The effect of pavement type and characteristics on rolling resistance of heavy-duty trucks from a road management perspective

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November 2021

Personal presentation and research context

- Graduated with a bachelor's degree in **mechanical engineering** since May 2021 at Laval University *(Quebec city, Canada)*
- Research Project with the **Quebec Ministry of Transportation**
  - Effect of **pavement types** (Cement vs Asphalt Concrete) on truck **fuel consumption**
    - Relatively small quantities → apply to all truck traffic
    - Cement concrete → **more polluting/expensive** to produce, but **better fuel consumption**
    - Focused on **highways** with important road traffic
  - Simulations of **road network management scenarios** in terms of greenhouse gas emissions

Physical phenomena regarding pavement properties influence on rolling resistance (1)

Road roughness (wavelength between 0.5 to 50 m) causes energy dissipation in the suspensions' dampers

- In North America, we use the ***IRI*** (International Roughness Index)
- An increase of **2 m/km** of the ***IRI*** could cause an excess fuel consumption between **1.4 %** and **3.2 %**
- Asphalt concrete road surface degradation is faster than cement concrete (harsh winter)

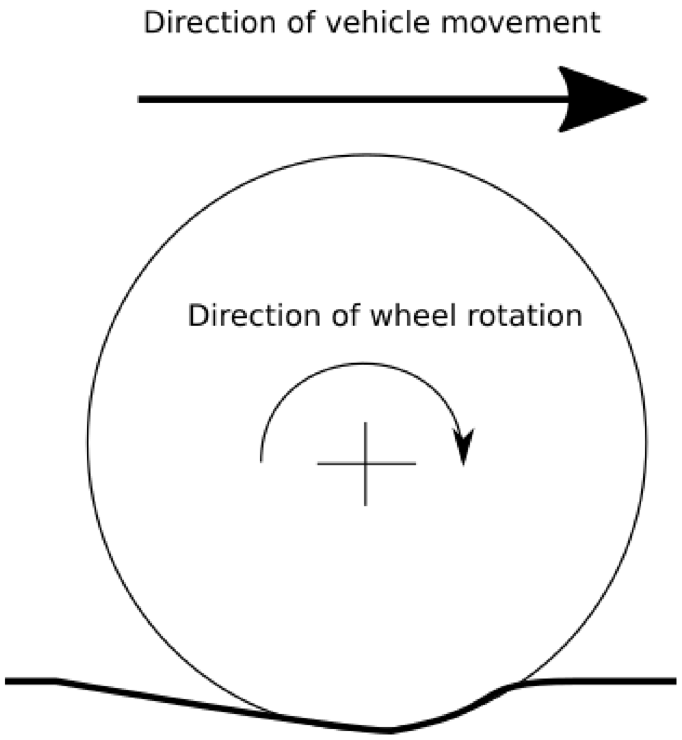
Macro-texture (wavelength between 0.5 to 50 mm) causes additional viscoelastic deformation on the rubber band of the tire

- Quantified with ***MPD*** or ***RMS*** (measured with laser profilometers)
- Poorly studied in the literature
- An increase in *MPD* of **1 mm** could cause an excess fuel consumption around **1.6 %**

Physical phenomena regarding pavement properties influence on rolling resistance (2)

