Thermo-hydro-mechanical behaviour of cold reclaimed asphalt aggregates without binder addition

Laura Gaillard, Cyrille Chazallon, Pierre Hornych, Juan Carlos Quezada & Christiane Raab

To cite this article: Laura Gaillard, Cyrille Chazallon, Pierre Hornych, Juan Carlos Quezada & Christiane Raab (2019): Thermo-hydro-mechanical behaviour of cold reclaimed asphalt aggregates without binder addition, Road Materials and Pavement Design, DOI: [10.1080/14680629.2019.1587490](https://doi.org/10.1080/14680629.2019.1587490)

To link to this article: <https://doi.org/10.1080/14680629.2019.1587490>

Published online: 14 Mar 2019.

Submit your article to this journal [↗](#)

Article views: 11

View Crossmark data [↗](#)

Thermo-hydro-mechanical behaviour of cold reclaimed asphalt aggregates without binder addition

Laura Gaillard^{a*}, Cyrille Chazallon^a, Pierre Hornych^b, Juan Carlos Quezada^{ib a} and Christiane Raab^c

^aICUBE, UMR 7357, CNRS, INSA de Strasbourg, Strasbourg, France; ^bIFSTTAR, LAMES, Bouguenais, France; ^cEMPA, Dübendorf, Switzerland

(Received 29 October 2018; accepted 20 February 2019)

This paper details a cold recycling evaluation of 100% reclaimed asphalt aggregates without any binder addition. In this context, a series of triaxial laboratory tests was performed. Monotonic triaxial tests were conducted to determine failure resistance at 20°C, 50°C and with a specimen preheated at 50°C then tested at 20°C. Repeated Load Triaxial (RLT) tests were performed to analyse the permanent and resilient strains at 20°C, at three frequencies and with two water contents. It is found that increasing temperature causes a drop of failure resistance while cohesion is increased. RLT tests reveal that higher water content implies higher strains, as well that water content presents a higher impact on resilient behaviour than low frequencies. Finally, the non-linear elastic Boyce model was used to describe the resilient strains. Total stress and effective stress calibrations were performed with a measurement of the initial suction. Eventually, these effective stress calibrations were performed with one set of parameters.

Keywords: reclaimed asphalt aggregates; cold recycling; thermo-hydro-mechanical behaviour; monotonic triaxial test; repeated load triaxial test; Boyce model

1. Introduction

For environmental reasons, recycling of asphalt aggregates is increasingly widespread in hot or cold mix. In fact, several researches developed the incorporation of Reclaimed Asphalts (RA) in new asphalt mixtures (Colbert & You, 2011; Kalman, 2013; Moon, Cannone Falchetto, Wang, Wistuba, & Tebaldi, 2016; Singh, Chitragar, & Ashish, 2017; Tran, West, Taylor, & Willis, 2015; Valdés, Pérez-Jiménez, Miró, Martínez, & Botella, 2010), in foamed asphalts (Guatimosim, Vasconcelos, Bernucci, & Jenkins, 2016; Kuna, Airey, & Thom, 2016; Plati, Loizos, Papavasiliou, & Kaltsounis, 2010), in bitumen emulsions (Dinis-Almeida, Castro-Gomes, & de Lurdes Antunes, 2011; Jacobson, 2002; Sangiorgi et al., 2017) or in half-warm process with bio-based additive (Porot & Eduard, 2016). This material is seldom appreciated pure, without any addition. However, experiences of cold recycling without binder addition have been conducted in Sweden (Jacobson & Waldemarson, 2011).

In France, hot recycling is limited to RA with a PAH (Polycyclic Aromatic Hydrocarbons) rate up to 50 mg/kg. Cold recycling is largely encouraged for RA with PAH content between 50 and 500 mg/kg and appears to be the only solution compared to the deposit solution of contaminated RA with PAH. This research aims to look at alternative use of RA having high PAH content:

*Corresponding author. Email: laura.gaillard@insa-strasbourg.fr

cold recycling of 100% RA without any binder addition. This strategy requires knowledge of performances of RA.

From the experimental point of view, monotonic triaxial tests were performed to study the failure resistance of RA as a function of temperature. Then the Repeated Load Triaxial (RLT) tests were performed to study the hydro-mechanical behaviour of the material and the influence of the frequency. Finally, the calibration of the Boyce model with effective stress concept allows to describe the resilient behaviour with one set of parameters for various water contents.

