Simulation of the Response of Heterogeneous Solid Under Impulsive Loads

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Abstract

This paper study the mechanical response of a granular solid subject to an impulse force. The proposed model simulate the behavior of an airport pavement structure with the different layers (surface and base). The analysis is performed on a representative volume element (RVE) under thermo-mechanical actions, as those produced by landing gear impact of an airbus A320 and variable high surface temperatures loads. Resulting stress and strain fields are compared to define the greater critical conditions and to evaluate the micro-scale structural integrity.

The model of RVE, implemented in COMSOL Multiphysics software, has been as developed to investigate the response under dynamic actions (by impact and sliding) with addition of thermal actions. We analyzed the state of stress and strain filed at the contact between aggregates comparing the three load conditions (normal loads, thermal surface and normal loads, thermal and normal surface loads after 6 hours). The simulated pavement structure is typical of flexible pavements for airport runways as given by ICAO standard. The results of the simulation demonstrate sufficient reliability with the theoretical illustrated models.

It is useful to observe how the stress and strain fields are depend by volumetric heat distribution inside the RVE in particular when the initial surface heat proceeds inside the RVE. The heat proceeds bringing, in medium time, high temperatures in the bottom layers of the pavement package.

The illustrated figures reported the stress (MPa) filed and the global displacement (cm) filed of the considered RVE in function of the pavement surface temperature.

In the numerical simulation, initially the temperature influence is only superficial layer then the heating proceeds inside the pavement and the temperature increase in deep layers of asphalt.

We investigate the response of the RVE in initial condition when it is subject only to the wheel loads and with no temperature gradient. In this condition, it is possible to observe a quasi-isotropic behavior of the RVE with displacements only in the surface of the RVE.

When the temperature gradient (+ 55°C) has been applied, after 6 hours (t = 6 h), the heat distribution extends across the model with a difference of temperature of 20°C between the superior and the deepest surface of the RVE.

All these elements can be used in appropriate analysis of aging and structural durability, considering cyclic (thermal and mechanical) loads.

Reference

M. Buonsanti, et. al. Modelling micro-damage in granular solids. Key Engineering Materials. 525-526: 497-500, (2013).

M. Buonsanti, et. al. A unified model for micromechanics damage in the asphalt concrete. Key Engineering Materials. 577-578: 465-468, (2014).

M. Buonsanti, et. al. A Finite Element Model to Evaluate Airport Flexible Pavements Response under Impact. Applied Mechanics and Materials. 138-139: 257-262, (2011).

G. Leonardi, Finite element analysis for airfield asphalt pavements rutting prediction. Bulletin of the Polish Academy of Sciences Technical Sciences. 63 (2): 397-403, (2015).

M. Buonsanti, et. al. Theoretical and computational analysis of airport flexible pavements reinforced with geo-grids. 7th RILEM International Conference on Cracking Pavements, 1219-1227, RILEM Bookseries. Springer. pp 1219-1227, (2012).

M. Buonsanti, et. al. FEM analysis of airport flexible pavements reinforced with geo-grids. Advanced Science Letters. 13 (11): 392-395, (2012).

R. D. Mindlin, Micro-structure in linear elasticity. Archive for Rational Mechanics and Analysis. 16 (1); 51-78, 1964).

C. Eringen, Theory of micropolar plate. Zeitschrift für angewandte Mathematik und Physik ZAMP. 18 (1): 12-30, (1967).

S. C. Cowin, et. al. Linear elastic materials with voids. Journal of Elasticity. 13 (2): 125–147, (1983).

C. S. Chang, et. al. Second-gradient constitutive theory for granular material with random packing structure. International Journal of Solids and Structures. 32 (16): 2279–2293, (1995).
M. Ferrari, et. al. Advances in Doublet Mechanics. Springer. ISBN: 9783540496366, (1997).

