INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES STRASBOURG

PhD proposal INSA Strasbourg

ANR BINARY: Towards a Better INtegration of the Aggressiveness of Road loads experienced bY wearing course

Title: Study of the aggressiveness of tires on the wearing courses of road structures.

Background:

If economic constraints nowadays mean transporting more goods at lower costs, heavy goods vehicles do not have the same effects on infrastructure for the same tonnage transported. The increase in total weights and flows of goods transport vehicles linked to the increasing share of the road in this area, lead managers today to periodically check that the infrastructures remain able to support traffic in safe conditions and acceptable cost. In a context where road networks are aging, and where the resources devoted to the maintenance of these networks are decreasing, it is important to better understand the mechanisms of degradation of road surface layers to optimize their formulation and maintenance. Currently, there are specifications in terms of adhesion, texture, evenness, but no standard or design method allows for the definition of mechanical characteristics, guaranteeing the lifetime of this layer which directly supports the traffic loads.

In this PhD project, we seek to better understand the stresses to which the wearing courses are subjected under traffic and to improve the prediction of lifespan of road wearing courses, by studying and modeling the behavior under rolling loads of bituminous mixes by means of numerical modelling using a discrete approach. Two key points will be examined: the aggregate pull-out resistance and the accumulation of plastic deformations, which cause surface defects and the acceleration of void generation and ruts on the surface.

The results of the rheological tests campaign on bituminous materials and reduced-scale tests on Triboroute devices (T2R) and WTT (rolling test), carried out by IFSTTAR at the MIT laboratory, will be used as a basis for comparing the numerical modelling. All of the tests / modeling results allow for the behavior prediction on full-scale fatigue tests on the IFSTTAR device.

This PhD project requires good skills in the fields of numerical methods, continuum mechanics, and geo-materials and structures modeling.

Numerical simulation of laboratory and full-scale tests:

The main objective of this work is to interpret laboratory and large-scale tests, from a particle-scale analysis of the behavior of materials and wearing courses, using a campaign of numerical simulations. The numerical data provided by these simulations allows for the identification of inter-aggregate resistance under shear and tensile stresses in the wearing courses to establish a damage criterion for the structural design of this layer.

Numerical simulations will be carried out using the Contact Dynamics (CD) method with rigid particles. This method uses a discrete approach for the simulation of non-regular granular dynamics [1]. For numerical simulations, the LMGC90 software will be used, capable of modeling a collection of rigid or deformable particles of various shapes by different algorithms [2]. To model the behavior of a bituminous material, a viscoelastic contact law was implemented in this code. The developed contact model mixes the original CD formulation for rigid particles to ensure the criterion of noninterpenetration, with a viscoelastic model acting on distant contacts. For the viscoelastic part of the contact law, the Burgers model was chosen, capable of reproducing the viscoelastic behavior of bituminous materials. The Burgers model includes a Maxwell model combined in series with a Kelvin-Voigt model. Thus, this model is composed of four parameters, two of rigidity and two viscosities. To model the brittle behavior in bituminous materials, a yield stress parameter is imposed to identify when the cohesive contacts are broken. Work in progress at INSA Strasbourg shows that the viscoelastic contact law based on the Burgers model is capable of reproducing rheological properties such as the evolution of the complex module and of the phase angle as a function of frequency and temperature, and the values of shear stresses in bituminous materials [3-5] (cf. Fig. 2).