2. Material and testing

2.1. Material characterisation

The reclaimed asphalt aggregates tested come from the demolition of wearing courses of Strasbourg and its suburbs. The main characteristics of the aggregates are summarised in Table 1.

The RA are materials between Unbound Granular Materials (UGM) and asphalt mixtures. Figure 1 displays the particle size distribution of the material as well as:

- The UGM 0/20 mm grading range of the European Standard EN 13285 (Association Française de Normalisation, 2004a).
- The asphalt mixture 0/20 mm grading range of the European Standard EN 13108–1 (Association Française de Normalisation, 2007).

The RA particle size distribution is inside both grading ranges, except for coarse particles, for which the curve is slightly higher.

2.2. Sampling

To guarantee the homogeneity of samples, the procedure proposed in the Re-Road European project was followed (Gabet & Wayman, 2012). The three steps are:

Table 1. Characteristics of reclaimed asphalt aggregates.

PAH content mg/kg	Grading mm	Optimum water content %	Maximum dry density Mg/m ³	Binder content %	Needle penetrability 1/10 mm	Ring & Ball °C
298	0/20	5.86	2.02	4.36	13	69.4°C

Figure 1. Particle size distribution.

Figure 2. Material storage in roof-shaped pile.

- Taking materials from different spots of initial stockpile
- Storing aggregates in roof-shaped pile and laying in layers, as reflected in Figure 2
- Taking back in tranches for the homogeneity.

The sampling method is based on the work of Jing, Nowamooz, and Chazallon (2016) as well as the researches of Ho, Nowamooz, Chazallon, and Migault (2014a). In order to control the water content of mix, the material is dried in the oven during 72 h at 50°C. Then a quantity of water is added in the heating mixer at the target temperature. The mix is sealed in a plastic bag for 48 h at the required temperature for moisture homogenisation. In accordance with the European Standard EN 13286-4 (Association Française de Normalisation, 2003), each sample is compacted with a vibrating hammer in seven layers at 97% of maximum dry density 1.96 Mg/m³. The precautions are taken to perform the compaction at the target temperature. The cylindrical specimen is 0.15 m diameter and 0.30 m height. The void ratio obtained for all specimens is about 27% and the porosity is about 21%.

2.3. Equipment

The experimental device (Figure 3) is made up of a temperature controlled triaxial cell, a pneumatic loading system and a measurement equipment:

- An axial force transducer submerged in the cell
- A cell pressure transducer

Figure 3. Temperature controlled triaxial cell and instrumented specimen.

- Four temperature transducers: two cell fluid sensors, one pedestal sensor and one topcap sensor
- An axial displacement transducer LVDT (used for the monotonic triaxial test)
- Three Hall-Effect transducers: two axial and one radial (used for the repeated load triaxial test).

2.4. Monotonic triaxial tests

The experiment consists of applying a constant confining pressure σ_3 and a constant vertical stress q to the sample in the cell. This deviator stress is increased up to reach failure. Monotonic triaxial tests are performed at a speed of 0.3 mm/min, with a water content of 3.86%, for four confining pressures (0, 20, 40 and 70 kPa) and three temperatures: 20°C, 50°C and 20°C with preheating at 50°C. Figure 4 describes the different temperature paths. The deviator stress q and mean stress p are obtained by:

$$q = \sigma_1 - \sigma_3 \quad (1)$$

$$p = (\sigma_1 + 2\sigma_3)/3 \quad (2)$$

2.5. Repeated load triaxial (RLT) tests

RLT test is one of the most interesting experiments to study the mechanical behaviour of unbound granular materials. Several stress paths can be applied to the sample: a Constant or Variable Confining Pressure σ_3 (CCP or VCP) and a cyclic deviator stress q . This test allows to analyse the permanent resilient strains, as shown Figure 5. In accordance with the European Standard EN 13286-7 (Association Française de Normalisation, 2004b), the specimen is submitted to two phases:

Figure 4. Temperature paths for monotonic triaxial tests.

Figure 5. Principle of the cyclic triaxial tests (Hornych, Gaudefroy, & Geffard, 2009).

Table 2. Parameters of RLT tests.

Water content (%)	Frequency for conditioning phase (Hz)	Frequency for resilient phase (Hz)
3.7	2	1
4.5	2	1–0.5–0.1

- Conditioning phase: a high stress level over 30,000 cycles to stabilise the permanent strains
- Resilient phase: several stress paths over 100 cycles to study the elastic strains.

