

**PhD subject: Study of the aggressiveness of tires on the wearing courses of road structures.**

**Job description:**

In a context where road networks are aging, and where resources for maintenance of these networks are decreasing, it is important to better control and understand the mechanisms of degradation of wearing courses in order to optimize their formulation and maintenance. Nowadays, only specifications for adhesion, texture, bonding are considered, but no standard or design method can define the mechanical characteristics, ensuring lifetime of this layer that directly supports traffic loads.

The aim of this project is to better understand the mechanical loads in asphalt roads under road traffic and to improve the prediction of lifetime for wearing courses, by studying and modeling the behavior under traffic loading of asphalt concrete, using the Discrete Element Modeling (DEM).

Two key points will be examined: the pull-out resistance of aggregates and the accumulation of plastic deformations, which lead to surface degradation and an acceleration in the formation of voids and rutting. The experimental results that will serve as a basis for comparing the numerical models developed will be based on reduced-scale trials conducted at IFSTTAR on the Triboroute device.

**Requirements:**

This topic requires skills in the field of numerical methods, continuum mechanics, constitutive laws for building materials and structural modeling.

**Laboratory:**

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**PhD Supervisor:**

J.C. Quezada (ICube GCE)

**PhD Co-supervision:**

C. Chazallon (ICube GCE)

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## Numerical simulation of laboratory and full-scale tests :

The main objective for this work package is to interpret laboratory and full-scale tests and to analyze at the particle-scale the behavior of wearing courses by means a campaign of numerical simulations. The numerical data provided by these simulation allow to identify the resistance between aggregates regarding shear and tensile strength within the wearing courses to establish a damage criterion for design.

The numerical simulations will be performed using the Contact Dynamics (CD) method with rigid particles. The CD method is a discrete element method for the simulation of non-smooth granular dynamics [1]. For the numerical simulations, the LMGC90 software will be used, which is capable of modeling a collection of rigid or deformable particles of various shapes by different algorithms [2]. To model the behavior of an asphalt mixture, a viscoelastic inter-particle contact law will be implemented. The developed contact model will mix the original CD formulation for rigid particles to ensure the non-interpenetration criterion with a viscoelastic model acting on distant contacts. For the viscoelastic part in the contact law the Burger's model was chosen, which is able to reproduce the viscoelastic behavior for asphaltic materials. The Burger's model comprises a Maxwell model combined in series with Kelvin-Voigt model. Thus, this model is composed of two values of stiffness and two viscosities. To model the brittle behavior in bituminous materials, a yield stress parameter will be imposed to identify when cohesive contacts are lost. Current work in INSA Strasbourg show that the viscoelastic contact law based on the Burger's model is able to reproduce the complex modulus properties and the shear stress values in asphalt materials [3, 4] (see Fig. 2).