M. H. Sadd, Elasticity: Theory, Applications, and Numerics, Elsevier, Amsterdam. ISBN: 978012374446, (2009).

S. Li et. al. Introduction to Micromechanics and Nanomechanics. World Scientific. Singapore. ISBN: 9812814132, (2008).

M. Frèmond M. Non-Smooth Thermo-mechanics, Springer, N.Y. ISBN: 9783662048009, (2002).

K. R. Shull. Contact mechanics and the adhesion of soft solids, Materials Science and Engineering. 36 (1): 1-45, (2002).

Figures used in the abstract

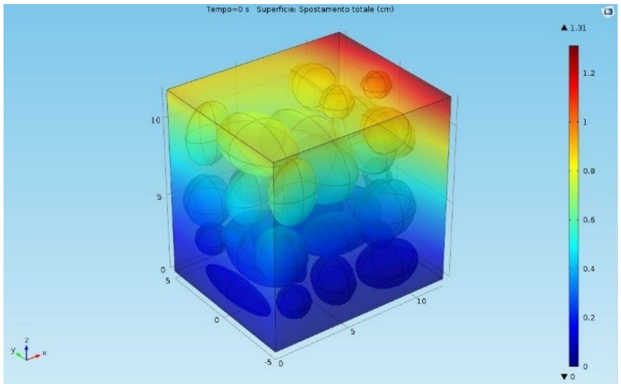

Figure 1: RVE global displacement field

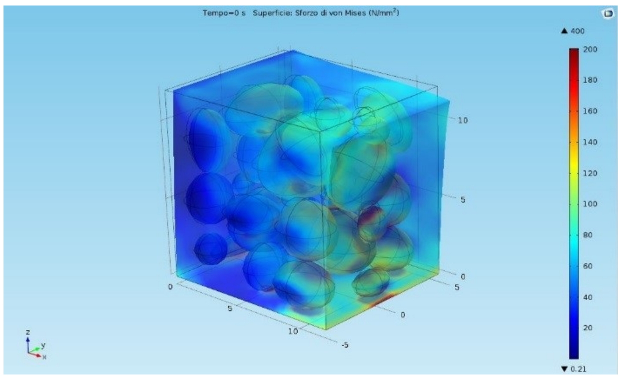

Figure 2: RVE Von Mises stress field

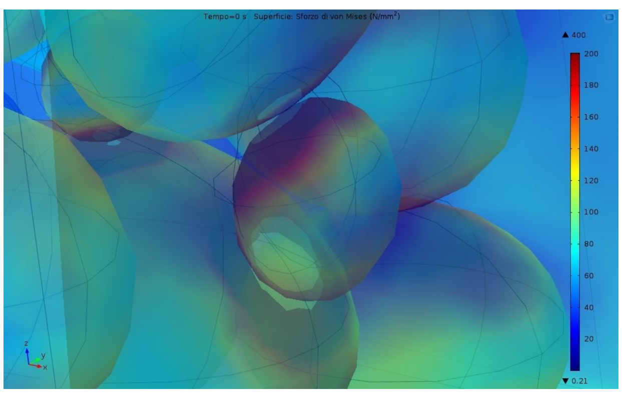

Figure 3: RVE- Detailed Von Mises stress field

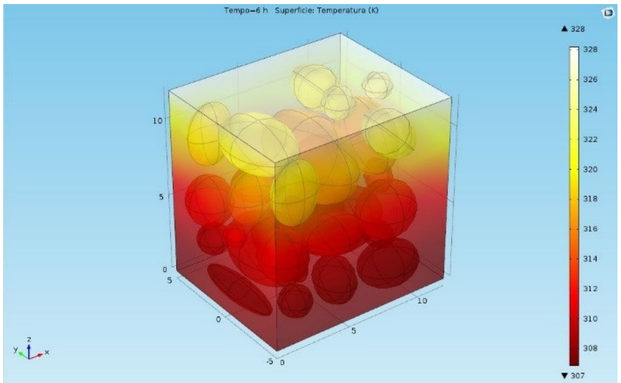

Figure 4: RVE Temperature distribution