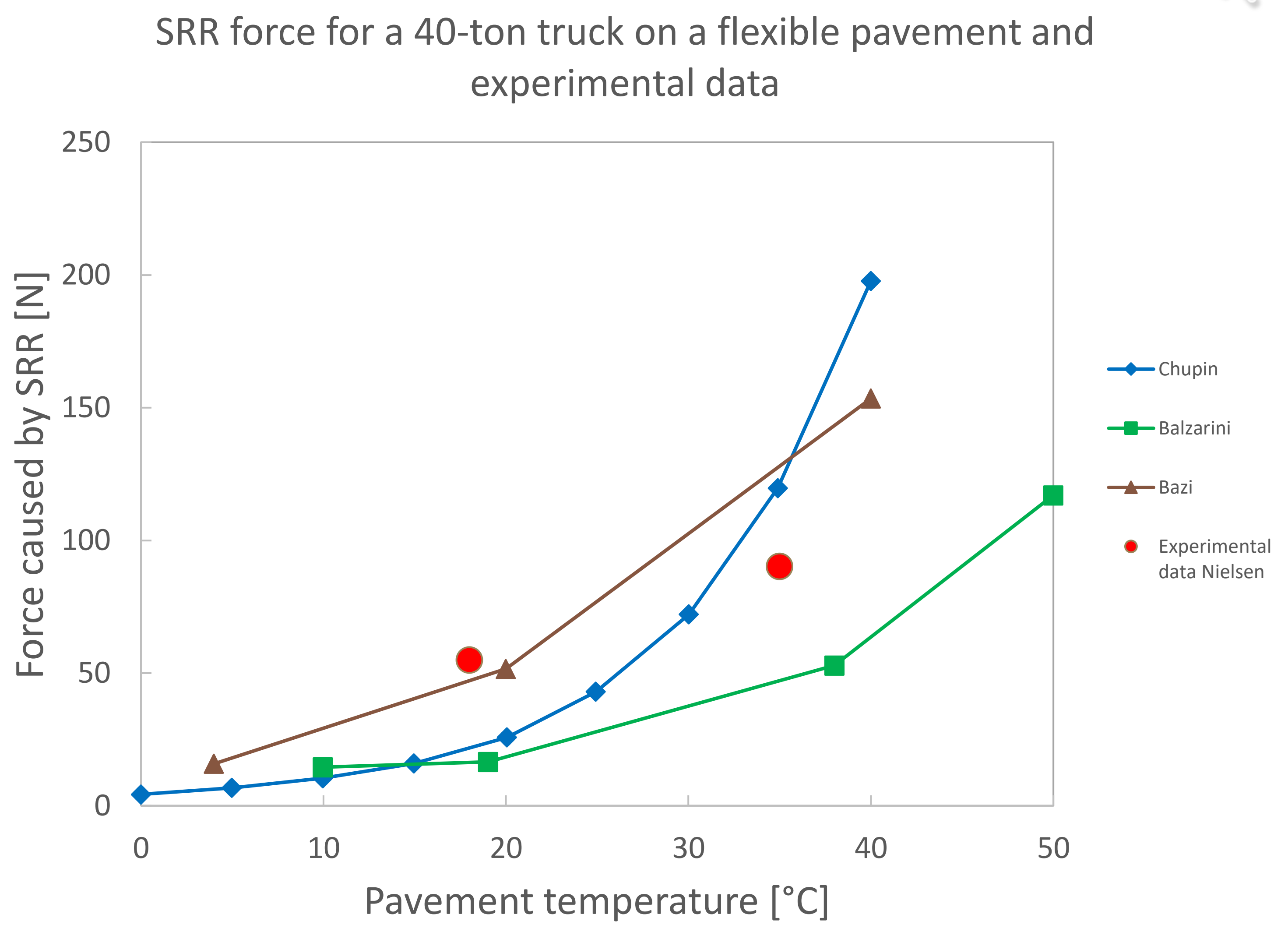
Structure-induced rolling resistance (SRR) caused by the viscoelastic behaviour of the pavement structure

- Two ways to quantified the *SRR* (reference frame)
  - The total area of the hysteretic loop of the **stress/strain history** in a certain volume of pavement (**fixed** reference frame)
  - The **perpetual uphill slope** perceived by truck tires (**mobile** reference frame)
- Believed to be the **main differentiator** between cement concrete (rigid) and asphalt concrete (flexible) pavements
  - Use to define the order of magnitude as a first simulation
  - Negligible for cars
- Strongly dependant on pavement **temperature**
  - For a **30 °C** pavement temperature, the SRR of the asphalt concrete pavement could be about **3,4 %** of the total **Rolling Resistance**