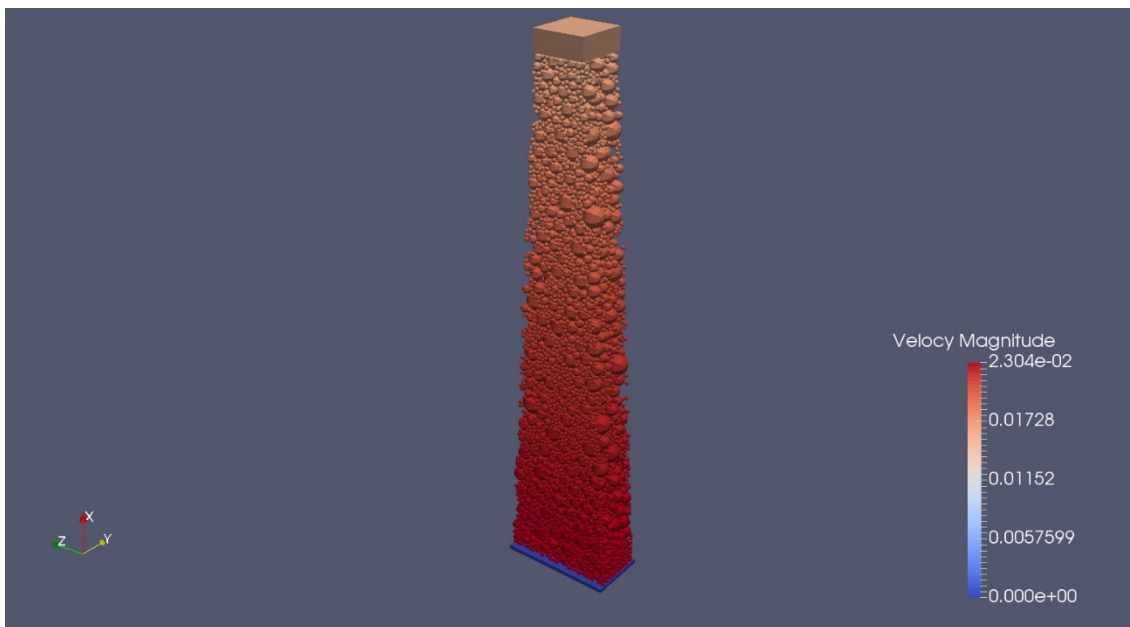


Fig. 1: Snapshot of a numerical sample for a complex modulus test in two bending points configuration.

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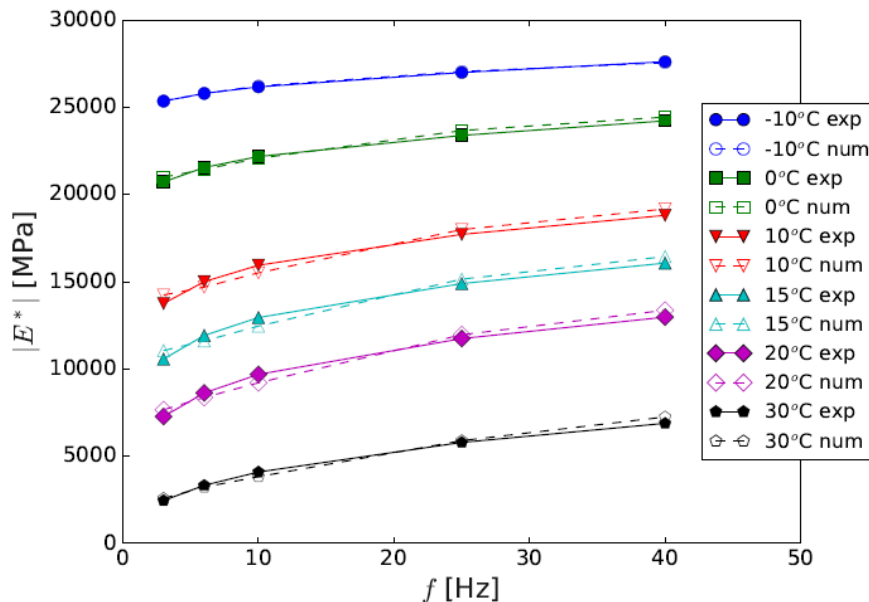


Fig. 2: Isotherms of the norm of the complex modulus for experimental and numerical tests.

The calibration of the Burger's model parameters, will be based on the rheological characterization performed in laboratory. Then, a numerical simulation campaign will be conducted to reproduce experimental data regarding at the micro-scale local fracture test on tensile and/or shear loading between two aggregates and at the macro-scale the complex modulus, fatigue, monotonic failure and aging tests performed by IFSTTAR.

To study the behavior of wearing courses under braking/acceleration effects a reduced scale simulation will be carried-out to modeling the Triboroute test. For this simulation, the modeled set-up will be acting on a wearing course layer with same geometrical and mechanical properties as the actual material used in the experiences. A parametric study will be carried-out for this modelling with two particle size distribution (well and poorly graded). Five samples for each configuration will be tested to characterize the average pull-out strength of grains. The measure of inter-particle force generated between aggregates will allows to identify the stress distribution at the macro-scale within the wearing course layer. At the micro-mechanical scale will be possible to identify critical areas where damage would be more likely to develop, which play a major role on the top-down crack initiation.

