Use of lignocellulosic liquid waste from wood hardboard manufacture as bitumen emulsion extender for cold asphalt mixtures for low traffic roads

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ABSTRACT

During the wet process of manufacturing wood hardboards, a large amount of water contaminated with lignocellulosic waste is generated. With the aim of promoting the circular economy, it is interesting to find new uses for this liquid waste, rich in biopolymer lignin. The present research is a preliminary laboratory analysis of the feasibility of using this industrial waste as bitumen emulsion modifier or extender. To this purpose the lignocellulosic industrial waste was tested as partial substitute of bitumen emulsion for cold asphalt mixtures type grave emulsion. Particularly, GE-2 grave emulsions for low traffic roads have been manufactured. Substitution percentages of 0% (control), 5%, 10%, and 15% were analysed. The envelope water was visually determined. Also the optimum fluid content was obtained by means of the Modified Proctor Test. In addition, the optimum bitumen emulsion content, the compressive strength, and the water resistance of the cold asphalt mixtures were analysed conducting immersion-compression tests. All the tested percentages of lignocellulosic waste led to grave emulsions that could be used for low traffic roads, according to the Spanish specifications. Nevertheless, the results indicate decreased compressive strength with increasing liquid waste percentages. For this reason, only percentages of substitution up to 10% of liquid waste rich in lignin are considered adequate as bitumen emulsion extender.

Keywords: lignin, waste, cold asphalt mixture, grave emulsion, water resistance, compressive strength

1. INTRODUCTION

The traditional economic model currently in force, that is, the linear economy model, generates multiple environmental problems. In addition to consuming a large amount of resources, misspends an important part of them by turning them into waste. However, in a circular economy model, materials that can be recycled are reinvested in the economy as new raw materials, thus increasing security of supply and leading to a more sustainable production model. For this reason, the European Union (EU) is promoting the implementation of the circular economic model. One of the main measures that the EU tries to implement to promote the circular economy consists of the proper waste management [1]. Biomass and bioproducts are biomaterials, that is, are materials based on biological resources (such as wood, crops or fibers). These biomaterials constitute one of the priority areas of action of the EU in terms of waste management, to promote the circular economy [1].

During the wet process of manufacturing wood hardboards, a large amount of water contaminated with lignocellulosic waste is generated [2]. The treatment of this water containing biomaterials generates high production costs, being the main drawback of this manufacturing process. In this regard and with the aim of promoting the circular economy, it is interesting to find new uses for this liquid waste, rich in lignin.

Some authors have demonstrated that the use of biopolymer lignin as bitumen modifier improves the performance of bituminous mixtures. Particularly, improved water resistance of the mixture [3, 4], lower temperature sensitivity of the asphalt [5], enhanced rutting resistance [5] and fatigue resistance [5] of the asphalt, were found. Other authors successfully used it as bitumen extender [6].

For this reason, in the present preliminary laboratory research, the possibility of using the liquid waste rich in lignin from the wood hardboard industry, as bitumen modifier or as asphalt extender, has been analysed.

Low temperature bituminous mixtures, particularly a cold asphalt mixture (CAM) type grave emulsion has been selected for this purpose. These mixtures require less energy consumption during its manufacture process, which is in line with the Sustainable Development Goals (SDGs) 9 (industry, innovation and infrastructure) and 13 (climate action) [7].

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Aggregates

In the present preliminary laboratory analysis, natural siliceous aggregates extracted from a quarry in Galicia (Spain) were used. The supplier provided a total of 3 fractions of hornfels: 0/2 mm, 2/6 mm and 6/16 mm.

2.1.2 Bitumen emulsion

The selected commercial bitumen emulsion, a C60B5 GE [8], is a slow setting cationic bitumen emulsion, with a residual binder content ranging from 58% to 62% that was specifically provided for the manufacture of cold asphalt mixtures type grave emulsion (GE).

2.1.3. Liquid lignin waste

As a consequence of the production of wood hardboards, some wastes are generated. Particularly, as shown in figure 1, in the present research a 100% natural viscous dark brown liquid waste rich in lignin (9.70% of lignin) was used.

