 0.15 to 3.45 ml/km/veh
    - Most sections selected for IRI less than 100 in/mi (1.6 m/km)
    - Roughness about 10 times more important than texture
- Roughness + macrotexture about 5 x greater than structural response for sections with IRI about of 90 in/mi
- For climate regions and traffic across 17 sections analyzed
  - Temperature (climate regions) generally more important than speed (urban vs rural) across typical ranges for California
  - Load very important, reflected in sensitivity of EFC_S ml/km/veh across all vehicles to % trucks
  - No clear trend between structures (flexible, semi-rigid, composite)

Recommendations

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

Acknowledgements

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