The full-scale test analysis will be performed by means a multi-scale method using the LMGC90 code [5, 6]. In this approach, the wearing course will be simulated by DEM using the developed contact model, while base courses will be modeled using the Finite Element Method (FEM). The moving loading will be simulated by tires rolling on the wearing course surface. In this system, a parametric study will be conducted, testing different configurations with: two particle size distribution, two traffic load levels applied by the simulated tires; two temperatures modifying the mechanical properties of the wearing course; and two elastic modulus values (soft and stiff) for the base course. The numerical results from this parametric study allows to determinate the resistance between aggregates under traffic loading. They will lead to the definition of an "aggressiveness" criterion with respect to the performance of these materials under fatigue loading, and the pull-out strength of the aggregates.

Based on these numerical results, an analytical method will be developed. This approach will integrate the identified stress distribution within the wearing course layer into the design calculation. Finally, this simplified method will be proposed for practitioners.

## Bibliography

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- [4] L. Sagnol, J.C. Quezada, C. Chazallon & M. Stöckner (2018) Effect of glass fibre grids on the bonding strength between two asphalt layers and its Contact Dynamics method modelling, *Road Materials and Pavement Design*, DOI: [10.1080/14680629.2018.1439764](https://doi.org/10.1080/14680629.2018.1439764)
- [5] Bagnéris, M., Dubois, F., Jean, M., Martin, A., Taforel, P., & Visseq, V. (2013, October). High performance hybrid FEM/DEM simulation tool for numerical analysis of historical structures. In *Digital Heritage International Congress (DigitalHeritage)*, 2013 (Vol. 1, pp. 537-544). IEEE.
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## Education

- 2009-2012 **PhD thesis**, *Université Montpellier 2, Mechanical and Civil Engineering.*
- 2008-2009 **Master 2R**, *UFR Sciences et Technologies de l'Université Blaise Pascal, Clermont-Ferrand, Master 2 Research : Innovation, Mechanics of Materials and Structures.*
- 2007-2008 **Student**, *Polytech' Clermont-Ferrand, 3rd year of Civil Engineering (Academic exchange).*
- 2001-2006 **Student**, *Pontificia Universidad Catolica de Valparaiso (PUCV), Chili, Civil Engineering.*

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## Professional Experience

- September 2015 - now **Associate professor**, *INSA de Strasbourg, France.*  
Civil Engineering and Topography department.
- September 2014 - August 2015 **Postdoctoral position**, *LTDS, Ecole Centrale de Lyon, Lyon, France.*  
DEM modelling of the 3D failure of dry stone retaining walls.
- January 2013 - August 2014 **Postdoctoral position**, *I&R - PSIG department, SNCF, Paris.*  
Implementation of granular modeling for railway applications.
- 2009 - 2012 **PhD candidate**, *Innovation & Research department, SNCF, Paris.*  
Mechanics of ballast settlement and its variability.
- February - July 2009 **Internship**, *Innovation & Research department, SNCF, Paris.*  
Study of settlement variability for a thin granular layer
- October - December 2008 **Internship**, *LAMI, University Blaise Pascal, Clermont-Ferrand.*  
Study of evaluation of ballast grain size distribution under track maintenance operations (en collaboration with the SNCF).
- February - June 2008 **Internship**, *LAMI, University Blaise Pascal, Clermont-Ferrand.*  
Estimation in-situ of permeability for sewerage systems, en collaboration with Veolia Eau France.
- October 2006 - January 2007 **Research Assistant**, *PUCV, Chili.*  
Research projects DI 202.711/2006 and DI 202.713/2006.
- August 2004 - June 2007 **Teaching assistant**, *PUCV, Chili.*  
Seminars and practical works for Soils mechanics class 1 and 2.

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## Other skills

- Languages **Spanish:** Native speaker  
**French:** Bilingual  
**English:** Good written and spoken.
- Computer skills Programming in Fortran90, Discrete element codes as LMGC90, 3DEC, PFC3D. Good knowledge of Matlab and Python. Use of the Microsoft Office, and Windows, GNU/Linux, Mac OS X operating systems

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## Interests

Geomechanics, Soil Mechanics, Granular Matter

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## Publications

- [1] Juan Carlos Quezada, Pierre Breul, Gilles Saussine, and Farhang Radjai. Stability, deformation, and variability of granular fills composed of polyhedral particles. *Phys. Rev. E*, 86:031308, Sep 2012.
- [2] Juan Carlos Quezada, Pierre Breul, Gilles Saussine, and Farhang Radjai. Penetration test in coarse granular material using contact dynamics method. *Computers and Geotechnics*, 55(0):248 – 253, 2014.
- [3] Juan Carlos Quezada, Gilles Saussine, Pierre Breul, and Farhang Radjai. Predicting the settlement of coarse granular materials under vertical loading. *Scientific reports*, 4, 2014.
- [4] Juan-Carlos Quezada, Eric Vincens, Rémy Mouterde, and Jean-Claude Morel. 3d failure of a scale-down dry stone retaining wall: A {DEM} modelling. *Engineering Structures*, 117:506 – 517, 2016.