FIGURE 1 Appearance of the natural liquid waste rich in lignin

In the present research, cold asphalt mixtures using 0% (control), 5%, 10%, and 15% of liquid waste in place of bitumen emulsion were manufactured.

2.2 Methods

2.2.1 Mix type

As shown in table 1, taking into account the grain size distribution of the provided fractions of hornfels, a grave emulsion type GE-2 was composed according to the Technical Association of Bituminous Emulsions (ATEB) [9], using 45% of the fraction 0/2 mm, 20% of the fraction 2/6 mm and 35% of the fraction 10/16 mm.

TABLE 1 Grain size distribution of the selected grave emulsion, type GE-2 (cumulative percent passing)

Sieve size (mm)	Cumulative percent passing (%)					
	Aggregates fraction			GE-2		
	0/2 mm	2/6 mm	10/16 mm	Selected GE-2	Lower limit [9]	Upper limit [9]
40	100	100	100	100	100	100
31.5	100	100	100	100	100	100
20	100	100	95.1	98.3	80	100
12.5	100	100	19.7	71.9	58	86
8	100	100	1.5	65.5	43	73
4	82.8	83.4	1.3	54.4	26	55
2	57.1	25.8	1.2	31.3	17	40
0.5	33.1	2.6	1.2	15.8	9	23
0.25	24.8	2.1	1.1	12.0	7	18
0.125	19	1.9	1	9.3	4	14
0.063	14.4	1.7	0.8	7.1	2	10

2.2.2 Optimum envelope water

The optimum envelope water content was determined following the standard NLT-145 [10], using a residual binder content of 2.5%.

2.2.3 Optimum fluids content

The optimum fluids (water and bitumen emulsion) content was determined by conducting Modified Proctor tests according to the EN-103501 [11]

2.2.4 Optimum residual binder content and water resistance

The optimum residual binder content and the water resistance of the grave emulsion was determined conducting immersion-compression tests, following the standard NLT-162 [10]. In the present test, a conserved resistance index (R) is obtained. This index is indicative of the loss of resistance produced by comparing the simple compressive strength obtained between specimens kept in the air (R_1) and duplicate specimens subjected to a water bath at 60ºC for 24 hours. (R_2). The conserved resistance index is obtained by using the expression indicated in equation (1):

$$R = \frac{R_2}{R_1} x100 \quad (1)$$

3. RESULTS

3.1 Optimum envelope water

A 3% of envelope water content was selected because it was the water content that led to better bitumen emulsion-aggregate coating.

3.2 Optimum fluids content

A 6.6% of fluids (water and bitumen emulsion) content was chosen as optimum, as shown in figure 2.