RLT tests are carried out with CCP method, at ambient temperature and with the parameters detailed in Table 2. The maximum water content tested is 4.5%. Indeed, the mastic coating of aggregates being hydrophobic, drainage in the sample is inevitable at higher water contents. In general, the maximum water content tested is the optimum water content minus 1%. As the optimum water content of RA is 5.86%, the maximum water content for tests was 4.86%.

3. Experimental results and analysis

3.1. Monotonic triaxial tests

Figure 6 details the stress–strain curves. As expected, for each temperature, higher confining pressure allows higher peak deviator stress. In the (p,q) stress space, the rupture lines at each temperature are presented in Figure 7. These lines, based on the peak value of deviator stress, are defined by Equation (3). Then, the Mohr-Coulomb parameters, cohesion c and friction angle φ at peak stress, are calculated. The different parameters are exposed in Table 3.

$$q = m.p + s \quad (3)$$

At same density, the following points can be noticed:

- A temperature increase causes a drop in resistance at the failure test. Indeed, the test at 50°C corresponds to the lowest values for Mohr-Coulomb parameters. The cause is the mastic coating of aggregates, which is much more sensitive at high temperatures.

Figure 6. Stress-strain curves of monotonic triaxial test.

Figure 7. Rupture lines for reclaimed asphalt aggregates.

- At 20°C, the rupture lines with and without preheating are similar. The preheating improves slightly failure resistance at low confining pressures only.

3.2. Repeated load triaxial (RLT) tests

Regarding sign conventions, positive axial strains indicate a decrease in the sample height and negative radial strains, an increase in the diameter of the sample. The volumetric and deviatoric strains are defined as:

$$\varepsilon_v = \varepsilon_1 + 2\varepsilon_3 \quad (4)$$

$$\varepsilon_q = 2(\varepsilon_1 - \varepsilon_3)/3 \quad (5)$$

where ε_1 is the axial strain and ε_3 is the radial strain.

Table 3. Parameters of reclaimed asphalt aggregates.

	50°C	20°C	Preheating 50°C – Test 20°C
M	1.1751	1.7474	1.4769
s (kPa)	66.929	87.285	121.57
c (kPa)	28.60	45.90	60.56
$\varphi(^{\circ})$ (at peak stress)	34.13	42.58	36.34

3.2.1. Conditioning phase

The stress path applied to the specimen over 30,000 cycles at a frequency of 2 Hz is $\Delta q/\Delta p = 3$ ($\Delta q = 340$ kPa et $\Delta p = 113.33$ kPa) from an initial stress state ($p_0 = 70$ kPa and $q_0 = 0$ kPa). Figures 8 and 9 show the evolution of permanent strains.

Both water contents present similar levels of strain. However, the strains increase with water content. The permanent strains increase quickly during the first cycles, then a stabilisation is noticed. Indeed, Table 4 shows the permanent strain rates over the last hundred cycles $\Delta\varepsilon/\Delta N$.

Figure 8. Permanent axial strains.

Figure 9. Permanent radial strains.

Table 4. The permanent strain rate over the last hundred cycles.

Water content	3.7%	4.5%
$\Delta\varepsilon_1/\Delta N$	2.37E-07	2.03E-07
$\Delta\varepsilon_3/\Delta N$	– 6.67E-08	– 2.00E-07

Figure 10. Stress paths for the resilient test.

3.2.2. Resilient phase

To study the elastic behaviour, the specimen is submitted to five loadings of slope $\Delta q/\Delta p = 3$. The different stress paths are presented in Figure 10. Each loading was applied during 100 cycles. For the water content $w = 3.7\%$ the tested frequency is 1 Hz, for the water content $w = 4.5\%$ several frequencies were tested: 0.1, 0.5 and 1 Hz.

