Freeze-Thaw Damage in Asphalt: A Set of Simplified Simulations

Lisa Lövqvist, M.Sc.
KTH Royal Institute of Technology
Stockholm, Sweden

Romain Balieu, Ph.D.
KTH Royal Institute of Technology
Stockholm, Sweden

Nicole Kringos, Ph.D.
Professor in Highway Engineering
KTH Royal Institute of Technology
Stockholm, Sweden

Acknowledgements

The Authors gratefully acknowledge the support of the Swedish Transport Administration within the BVFF program and the KTH Road2Science Center under which this research project is performed.

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ABSTRACT

Winter damage in pavements, such as potholes, dislodging of stones and structural layer separation, occurs during and after winter seasons. This damage is caused by several processes, such as freezing and thawing action, moisture accumulation, traffic loads and winter maintenance actions, which combined makes winter damage a highly complex phenomenon. To better understand this process and, in the future, being able to predict the damage propagation by modeling, this paper discusses the possibility to separate these actions and phenomena into different cases. The focus in this paper is on the freezing -and thawing damage and how it is affected by different environmental conditions, inspired by real weather data from the City of Luleå in the north of Sweden. To investigate this, a microscale model is utilized. The results from the simulations show an increasing adhesive damage with the number of freeze-thaw cycles while the cohesive damage in the viscoelastic mastic increases is the most severe for a period with several days of freezing temperatures. A discussion of how the separation of winter damage into different cases will contribute to the ultimate goal of a multiscale model is also included.

RÉSUMÉ

Les dommages hivernaux des chaussées telles que nids de poules, décohésions des agrégats et séparation des couches structurelles surviennent pendant et après les saisons hivernales. Ce type d'endommagement est causé par différents processus tels que les cycles de congélations-décongélations, accumulation d'humidité, charges liées au trafic et maintenances hivernales, qui combinés rendent les dommages hivernaux des phénomènes très complexes. Afin de mieux comprendre ce processus et, dans le futur, être capable de prédire cet endommagement par la modélisation, cet article discute de la possibilité de séparer les différentes actions et phénomènes en différents cas. Cet article est axé sur l'endommagement causé par les cycles de congélations-décongélations en prenant en compte l'effet de conditions environnementales inspirées par des données météorologiques réelles de Luleå dans le nord de la Suède. Afin d'investiguer là-dessus, un modèle microscopique est utilisé. Les résultats des simulations montrent une augmentation de l'endommagement de type adhésif en fonction du nombre de cycles de congélations-décongélations tandis que l'endommagement de type cohésif dans le mastic viscoélastique est le plus critique lors d'une période avec des températures négatives sur plusieurs jours. Une discussion sur la façon dont la séparation des dommages hivernaux dans différents cas pourrait contribuer au but ultime du modèle multi-échelle est également incluse.

1.0 INTRODUCTION

Each winter, and the spring that follows, the asphalt wearing course in pavements displays various degrees of winter damage in the form of dislodging of stones, pothole formation, and structural interface layer separations. The quality of the individual components, their bonds, as well as their long term exposure to environmental and mechanical loading all play an important role in the resulting annual winter damage. In addition to the mastic becoming more brittle at low temperatures, and therefore more prone to fracturing, moisture, from both rain and melting snow, which infiltrates the pavement, will further add to the deterioration process. Apart from the damage caused on the macro-scale by the frost heave occurring due to ice expansion in the bottom layers of the pavement, moisture also contributes to the damage on smaller scales in the top layers of the pavement. Firstly, the volume expansion caused by freezing of partially or fully moisture saturated air voids may lead to microscale damage in the interface between the mastic and the aggregates and inside the mastic. This micro-scale damage may then ultimately lead to meso-scale damage. Secondly, long-term action of moisture inside the asphalt is well known to weaken both the material components and their bonds [1, 2, 3].

While winter maintenance on the roads is needed to ensure safe driving conditions for vehicles, it may contribute to some of the damage in the roads due to high shear stresses on the pavement surface from snow plows and potential chemo-mechanical degradation from anti-freezing additives such as salt and brine infiltrating the pavement.

These processes are by themselves risk factors leading to damage in pavements during winter. The interdependency of these processes further adds to the complexity of damage associated to winter conditions. For instance, if micro-damage increases due to the loads from cars during the autumn, the net asphalt concrete porosity increases which, in turn, may increase the pavements stress release ability.

Due to the combination of these actions and phenomena, winter damage is a highly complex phenomenon to understand and minimize. To obtain a better handle on the parameters that are most relevant, this research project firstly aims to characterize the different phenomena by separating them into different cases, each describing one phenomenon. This allows a comparison of the active time-scales of the different cases as well as an investigation of the most important parameters. Future research will consider the most important interdependency of the different phenomena.

The ultimate aim of this research project is to develop a tool that predicts the development of frost damage in Swedish pavements over the course of a desired time period, e.g. one year, taking into consideration both the actual status of the pavement as well as its environmental and traffic circumstances. This tool can assist road authorities and pavement engineers to minimize the damage in pavements attributed to winter conditions, help plan winter maintenance actions, provide updates of pavement design guides, and give guidance on materials choices. All of this requires knowledge about how the pavement behaves and reacts to different kinds of loads. However, in order to make a reliable prediction of this on a pavement scale it is vital to also know how the pavement behaves on a microscale, meaning how the components of the pavement behave and how they interact with each other, as well as how it is affected by different load cases associated with winter damage.

In this paper, the uncoupling of winter damage to different cases will be discussed. The case of frost damage will be investigated closer where comparative simulations will be performed to investigate the effect of different weather conditions.