Master's Thesis Engineering Technology 2021-2022

Automated vehicles: impact of pavement structure and load distribution on pavement fatigue performance

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Introduction

As automated vehicle (*AV*) implementation gets closer, knowledge of their impact on road pavement performance is one of the crucial aspects of their deployment.

Figure 1: Longitudinal or top-down cracking [1]

Pavement fatigue performance is determined by two main types of fatigue cracking:

- **longitudinal Cracking** or **top-down cracking** (*TDC*) is a failure mode in which cracks, mainly parallel to the centerline of the pavement occur (see Fig. 1);
- **alligator** or **bottom-up cracking** (*BUC*) is a failure mode in which numerous connected cracks occur, longitudinal or transverse in the wheel path (see Fig. 2).

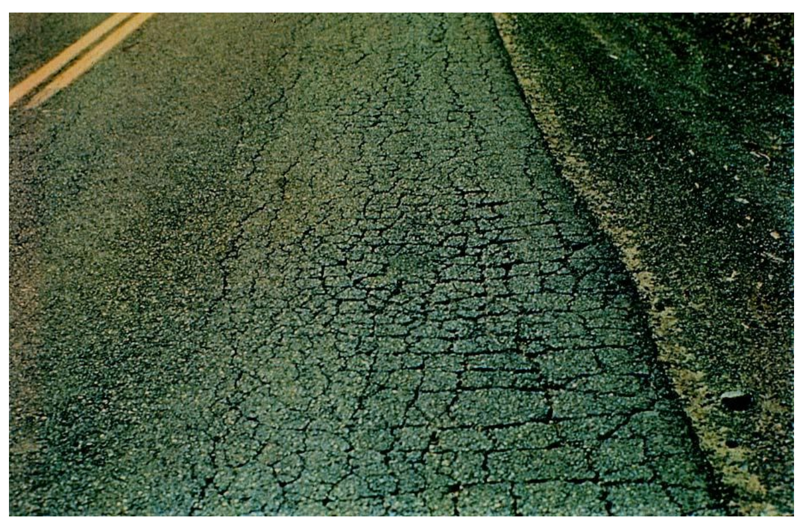

Figure 2: Alligator or bottom-up cracking [2]

The novelty of this research is found in the combination of *AVs* and human driven vehicles (*HDVs*) to calculate **pavement fatigue damage** in structures with different hot mix asphalt (HMA) thicknesses and temperatures. This combination is a new, underdeveloped subject that provides a guideline for future *AV* implementation.

Problem statement

Pavement fatigue damage is a common problem in flexible pavement structures and is determined by:

- climate,
- traffic,
- pavement structure,
- mechanical properties.

This research calculated **fatigue damage** in the HMA layer, subjected to various types of vehicle wander, and percentages of *AV* implementation