The resilient behaviour of UGM is very effectively predicted by a non-linear elastic model proposed by Boyce (1980). To introduce the anisotropy of materials, this model was improved with γ coefficient (Hornych, Kazai, & Piau, 1998). As part of the Boyce Model, Equations (6)–(9) define mean stress p^* , deviator stress s^* , volumetric strain ε_v and deviatoric strain ε_q . K_a , G_a , γ , n are model parameters and p_a is the atmospheric pressure, equal to 100 kPa. K_a and G_a are related to the bulk and shear moduli respectively and γ is the anisotropy coefficient.

$$p^* = (\gamma\sigma_1 + 2\sigma_3)/3 \quad (6)$$

$$q^* = \gamma\sigma_1 - \sigma_3, \quad 0 < \gamma < 1 \quad (7)$$

$$\varepsilon_v = \frac{p^{*n}}{p_a^{n-1}} \left[\frac{\gamma + 2}{3K_a} + \frac{n-1}{18G_a}(\gamma + 2) \left(\frac{q^*}{p^*} \right)^2 + \frac{\gamma - 1}{3G_a} \cdot \frac{q^*}{p^*} \right] \quad (8)$$

$$\varepsilon_q = \frac{2}{3} \cdot \frac{p^{*n}}{p_a^{n-1}} \left[\frac{\gamma - 1}{3K_a} + \frac{n-1}{18G_a}(\gamma - 1) \left(\frac{q^*}{p^*} \right)^2 + \frac{2\gamma + 1}{6G_a} \cdot \frac{q^*}{p^*} \right] \quad (9)$$

The experimental results calibrate K_a , G_a , γ and n . The least square method is used to optimise the model parameters. The squared error $S_{\min}$ is minimised and the correlation value c is calculated as:

$$S_{\min} = \frac{\sum(\varepsilon_v - f(p^*, q^*))^2}{\sum(\varepsilon_v - m_v)^2} + \frac{\sum(\varepsilon_q - g(p^*, q^*))^2}{\sum(\varepsilon_q - m_q)^2} \quad (10)$$

$$c = 1 - (S_{\min}/2)^{1/2} \quad (11)$$

where $f(p^*, q^*)$, $g(p^*, q^*)$ are the Boyce model volumetric and deviatoric strains and m_v , m_q are the average values of volumetric and deviatoric experimental strains.

Using the Bishop effective stress parameter χ (Equation (12)) (Bishop & Blight, 1963), the Boyce model can be applied with effective mean stress p' and effective shear stress q' (Ho,

Nowamooz, Chazallon, & Migault, 2014b).

$$\chi = S_r \quad (12)$$

$$p' = p^* + \chi \cdot s \quad (13)$$

$$q' = q^* \quad (14)$$

with S_r degree of saturation and s initial suction value of RA. Figure 11 shows the variation of matric suction as a function of water content in the wetting path. This curve was obtained with a filter paper method (American Society for Testing and Materials International, 2010).

The suction indicates the effect of water content on the specimen. Indeed, the water improves the compatibility of the material. Several researchers studied this process with effective stress for sand (Ho et al., 2014b; Nowamooz, Chazallon, Arsenie, Hornych, & Masrouri, 2011) or for Unbound Granular Materials (Azam, Cameron, & Rahman, 2013; Coronado et al., 2016). However, no procedure was found for reclaimed asphalt aggregates.

Influence of water content. Figures 12 and 13 describe the resilient deviatoric strain ε_q and the resilient volumetric strain ε_v for the different stress paths at 1 Hz, with effective stresses, for a water content $w = 3.7\%$ and 4.5% , respectively. For each water content, the anisotropic Boyce model was fitted with total and effective stresses. The model parameters and the correlation value are summarised in Table 5.

Several observations on these experimental results and these model fits can be stated:

- Higher water content implies higher deviatoric strains. By considering experimental values, for ε_q the increase varies from 16% (for $\sigma_3 = 150$ kPa) to 76% (for $\sigma_3 = 20$ kPa).
- Higher water content causes mechanical behaviour modification. Indeed, at the water content $w = 3.7\%$ the volumetric strains are positive, while at $w = 4.5\%$ ε_v decrease and are negative for low confining pressures. RA has a contracting behaviour, and then becomes dilating with water content increase. At higher water content, the correlation value is higher than at low water content.
- The higher the water content, the lower are bulk and shear moduli.
- Only the calibration with the effective stress concept allows a quite good calibration with one set of parameters at 1 Hz.

Figure 11. Evolution of matric suction in wetting path.

Figure 12. Deviatoric and volumetric strains at $w = 3.7\%$ and 1 Hz with effective stresses.

Figure 13. Deviatoric and volumetric strains at $w = 4.5\%$ and 1 Hz with effective stresses.

Influence of frequency. Figure 13, Figures 14 and 15 show the resilient deviatoric strain ε_q and the resilient volumetric strain ε_v at the water content $w = 4.5\%$ for the different stress paths at 1, 0.5 and 0.1 Hz, with effective stresses. For each frequency, the anisotropic Boyce model was fitted with total and effective stresses. The model parameters and the correlation value are listed in Table 5.