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## Patents

French patent application N° 12 02928 "Prediction of sleepers settlement".

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## Honors and Awards

Conference Poster Prize, Powders and Grains 2013.

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## References

- F. Radjai [franck.radjai@univ-montp2.fr](mailto:franck.radjai@univ-montp2.fr) ; Research director CNRS - LMGC Montpellier France
- G. Saussine [gilles.saussine@sncf.fr](mailto:gilles.saussine@sncf.fr) ; Head of Research group MSI - SNCF, Paris France
- G. Combe [gael.combe@3sr-grenoble.fr](mailto:gael.combe@3sr-grenoble.fr) ; Professor, 3SR Grenoble France
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## **Curriculum vitae**

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**2010 - present : Professor** INSA de Strasbourg

Head of Energy and Civil Engineering team

Head of Materials and Structures of Civil Engineering group

Associate professor H. Nowamooz

Assistant professors G. Koval, S. Mouhoubi, J.C. Quezada

Current phd students : G. Liu, A. Dansou, L. Gaillard

- *Articles*

## **Revue internationale avec comité de lecture**

### **2018**

**Peng Jing**, Hossein Nowamooz & **Cyrille Chazallon**, Unsaturated Mechanical Behaviour of a Granular Material, Road Materials and Pavement Design, 2018, 02/2018 accepted

**Loba Sagnol**, Juan Carlos Quezada, **Cyrille Chazallon** and Markus Stöckner, Effect of glass fibre grids on the bonding strength between two asphalt layers and its Contact Dynamics Method modelling, Road Materials and Pavement Design, 2018, <https://doi.org/10.1080/14680629.2018.1439764>

**Kai Li**, Hossein Nowamooz, **Cyrille Chazallon** and Bernard Migault, Finite element modelling of the mechanical behaviour of unsaturated expansive soils subjected to wetting and drying cycles with shakedown concept, European Journal of Environmental and Civil Engineering, 2017, <https://doi.org/10.1080/19648189.2017.1363666>

Kai Li, Hossein Nowamooz, **Cyrille Chazallon** and Bernard Migault, Limit Deformation Analysis of Unsaturated Expansive Soils During Wetting and Drying Cycles, Soil Mechanics and Foundation Engineering, March 2018, Volume 55, Issue 1, pp 33–39

**Peng Jing**, Hossein Nowamooz & **Cyrille Chazallon**, Permanent deformation behaviour of a granular material used in low-traffic pavements, Road Materials and Pavement Design, Volume 19, 2018 - Issue 2, p289-314

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## 2017

**Peng Jing**, Hossein Nowamooz, **Cyrille Chazallon**, Effect of Anisotropy on the Resilient Behaviour of a Granular Material in Low Traffic Pavement, **Materials**, 10(12), 1382; doi:10.3390/ma10121382 (registering DOI) - 3 December 2017

**Xiaofeng Gao**, Georg Koval, **Cyrille Chazallon**, Energetical formulation of size effect law for quasi-brittle fracture, *Engineering Fracture Mechanics*, DOI 10.1016/j.engfracmech.2017.02.001, [Volume 175](#), 15 April 2017, Pages 279-292

**Themeli A.**, Chailleux E., Farcas F., **Chazallon C.**, Migault B., Buisson N., Molecular structure evolution of asphaltite-modified bitumens during ageing; Comparisons with equivalent petroleum bitumens, *International Journal of Pavement Research and Technology*, DOI 10.1016/j.ijprt.2017.01.003, [Volume 10, Issue 1](#), January 2017, Pages 75-83