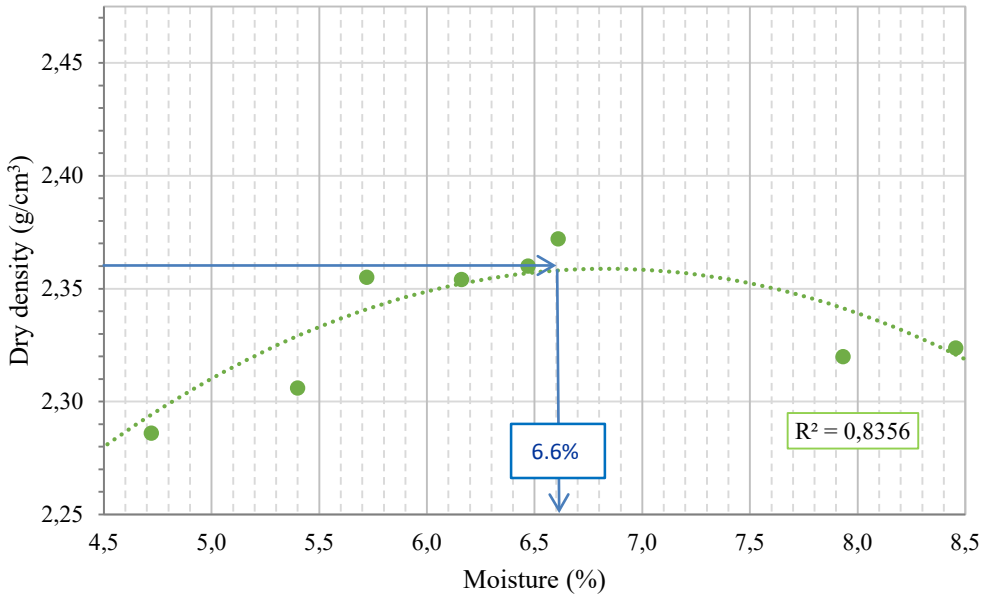

FIGURE 2 Maximum dry density vs moisture for the selected GE-2

3.3 Optimum residual binder content and water resistance

For the control mixture (0% of liquid waste rich in lignin), the minimum residual binder content (2.5%) stated by the ATEB [9] was selected as optimum residual binder content, because it was the minimum that complied with the ATEB [9] specifications (Table 2). In this regard, the GE-2 manufactured with 2.5% of residual binder content, is suitable for heavy traffic category T4 (traffic category T4 refers to annual average daily heavy traffic (AADHT) <50).

Table 2 shows the dry (R_1) and wet (R_2) simple compressive strength and the retained strength (R), for GE-2 manufactured substituting 0%, 5%, 10%, and 15% of bituminous emulsion by the liquid waste rich in lignin, by weight, at the optimum residual binder content (2.5%).

TABLE 2 Immersion-compression results for the GE-2 manufactured using 0%, 5%, 10%, and 15% of liquid waste rich in lignin

Liquid waste in place of bitumen emulsion (%)	Test results			Specifications [9]		
	R1 (MPa)	R2 (MPa)	R (%)	R1 (MPa)	R2 (MPa)	R (%)
0 (control)	1.72	1.23	71.5	0.9	0.7	50%
5	1.62	1.21	74.2			
10	1.76	1.15	65.0			
15	1.32	0.94	71.4			

As can be seen in table 2, for all the tested liquid waste percentages, the GE-2 complies with the specifications for low traffic roads (T4). Nevertheless, table 3 shows that as the liquid waste percentage increases, the simple compressive strength decreases. Particularly, as shown in table 3, from 0% to 15% a reduction of 23.6% was achieved for the wet group and of 23.3% for the dry group. The reductions obtained for 5% and 10% of liquid waste are lower or equal than 6.5% and in the case of the use of 10% of liquid waste, the dry compressive strength increases a 2.3%. In the case of the water resistance, there is not a general trend.

TABLE 3 Reductions in the water resistance and the compressive strength when using liquid waste in place of bitumen emulsion

Liquid waste in place of bitumen emulsion (%)	Test results		
	ΔR1 (%)	ΔR2 (%)	ΔR (%)
0 (control)	0	0	0
5	-5.8	-1.6	3.8
10	2.3	-6.5	-9.1
15	-23.3	-23.6	-0.1

Therefore, despite being rich in lignin, and contrary to what was expected, the liquid waste does not improve the properties of the cold mix in terms of compressive strength, especially when used in percentages higher than 10%.

4. CONCLUSIONS

In this preliminary laboratory research, with the aim of collaborating with the sustainable development and the circular economy, a lignin rich industrial waste was tested as partial substitute of bitumen emulsion for grave emulsions type GE-2 for pavements of low traffic roads. Substitution percentages of 0% (control), 5%, 10%, and 15% were analysed. Contrary to expectations, the results testify that as the percentage of liquid lignin rich waste increases, the compressive strength of the grave emulsion decreases. Particularly, reductions greater than 23% have been obtained by using 15% residue. For this reason, despite the grave emulsions manufactured using all the tested percentages of liquid waste comply with the Spanish specifications for low traffic roads, the use of this waste is considered only suitable as bitumen emulsion extender when used in low substitution percentages (up to 10%).