Table 5. Boyce model parameters.

Water content %	Degree of saturation %	Frequency Hz	Stress	K_a MPa	G_a MPa	n	γ	Correlation
3.7	33.86	1	Total	8.60	28.49	0.28	0.34	0.574
			Effective	7.41	33.82	0.20	0.39	0.548
4.5	41.46	1	Total	4.43	13.40	0.25	0.24	0.755
			Effective	3.77	13.35	0.22	0.24	0.789
		0.5	Total	3.40	9.31	0.27	0.19	0.765
			Effective	2.68	7.83	0.26	0.18	0.827
		0.1	Total	2.58	5.51	0.35	0.15	0.763
			Effective	2.54	5.74	0.34	0.16	0.791

Figure 14. Deviatoric and volumetric strains at $w = 4.5\%$ and 0.5 Hz with effective stresses.

The following points can be noticed:

- In the 0.1 – 1 Hz range, the impact of frequency is less evident than the influence of water content. From 1 Hz to 0.1 Hz the range of ε_q increase is from -4% (for $\sigma_3 = 20$ kPa) to 20% (for $\sigma_3 = 100$ kPa).
- As the same way as above, lower frequency implies a decrease of volumetric strains and accentuates the dilation. Indeed, ε_v are negative therefore increase in absolute value, except for $\sigma_3 = 150$ kPa.
- At the water content of 4.5% , for each frequency, the correlation value is higher with effective stresses than with total stresses.
- The lower the frequency, the lower are bulk and shear moduli.

One can observe for the same frequency that the total stress Boyce model parameters exhibit too much differences between them, whereas the effective stress Boyce model parameters exhibit less discrepancy as it has been observed previously (Ho et al., 2014b; Nowamooz et al., 2011).

Figure 15. Deviatoric and volumetric strains at $w = 4.5\%$ and 0.1 Hz with effective stresses.

Table 6. One set of the Boyce model parameters for $w = 3.7\%$ and $w = 4.5\%$ at 1 Hz.

Stress	K_a	G_a	n	γ	Correlation
	MPa	MPa			
Effective	2.22	11.68	0.145	0.21	0.547

Finally, with effective stress concept, a calibration of the Boyce model with the two water contents and three stress paths at 1 Hz, corresponding to confining pressures 100 and 150 kPa, was established. The parameters of this fit are presented in Table 6.

4. Conclusions and perspectives

This paper reports the first results of the study of a source of reclaimed asphalt aggregates with high PAH content, 298 mg/kg. In France, hot recycling is prohibited beyond 50 mg/kg of PAH, while the cold reuse is allowed up to 500 mg/kg. The cold recycling of 100% reclaimed asphalt aggregates without binder addition is studied. Several tests were performed:

- (1) Monotonic triaxial tests were carried out at three temperatures, fixed water content and fixed density. This investigation demonstrates that:
 - At 50°C, the material presents a lower resistance to failure than at 20°C.
 - Preheating the specimen does not have a significant impact on the resistance at the same density and causes an increase of cohesion.
 - Compaction at 50°C could increase the density of the sample and consequently improve performances during a test at 20°C.
- (2) RLT tests were performed at ambient temperature, two water contents and three frequencies. Some conclusions can be stated:
 - The samples prepared at higher water content presents higher strains.

- At low frequencies, water content reveals a higher influence on the resilient behaviour than frequency.

The non-linear elastic Boyce model, used for Unbound Granular Materials, can describe the resilient behaviour of reclaimed asphalt aggregates at ambient temperature and for a frequency equal to that used for UGM tests in works of Coronado et al. (2016) or Ekblad and Isacsson (2008).

Additional RLT tests are needed to evaluate the effects of temperature, grading and density on permanent and resilient behaviours of the material.

5. Future works

To control the use of Reclaimed Asphalts (RA) as base layer in low traffic pavement, rutting tests have been carried out with MMLS3 (Model Mobile Load Simulator) device at Empa at ambient temperature. The MMLS3, developed at Stellenbosch University, is an Accelerated Pavement Testing (APT) device that applies a scaled load on four single tires. The machine is 2.4 m long by 0.6 m wide by 1.2 m high and 80,000 load applications have been performed. The MMLS3 applies a load of 2.1 kN on each of its tires that are inflated to 800 kPa. The rutting tests were made at a speed of 2.6 m/sec that corresponds approximately to a 4 Hz frequency of loading for a measured tread length of 0.11 m (Raab, Partl, Jenkins, & Hugo, 2005; Smit, Hugo, Rand, & Powell, 2003). These results will be presented in the next step of this study dealing with rutting of low traffic pavement with RA base layer.