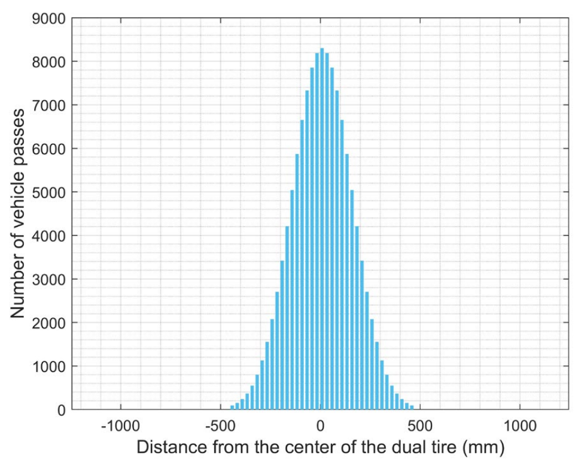

Figure 3: Normal-wander distribution

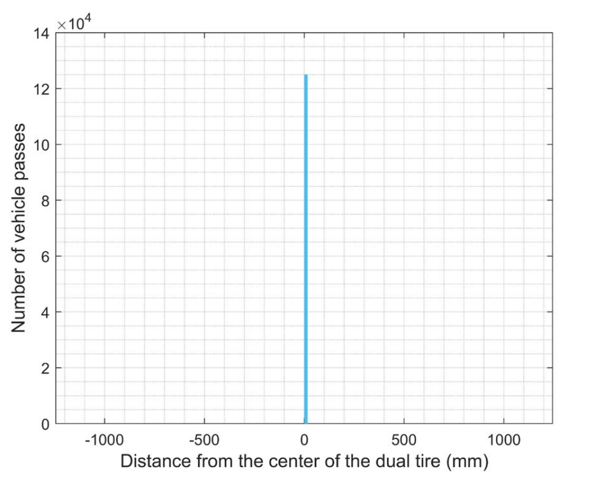

Figure 4: Uniform-wander distribution

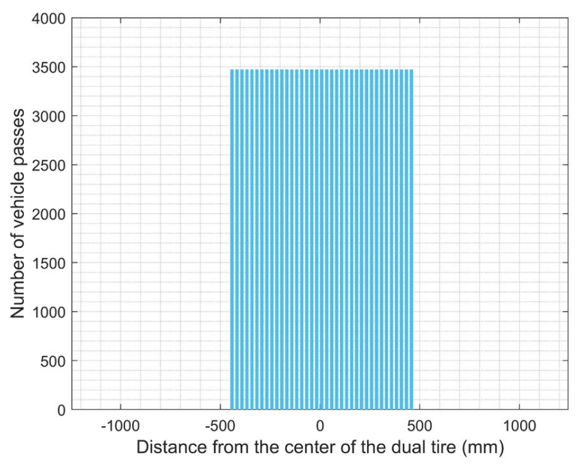

Figure 5: Zero-wander distribution

This research focuses on three *AV* wander scenarios:

- **normal-wander**, in which the load of the *AVs* is distributed normally within the lane (see Fig. 3);
- **zero-wander**, in which vehicles do not wander across the road and follow a straight path (see Fig. 4);
- **uniform-wander,** in which an even load is applied throughout each single pavement section (see Fig. 5).

Conclusion

- The determining type of fatigue cracking in a pavement structure with a granular base layer is *BUC*.
- **Normal**- and **zero-wander** *AVs* create higher maximum damage indices compared to *HDVs*.
- **Uniform-wander** is the only *AV* wander mode that increases pavement fatigue life.
- Climate factors influence **pavement fatigue performance**.
- This research could be seen as a guideline for future *AV* implementation under potential future scenarios.

Results

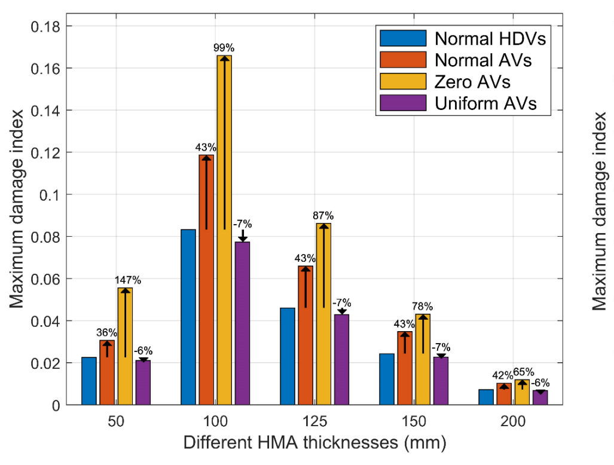

Figure 8: Maximum damage index for five HMA thickness under various AV wander scenarios considering BUC

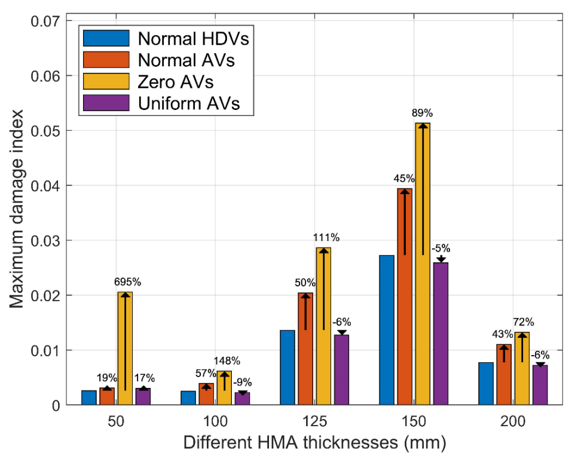

Figure 9: Maximum damage index for five HMA thickness under various AV wander scenarios considering TDC

As shown in figures 8 and 9, **Normal**- and **zero-wander** *AVs* provide a significant increment in maximum DI compared to *HDVs*. Thickness has no significant effect on the DI for **uniform-wander** *AVs.*