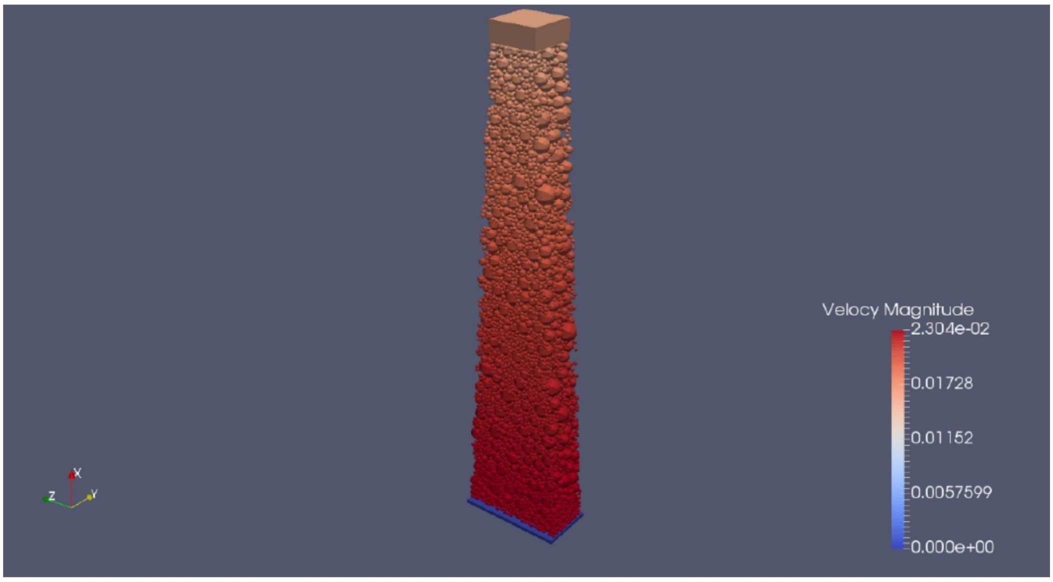

Fig. 1: Image of a numerical sample for a complex module test in a two-point bending configuration.

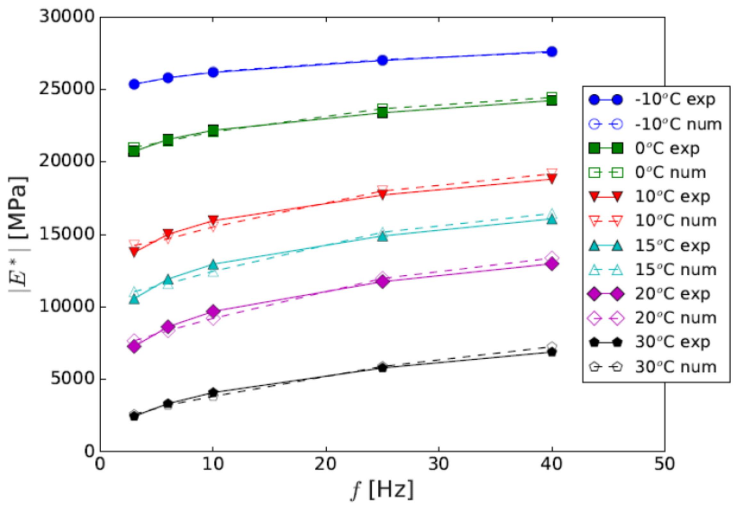

Fig. 2: Isotherms of the standard of the complex module for experimental and numerical tests.

The calibration of the parameters of the Burgers' model will be based on the rheological characterization carried out in laboratory by IFSTTAR. Then, a numerical simulation campaign will be carried out to reproduce the experimental data concerning, at the microscopic scale, the local failure tests under tensile and / or shear loads between two aggregates, then at the macroscopic scale, the complex module, monotonic compression and the effects of aging on rheological behavior.

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To study the behavior of wearing courses under the effect of braking / acceleration, a reduced-scale simulation will be performed to model the Triboroute test. For this simulation, the modeled configuration will take into account the stresses on the wearing course with the same geometric and mechanical properties as the actual material used in the experiments. A parametric study will be carried out for this modeling with two particle size distributions. Five samples for each configuration will be tested to characterize the average grain pull-out resistance. Measuring the inter-particle forces generated between the aggregates will identify the distribution of stresses at the macroscopic scale in the wearing course. At the micromechanical level, it will be possible to identify the critical areas where damage is more likely to develop. Experimental analyzes of deflection basins and depths of texture scanned using laser devices will validate the boundary conditions used.

The analysis of full-scale tests will be carried out using a multi-scale method using the LMGC90 code [6,7]. In this approach, the wearing course will be simulated by the CD method using the developed contact model, while the base layers will be modeled using the finite element method (FEM). The traffic loading will be simulated by tires rolling on the surface of the wearing course. This last data will be obtained at the end of the second thesis in progress since 2019 in the GCE team on this subject. In this system, a parametric study will be conducted, testing different configurations with: two particle size distributions, two levels of traffic load applied by the simulated tires, two temperatures modifying the mechanical properties of the wear layer, and two Young modulus values (flexible and rigid) for the support layer. The numerical results of this parametric study allows for the determination of the resistance between aggregates under traffic load. They will lead to the definition of a criterion of "aggressiveness" regarding the performance of these materials under fatigue load and the aggregates pulling-out resistance. On the basis of these numerical results, an analytical method will be developed. This approach will integrate the stress distribution identified within the wearing course in the design calculation.

Bibliography:

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