5. REFERENCES

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Symposium ISAP

Costa Rica, October 25-27, **2022**

International Symposium of **Asphalt Pavements**
Simposio Internacional de **Pavimentos Asfálticos**

Wednesday, October 26th

7:30 Registration

08:30 Opening Session

9:00  **"Moisture damage in asphalt mixtures".** Silvia Caro, Colombia ●

9:45 Coffee Break

	Meeting Room No 1	Meeting Room No 2	Meeting Room No 3
	Sustainable Bituminous Materials Emanuelle Chailleaeux - Pierre Hornych, France	**Recycling of bituminous materials** Moderator: Kamilla Vasconcelos, Brasil	**Evaluation of environmental impact of bituminous materials and pavements** Moderator: Eshan Dave, USA
10:15	**Impact of Aggregate Structure Restoration on Rutting Resistance in Asphalt Mixtures with Very High Percentage of RAP.** ● Reza Imaninasaba, Canada	**Incorporating a temperature dependent plastic response for cold in-place recycled layers.** ● Antonio Roberto, Italy	**Understanding the Cost and Life Extension Relationships between Flexible Pavement Maintenance and Rehabilitation Treatments.** ● Andrew Braham, USA
10:35	**Use of lignocellulosic liquid waste from wood hardboard manufacture as bitumen emulsion . Jose Pablo Orosa,** ● Jose Pablo Orosa, Ignacio Pérez Pérez, Spain	**Influence of Temperature on Global and Local Elastic and Shear Strength Properties of Bituminous Stabilized Material (BSM).** ● Antonio Roberto, Italy	**Durability of Bitumen Stabilised Materials.** ● Kim Jenkins, South Africa
10:55	**Analysis of Sustainable Pavements Strategies from the Thermoacoustics Perspective.** ● Carla Marília Cavalcante, Brasil	**The Rejuvenating Effect of Bio-Emulsion from Soybean Oil Partially Epoxidized on Chip Seals.** ● Ataslina de Paula Da Silva, Brasil	**Formulation and characterization of an alternative binder 1 to petroleum bitumen, produced from waste cooking oils.** ● Mildrède Debello, France
11:15	**Analysis of Synergistic Mechanisms of Bio-oils and Crumb rubber on Asphalt Binder.** ● Lei Lyu, China	**Post-Industrial Waste Polymer Effects on Hot Mix Asphalt Volumetric and Mechanical.** ● Gustavo Dos Santos Pinheiro, Brasil	**Pavement Thickness and Base Layer Effects on Density Profile System Measurement.** ● Anthony Brenes - Surendra Gatiganti, USA
	Meeting Room No 1	Meeting Room No 2	Meeting Room No 3
	Sustainable Bituminous Materials Oswaldo Chavez, Nicaragua. Roberto Hernández, Mexico	**Recycling of bituminous materials** Moderator: Salvatore Mangiafico, France	**Performance of asphalt pavements** Moderator: Alan Carter, Canada
11:35	**Road Use Contributions to Energy Consumption and CO2 Emissions for Two Maintenance Strategies.** ● Andrew Braham, USA	**Challenges in sustainability practice related to road infrastructure of developing countries – a case study in Brazil.** ● Liseane P. Thives, Brasil	**2-D FEM thermomechanical coupling in the analysis of a flexible eRoad.** ● Talita De Freitas Alves, Brazil
11:55	**Evaluating the damage of a new long heavy vehicle on a thin pavement under spring thaw.** ● Denis Saliko, Sweden	**Impact of Density and Component Materials on Curing Evolution of Cold In-place Recycled.** ● Jo Sias, USA	**Mapping the Evolution of the World Literature on Smart Asphalt: A Bibliometric Analysis.** ● Iran Rocha Segundo, Portugal
12:15	**Effect of Conditioning procedures on Moisture Suseptibility Foamed Cold-Mix Asphalt Mixtures.** ● G. Bharath, India	**Full-scale life cycle assessment of asphalt concrete base course containing RAP under different.** ● Elio Ziade, France	**Probabilistic machine learning approach for asphalt concrete dynamic modulus.** ● Jorge Barbosa Soares, Brasil
12:35	**Influence of NO and NO2 on the long-term ageing of bitumen.** ● Kristina Hofer, Austria	**Alternative biobased emulsifiers for road materials.** ● Fanny Lévenard, France	**Evolution of Intermediate Binder Properties with In-Field Ageing.** ● Elaine Simone Goosen, South Africa