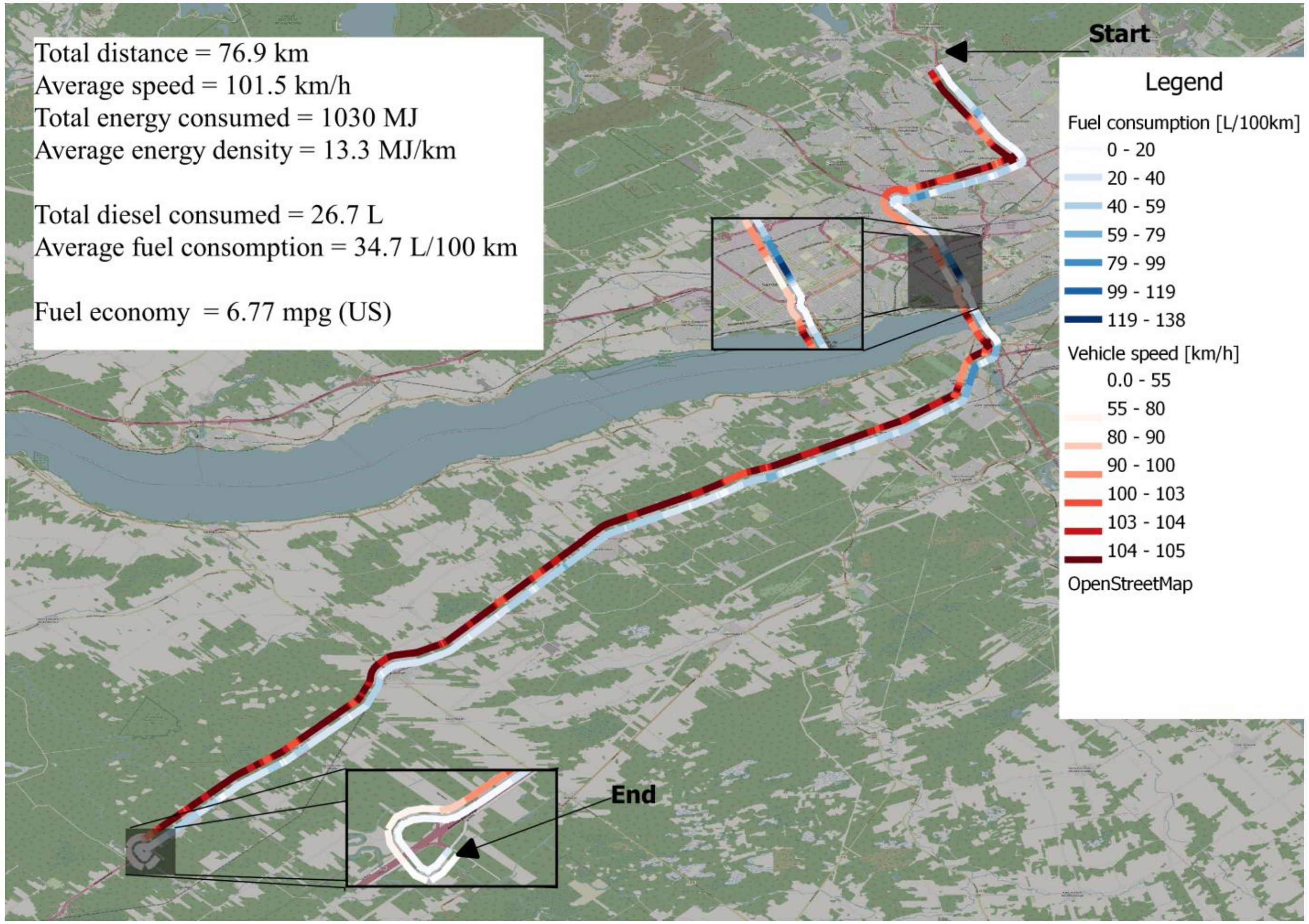
The SRR in the literature

- Simulated with **finite element models**
  - Moving load on a bloc of viscoelastic pavement
- **Different parameters** chosen by the authors
  - Scaling relationships from the viscoelastic Euler beam on elastic foundation
- **Average curve** and **exponential regression**
- **Experimental validation** at two different temperatures
  - Real-time pavement deflection measurements with doppler lasers