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G. Koval, **B.D. Le**, **C. Chazallon**, Discrete element model for quasi-brittle rupture under tensile and compressive loading, *International Journal for Numerical and Analytical Methods in Geomechanics*, 40, 17, 10 December 2016, Pages 2339–2352 DOI:10.1002/nag.2532

**Andrea Themeli**, Emmanuel Chailleux, Fabienne Farcas, **Cyrille Chazallon**, Bernard Migault, Nadège Buisson, Modeling the linear viscoelastic behavior of asphaltite-modified bitumens, *Rheologica Acta*, December 2016, Volume 55, Issue 11, pp 969–981

**S. Nikoosokhan**, H. Nowamooz, **C. Chazallon**, "Effect of dry density, soil texture and timespatial variable water content on the soil thermal conductivity", *International Journal of Geomechanics and Geoengineering*, Volume 11, Issue 2, April 2016, pages 149-158, DOI: 10.1080/17486025.2015.1048313



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## 2013

F. Thøgersen, C. Gregoire, J. Stryk, P. Hornych, **C. Chazallon**, Y. Descantes, M. Arm, “*Recycling of road materials in new unbound road layers*”, *International Journal of Road Materials and Pavements Design*, Volume 14, Issue 2, June 2013, pages 438-444.

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H. Nowamooz, **C. Chazallon**, “*Finite element modelling of a rammed earth wall*”, International Journal of Construction and Building Materials, Elsevier, 2011, 25, 4, 2112-2121

## 2010

**F. Allou**, C. Petit, **C. Chazallon**, P. Hornych, ‘*Shakedown approaches to rut depth prediction in low volume roads*’, Journal of Engineering Mechanics - ASCE, Vol. 136, No. 11, November 2010, pp. 1422-1434,

## 2009

**C. Chazallon**, G. Koval, P. Hornych, **F. Allou**, S. Mouhoubi ‘*Modelling of rutting of two flexible pavements with the shakedown theory and the finite element method.*’, Computers and Geotechnics, Elsevier, Volume 36, Issue 5, June 2009, Pages 798-809

**C. Chazallon**, **F. Allou**, P. Hornych, S. Mouhoubi, ‘*Finite element modelling of the long term behaviour of a full scale flexible pavement with the shakedown theory*’, International Journal for Numerical and Analytical Methods in Geomechanics, Wiley editor, 33, 1, p 45-70, 2009.

## 2007

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**F. Allou**, **C. Chazallon**, P. Hornych ‘*A numerical model for flexible pavements rut depth evolution with time*’, International Journal for Numerical and Analytical Methods in Geomechanics, Wiley editor, 2007, 31, 1, pp 1-22.

## 2006

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**T. Habiballah, C. Chazallon** 'An elastoplastic model based on the shakedown concept for flexible pavements unbound granular materials', International Journal for Numerical and Analytical Methods in Geomechanics, Wiley editor, 2005, 29, 6, pp 577 - 596.

**C. Chazallon, T. Habiballah**, 'Finite elements modelling of flexible pavements with the shakedown concept', International Journal of Road Materials and Pavements Design, Hermès editor, 2005, 6, 1, pp 97 - 117.

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## Revue nationale avec comité de lecture

### 2017

Godard Eric, **Chazallon Cyrille**, Hornych Pierre, Nguyen Mai Lan, Doligez Daniel, Pelletier Hervé, Pour une solution durable du renforcement des infrastructures par grilles en fibre de verre, RGRA, 949, Octobre 2017, p24-33

### 2014

**Ioana ARSENIE, Cyrille CHAZALLON**, Jean-Louis DUCHEZ, Caractérisation expérimentale de l'endommagement en fatigue d'un béton bitumineux renforcé à l'aide de géo-grilles, Annales du Bâtiment et des travaux Publics, Volume 6, pp 9-16, Décembre 2014, ESKA publishing Group

- *Ouvrages individuels et collectifs :*

- Water in road structures, movement, damage and effects  
Paru en Novembre 2008  
Editeur : Springer  
ISBN : 978-1-4020-8561-1  
Page : 438  
Co auteur des chapitres 8 et 9.  
Chapter 8 : Mechanical effects on water in pavement and its control –  
Theoretical aspects and mechanical constitutive modelling