12:55 Lunch

Wednesday, October 26th

	Meeting Room No 1	Meeting Room No 2	Meeting Room No 3
	Sustainable Bituminous Materials Moderator: Paulina Leiva, France	**Recycling of bituminous materials** Moderator: Elena Romeo, Italy	**Evaluation of environmental impact of bituminous materials and pavements** Moderator: Imad Al-Qadi, USA
14:00	**Multi Stress Creep Recovery test to address high temperature property of bituminous binder.** ● Laurent Porot, Netherland	**Optimization of the Preparation Procedure of Crumb Rubber Modified Bitumen with Wax-based Additives.** ● Haopeng Wang, United Kingdom	**Fatigue and recovery properties of a bituminous mixture during cyclic loading and rest.** ● Cédric Sauzeat, France
14:20	**Laboratory evaluation of the effectiveness of rejuvenation in multiple hot recycling of asphalt.** ● Emiliano Pasquini, Italy	**Performance Benefits of Maintenance, Reclamation, and Recycling on Heavy Distressed Roadway.** ● Michael Vrtis, USA	**Designing Stone-Matrix Asphalt with Sedimentary Carbonate Aggregates.** ● Javier García, USA
14:40	**A thermo-mechanical model based on Paris law to simulate fatigue tests on sand bitumen.** ● Olivier Chupin, France	**Rheological and Physical Properties of Multiple Reclaimed Asphalt Pavement Sources from Quebec, Canada.** ● Marc-André Bérubé, Canada	**Enhancing Traditional Asphalt Concrete Perpetual Pavements: Perpetual Pavements Plus (PP+).** ● Andrew Braham, USA
15:00	**Evaluation of solutions for the integration of inductive charging systems for electric vehicles in a bituminous pavement.** ● Pierre Hornych, France	**Microstructure Analysis of Cold Bituminous Emulsion Mixture using Different Filler Type.** ● G. Bharath, India	**Laboratory evaluation on interlayer bonding and characterization of microsurfacings.** ● Christiane Raab, Switzerland
15:20	**Responses of a thin flexible pavement loaded with different types 1 of tires and tire configurations.** ● Shafiqur Rahman, Sweden	**Six Sigma Production Implementation of PET modified HMA - Latin American Case Study.** ● Sergio B. Velásquez-Garnica, Bolivia	**Rutting Analysis of different Asphalt Surface Layers in the same thermal conditions.** ● Christophe Petit, France
15:40	**Evaluation of High Percentage of Recycled Aggregates for the Production of Hot Mix Asphalt Surface Layers.** ● Simone Raschia, Italy	**Use of a Pre-conditioned resin aggregate made from recycled plastic as hot-mix asphalt additive.** ● Luis Loria, Costa Rica	**Use of the semicircular bending test to evaluate the cracking potential of non-Superpave.** ● David Hernando, Spain
16:00	**Drying shrinkage of cold recycled cement-treated mixtures of asphalt pavement materials.** ● William Fedrigo, Brasil	**Correlation between dynamic shear modulus and FTIR indices.** ● Ingrid do Nascimento Camargo, Austria	**Thermal behaviour of a novel hybrid road for the energy harvesting.** ● Domenico Vizzari, France
16:20	Coffee Break		
	Meeting Room No 1	Meeting Room No 2	Meeting Room No 3
	Evaluation of environmental impact of bituminous materials and pavements Hervé Di Benedetto, France. Johannes Mirwald, Austria	**Recycling of bituminous materials** Elena Romeo, Italy. José Pablo Aguiar, Costa Rica	**Performance of asphalt pavements** Moderator: Hasan Baaj, Canada
16:50	**Rheological behaviors of waste polyethylene modified asphalt binder: statistical analysis of inter-laboratory testing results.** ● Augusto Cannone Falceto, Finland	**Laboratory behavior and field performance of granular bases stabilized with asphalt emulsion and with rap and cement incorporation.** ● William Fedrigo, Brasil	**Evaluation of the long-term rheological and degradation properties of recycled asphalt blends with crude palm oil rejuvenators.** ● Silvia Caro, Colombia
17:10	**Proposal of Methodologies for Mechanical Analysis in Concrete Paving Blocks with the Use of Recycled Materials from Civil** ● **Construction.** Webert Silva, Brasil	**Automated detection of defects and vertical signs on road transportation infrastructures using images produced by drivers.** ● Lucas Feitosa de Albuquerque, Brasil	**Evolutionary resilient response of cold in-place recycled mixtures during the curing period.** ● Pablo Orosa, Spain
17:30	**Evaluation of ERAPave PP permanent deformation models using APT.** ● Yared Dinegdae, Sweden	**Mechanical behavior of lime treated tropical soils for asphalt pavement layers.** ● Thaís Radünz Kleinert, Brasil	**Use of Municipal Solid Waste Bottom Ashes in Rubberized Asphalt Mixtures.** ● Pier Paolo Riviera, Italy
17:50	**Comparative Life Cycle Assessment for Recycling Waste Polyethylene and Electric Arc Furnace Steel Slag in the Surface Course of Low-Noise Asphalt Pavements.** ● Zhengyin Piao, Switzerland	**The influence of pavement surface characteristics on vehicle pollutant emissions.** ● Victor Cardoso Oliveira, Brasil	**Warm Mix Asphalt with Reclaimed Asphalt and plant-based binder: mechanical and environmental performance.** ● Julien Van Rompu, France
18:10	**Costa Rican tipycall coctail night**		