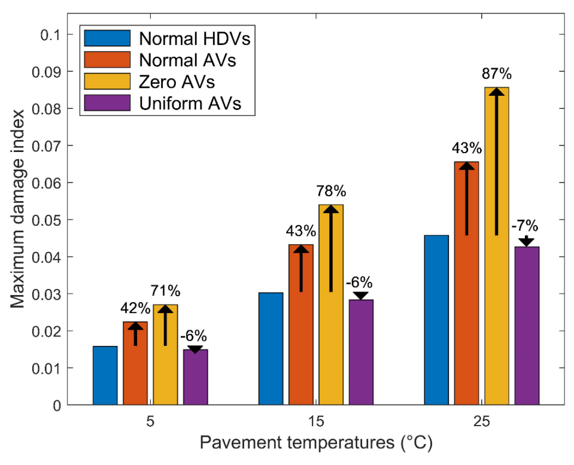

Figure 10: Maximum damage index for three HMA temperatures under various AV wander scenarios considering BUC

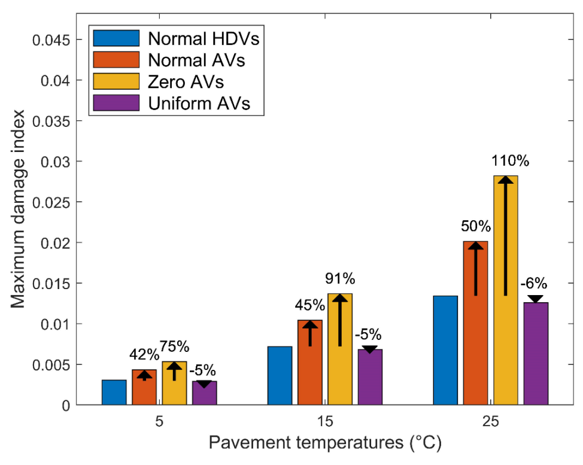

Figure 11: Maximum damage index for three HMA temperatures under various AV wander scenarios considering TDC

As shown in figures 10 and 11 **normal**- and **zero-wander** *AV* implementation results in higher **fatigue damage** in hotter climates, while **uniform-wander** has a positive influence.

Materials and methods

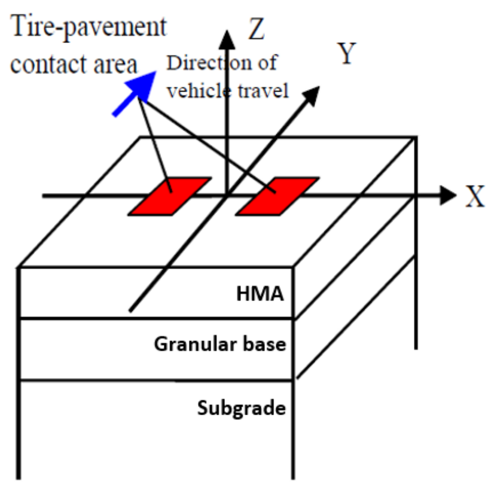

Figure 6: Pavement buildup and load configuration [3]

The strain calculations were performed for pavement structures with different:

- HMA thicknesses,
- HMA temperatures.

This research used two tire pavement contact areas, represented by a dual tire buildup (see Fig. 6, 7).

Figure 7: Standard axle buildup [4]

Pavement fatigue performance was calculated for both *BUC* and *TDC* through the following steps:

- the **fatigue damage** index was calculated through the approach presented in the MEPDG. This index divided the actual number by the allowable number of axle load applications;
- wander scenarios and percentages of *AV* implementation on the road were combined with the **fatigue damage** index;
- this resulted in graphs and tables, which showed **pavement fatigue performance**.

Supervisors / Co-supervisors / Advisors

Prof. dr. ir. Ali Pirdavani
Dr. ir. Ali Yeganeh

[1] Pavement Interactive, "Top-Down Cracking." .

[2] Pavement Interactive, "Bottom-up cracking." https://pavementinteractive.org/reference-desk/pavement-management/pavement-distresses/fatigue-cracking/.

[3] X. Hu and L. F. Walubita, "Modelling tensile strain response in asphalt pavements: Bottom-up and/or top-down fatigue crack initiation," *Road Mater. Pavement Des.*, vol. 10, no. 1, pp. 125–154, 2009, doi: 10.3166/rmpd.10.125-154.

[4] A. Maria Coca, S. A. Romanoschi, M. Talebsafa, and C. Popescu, "Simple Method for Incorporating Lateral Wheel Wander in the Computation of Fatigue Damage in New Flexible Pavement Structures," *J. Transp. Eng. Part B Pavements*, vol. 146, no. 4, p. 04020074, Dec. 2020, doi: 10.1061/jpeodx.0000229.