Funding

This work is part of the ORRAP (Optimal Recycling of Reclaimed Asphalts in low-traffic Pavements) project funded by ERDF - INTERREG V (3.1 ORRAP), which studies the cold recycling of reclaimed asphalts aggregates without binder addition.

ORCID

Juan Carlos Quezada <http://orcid.org/0000-0001-6164-7949>

References

- American Society for Testing and Materials International. (2010). Standard Test Method for Measurement of Soil Potential (Suction) Using Filter Paper. ASTM D 5298-10.
- Association Française de Normalisation. (2003). Mélanges traités et mélanges non traités aux liants hydrauliques – Partie 4: Méthodes d’essai pour la masse volumique de référence et la teneur en eau en laboratoire – Marteau vibrant. [Unbound and hydraulically bound mixtures – Part 4: Test methods for laboratory reference density and water content – Vibrating hammer.] Norme européenne EN 13286-4.
- Association Française de Normalisation. (2004a). *Graves non traitées: Spécifications*. [Unbound Granular Materials: Specifications.] Norme européenne EN 13285 (pp. 6–7).
- Association Française de Normalisation. (2004b). Mélanges avec ou sans liant hydraulique – Partie 7: Essai triaxial sous charge cyclique pour mélanges sans liant hydraulique. [Unbound and hydraulically bound mixtures – Part 7: Triaxial test under cyclic loading for unbound mixtures.] Norme européenne EN 13286-7.
- Association Française de Normalisation. (2007). Mélanges bitumineux: Spécifications des matériaux – Partie 1: Enrobés bitumineux. [Asphalt mixtures: Specifications of materials – Part 1: Asphalt concretes.] Norme européenne EN 13108-1 (pp. 9–11).