Chapter 9 : Mechanical behaviour: experimental investigation, dependency on water and moisture

- COST337 'Unbound granular materials for road pavements' - Final Report  
Paru en Juillet 2003

Page : 385

Co auteur du chapitre 6 : Modelling of the resilient behaviour of unbound granular materials

- *Conférences, congrès et colloques à communication (Conférences internationales à comité de lecture et actes publiés) :*

## 2018

**Cyrille Chazallon**, Cédric Barazzutti, Hervé Pelletier, Mai-Lan Nguyen, Pierre Hornych and Daniel Doligez, Laboratory evaluation and reproduction of geogrid in situ damage used in asphalt concrete pavement, 13th ISAP Conference on Asphalt Pavements, Fortaleza, Brasil, 19-22 June, 2018, 7 pages

## 2017

Juan Carlos Quezada, **Cyrille Chazallon**, Shear test on viscoelastic granular material using Contact Dynamics simulations", Powders and Grains 2017: 8th International Conference on Micromechanics of Granular Media, Montpellier, 3/7 July, 8 pages

**Xiaofeng Gao**, Georg Koval, **Cyrille Chazallon**, "A discrete element model for damage and fracture of geomaterials under fatigue loading", Powders and Grains 2017: 8th International Conference on Micromechanics of Granular Media, Montpellier, 3/7 July, 8 pages

**C. Chazallon**, T.C. Nguyen, M. L. Nguyen, P. Hornych, D. Doligez, L. Brissaud, E. Godard, "In situ damage evaluation of geogrid used in asphalt concrete pavement", 10<sup>th</sup> BCRRA 2017, 28/30 June, Athens, 8 pages

**L. Sagnol, C. Chazallon**, M. Stöckner, « Effect of glass fibre grids on the bonding strength between two asphalt layers", 10<sup>th</sup> BCRRA 2017, 28/30 June, Athens, 8 pages

**P. Jing, C. Chazallon**, H. Nowamooz, "Unsaturated resilient strain behaviours of a granular material", 10<sup>th</sup> BCRRA 2017, 28/30 June, Athens, 8 pages

**Loba Sagnol**, Juan Carlos Quezada, **Cyrille Chazallon**, Markus Stöckner, Effect of glass fibre grids on the bonding strength between two asphalt layers and its DEM modelling, 7<sup>th</sup> EATA, Dübendorf, 12-14 June

**L. Gaillard**, J.C. Quezada, **C. Chazallon**, P. Hornych, Thermo-hydro-mechanical behaviour of the unsaturated compacted asphalt aggregates, **Eccografi 2017**, Second International Conference on Biobased Building Materials (3BM) June 21st - 23th 2017. Clermont-Ferrand, France, Poster.

## 2016

**Peng Jing**, H. Nowamooz, **C. Chazallon**, Influence of Fine Content and Water Content on the Permanent Mechanical Behavior of a Granular Material Used in Low Traffic Pavements, 4th GeoChina International Conference, July 25-27, 2016, Jinan, Shandong, China

**X. Gao**, G. Koval, **C. Chazallon**, « Effect of fiber grid reinforcement on crack initiation and propagation in asphalt concrete », 8<sup>th</sup> International Conference on Mechanisms of Cracking and Debonding in Pavements, Nantes, France, 8 pages, 7-9 June 2016.

**Cyrille Chazallon**, **Arsenie Ioana Maria**, Duchez Jean-Louis, « Modelling of the fatigue damage of a geogrid reinforced asphalt concrete », 8<sup>th</sup> International Conference on Mechanisms of Cracking and Debonding in Pavements, Nantes, France, 8 pages, 7-9 June 2016.

## 2015

**A. Themeli**, E. Chailleux, F. Farcas, **C. Chazallon**, B. Migault, Ageing performances of asphaltite modified bitumens; comparisons with equivalent petroleum bitumens, 8th International RILEM SIB Symposium, 8 pages, 7-9 Octobre, Ancone, Italie

**A. Themeli**, E. Chailleux, F. Farcas, **C. Chazallon** & B. Migault, “Molecular weight distribution of asphaltic paving binders from phase-angle measurements”, 6th European Asphalt Technology Association, 21 pages, 15-17 June, Stockholm, Sweden

## 2014

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