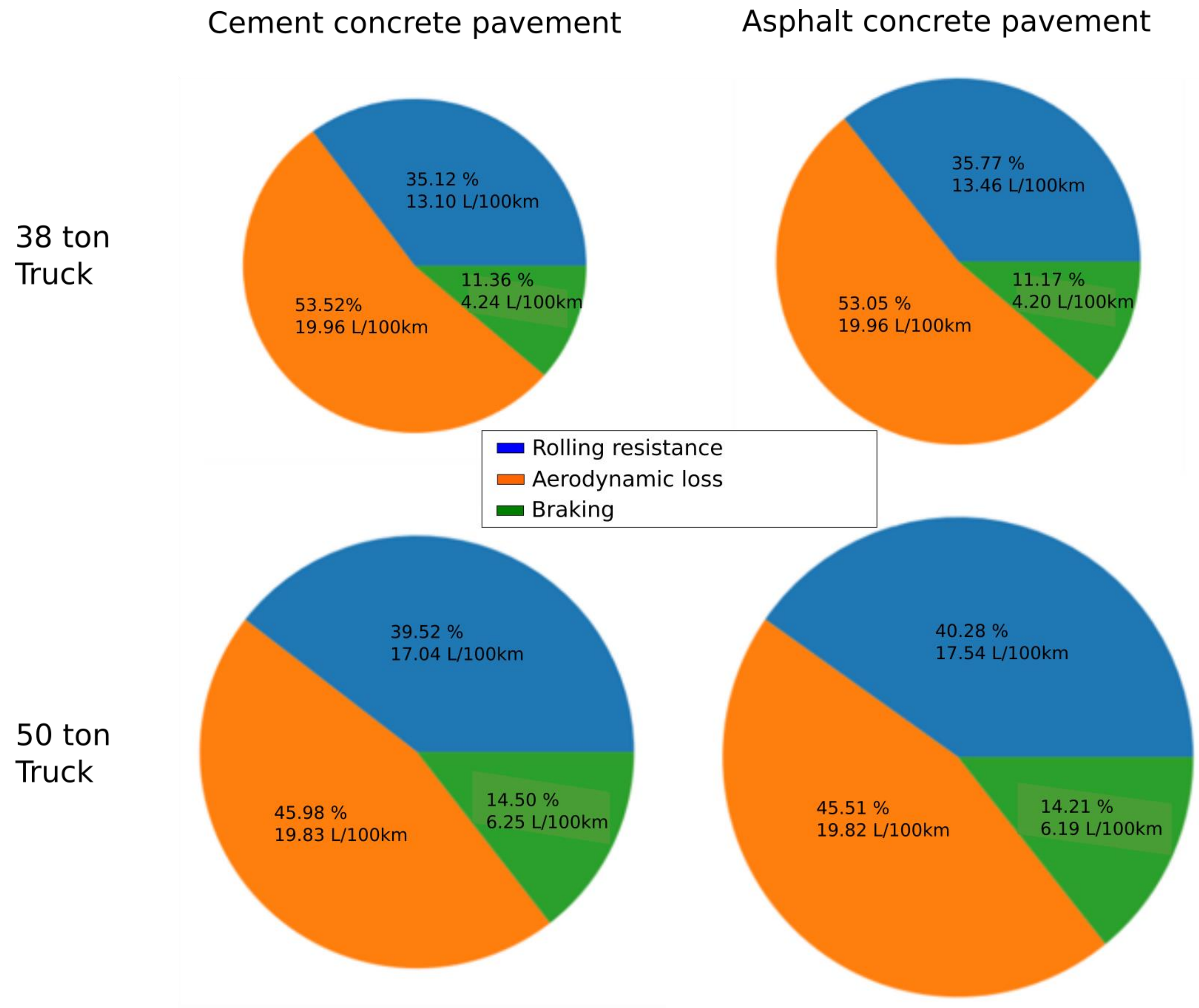
The Simulation

- MapEUR (custom software tool)
- 2 different truck masses → **38-ton** and **50-ton**
- Each truck travels **every week** during **one year**
  - Same day and hour
- **Pavement temperature** estimated with an empirical model
  - Air temperature
  - Solar irradiation
  - Wind speed
  - Relative Humidity
- 2 theorical scenarios
  - Only asphalt concrete pavement (flexible)
  - Only cement concrete pavement (rigid)



The Results

- The **average excess fuel consumption** over one year caused by the SRR
- Difference of 0.36 L/100km and 0.50 L/100km for 38-ton and 50-ton respectively
    - Much more important difference during **summer**
- Only valid for Quebec **weather conditions**



Perspectives

Introduction of a new road roughness index more relevant to the dynamic properties of the suspension of trucks

- Analogous to the *IRI*
- Could be integrated in degradation model of road pavement

Monte Carlo analysis to take into account the specificities of truck traffic

Development of instrumentation to measure the rolling resistance force and the damper motion on a real semi-trailer suspension

- Experimentally compare cement concrete and asphalt concrete pavements
- Implicitly include the 3 relevant phenomena

Conclusion

The difference in truck fuel consumption between cement and asphalt concrete pavements is significant, even with the Quebec winter

The order of magnitude of the simulation is validated by experimental data

It is relevant to continue the investigation by incorporating the effect of other physical phenomena

- As precise as possible to guide road management decisions

Questions ?