- Azam, A. M., Cameron, D. A., & Rahman, M. M. (2013). Model for prediction of resilient modulus incorporating matric suction for recycled unbound granular materials. *Canadian Geotechnical Journal*, 50(11), 1143–1158.
- Bishop, A. W., & Blight, G. E. (1963, September). Some aspects of effective stress in saturated and partly saturated soils. *Géotechnique*, 13(3), 177–197.
- Boyce, J. R. (1980, January). A non-linear model for the elastic behaviour of granular materials under repeated loading. *Proceedings of International Symposium on Soils under cyclic and Transient loading* (pp. 285–294). Swansea.
- Colbert, B., & You, Z. (2011). The determination of mechanical performance of laboratory produced hot mix asphalt mixtures using controlled RAP and virgin aggregate size fractions. *Construction and Building Materials*, 26(1), 655–662.
- Coronado, O., Caicedo, B., Taibi, S., Gomes Correia, A., Souli, H., & Fleureau, J. M. (2016). Effect of water content on the resilient behavior of non standard unbound granular materials. *Transportation Geotechnics*, 7, 29–39.
- Dinis-Almeida, M., Castro-Gomes, J., & de Lurdes Antunes, M. (2011). Mix design considerations for warm mix recycled asphalt with bitumen emulsion. *Construction and Build Materials*, 28(1), 687–693.
- Eklblad, J., & Isacson, U. (2008). Influence of water and mica content on resilient properties of coarse granular materials. *International Journal of Pavement Engineering*, 9(3), 215–227.
- Gabet, T., & Wayman, M. (2012). *Sampling procedure for reclaimed asphalt* (Deliverable 1.3). Retrieved from RE-ROAD – End of Life Strategies of Asphalt Pavements website: <http://re-road.fehrl.org/>
- Guatimosim, F. V., Vasconcelos, K. L., Bernucci, L. L. B., & Jenkins, K. J. (2016). Laboratory and field evaluation of cold recycling mixture with foamed asphalt. *Road Materials and Pavement Design*, 19(2), 385–399.
- Ho, X. N., Nowamooz, H., Chazallon, C., & Migault, B. (2014a). Influence of fine content and water content on the resilient behaviour of a natural compacted sand. *Road Materials and Pavement Design*, 15(3), 606–621.
- Ho, X. N., Nowamooz, H., Chazallon, C., & Migault, B. (2014b). Effective stress concept for the effect of hydraulic hysteresis on the resilient behaviour of low traffic pavements. *Road Materials and Pavement Design*, 16(9), 842–856.
- Hornych, P., Gaudefroy, V., & Geffard, J. L. (2009, May). Study of the mechanical behaviour of gravel-emulsions using triaxial tests. *Proceedings of 7th International Symposium on Advanced Testing and Characterization of Bituminous materials* (pp. 639–649). Rhodes, Greece.
- Hornych, P., Kazai, A., & Piau, J. M. (1998, July). Study of the resilient behaviour of unbound granular materials. *Proceedings of 5th International Conference on the Bearing Capacity of Roads and Airfields* (pp. 1277–1287). Trondheim, Norway.
- Jacobson, T. (2002, October). *Cold recycling of asphalt pavement – mix in plant*. *Proceedings of Road pavement recycling*, Warsaw (Poland).
- Jacobson, T., & Waldemarson, A. (2011). Återvinning av asfaltgranulat vid motorvägsbygget på E4, Markaryd – Uppföljningar åren 2005–2010. [Recycling of asphalt aggregates for the construction of E4 highway – Follow-up between 2005 and 2010.] VTI notat 25-2010.
- Jing, P., Nowamooz, H., & Chazallon, C. (2016). Permanent deformation behaviour of a granular material used in low-traffic pavements. *Road Materials and Pavement Design*, 19(2), 298–314.
- Kalman, B. (2013). Project Final Report (Deliverable 7.3). Retrieved from RE-ROAD – End of Life Strategies of Asphalt Pavements website: <http://re-road.fehrl.org/>
- Kuna, K., Airey, G., & Thom, N. (2016). Mix design considerations of foamed bitumen mixtures with reclaimed asphalt pavement material. *International Journal of Pavement Engineering*, 18(10), 902–915.
- Moon, K. H., Cannone Falchetto, A., Wang, D., Wistuba, M. P., & Tebaldi, G. (2016). Low-temperature performance of recycled asphalt mixtures under static and oscillatory loading. *Road Materials and Pavement Design*, 18(2), 297–314.
- Nowamooz, H., Chazallon, C., Arsenie, M. I., Hornych, P., & Masrouri, F. (2011). Unsaturated resilient behavior of a natural compacted sand. *Computers and Geotechnics*, 38(4), 491–503.
- Plati, C., Loizos, A., Papavasiliou, V., & Kaltsounis, A. (2010). Investigation In Situ Properties of Recycled asphalt pavement with foamed asphalt as base Stabilizer. *Advanced in Civil Engineering*. Retrieved from doi:10.1155/2010/565924
- Porot, L., & Eduard, P. (2016, June). *Laboratory evaluation of half-warm recycling with bio-based additive*. *Proceedings of 6th Eurasphalt & Eurobitume Congress*, Prague, Czech Republic.

- Raab, C., Partl, M. N., Jenkins, K., & Hugo, F. (2005, June). *Determination of rutting and water Susceptibility of Selected pavement materials using MMLS3. Proceedings of 7th International Conference on the Bearing Capacity of Roads and Airfields*, Trondheim, Norway.
- Sangiorgi, C., Tataranni, P., Simone, A., Vignali, V., Lantieri, C., & Dondi, G. (2017). A laboratory and filed evaluation of cold Recycled mixture for base layer entirely made with reclaimed asphalt pavement. *Construction and Building Materials*, 138, 232–239.
- Singh, D., Chitragar, S. F., & Ashish, P. K. (2017). Comparison of moisture and fracture damage resistance of hot and warm asphalt mixes containing reclaimed pavement materials. *Construction and Building Materials*, 157, 1145–1153.
- Smit, A., Hugo, F., Rand, D., Powell, B. (2003). Model Mobile load Simulator Testing at National Center for asphalt Technology test Track. *Transportation Research Record: Journal of the Transportation Research Board*, 1832(1), 182–190.
- Tran, N., West, R., Taylor, A., & Willis, R. (2015). Evaluation of moderate and high RAP mixtures at laboratory and pavement scales. *International Journal of Pavement Engineering*, 18(9), 851–858.
- Valdés, G., Pérez-Jiménez, F., Miró, R., Martínez, A., & Botella, R. (2010). Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP). *Construction and Building Materials*, 25(3), 1289–1297.