Thursday, October 27th

8:30  **System Dynamics for Solving Complex Problems in Pavement Engineering.** Rajib Basu Mallick, India

	Meeting Room No 1 **Characteristics and performance of bitumens** Moderator: Gaylon Buamgarder, USA	Meeting Room No 2 **Chacteristics and performance of Hot-mix asphalt** Moderator: Christianne Raab, Switzerland
9:15	**How infrared and fluorescence spectroscopy can shed new light on the characterization of bitumen and its ageing processes.** Stefan Werkovits, Kristina Hofer, Ayse Koyun; Austria	**Thermal properties and random particle modelling of asphalt mixture with steel slag.** Augusto Cannone Falchetto, Finland
9:35	**Laboratory Evaluation of Airfield Warm Mix Asphalts (WMA) as Related to Rutting Performance in Accelerated Pavement Tests at NAPMRC.** Dario Batioja-Alvarez, USA	**A numerical analysis of how friction damages roads.** Daniel Nelias, France
9:55	**Relation between crossover modulus and asphalt chemistry to oxidation process based on the RHEO+ Method.** Luis G. Loria, J. Pablo Aguiar, Costa Rica	**Development of a UAS-based Sensing Approach to Detect and Measure Pavement Frost Heaves.** Eshan Dave, USA
10:15	**Analysis of the new MSCR approach for binder selection.** Aline Cavalcanti Fialho, Brasil	**Assessing the Structural Health of the Pavement Sections using FWD Parameters.** Mena Souliman, USA
10:35	Coffee Break	

	Meeting Room No 1 **Characteristics and performance of bitumens** Moderator: Augusto Canonne, Finland	Meeting Room No 2 **Chacteristics and performance of Hot-mix asphalt** Moderator: Manfred Partl, Switzerland
11:00	**Analysis of the use of Euphorbia Tirucalli sap in the composition of an asphalt bio-emulsion.** Mateus Silva Brito, Brasil	**Triaxial Resilient Modulus Regression Models for Cold Recycled Asphalt Mixtures.** Kamilla Vasconcelos, Brasil
11:20	**Mechanical performance of asphalt base layers with high RAP content and rejuvenating agents.** Geert Jacobs, Belgium	**Determination of the International Roughness Index using images of Unmanned Aerial Vehicles.** José P. Aguiar, Costa Rica
11:40	**Quantification of the Bitumen Microstructure - Addressing Crucial Parameters during Sample Preparation by Particle Analysis.** Johannes Mirwald, Austria	**Moisture damage susceptibility of a wood-based binder for total replacement of asphalt binders.** Leidy V. Espinosa, Brasil

		Meeting Room No 2 **Numerical modeling for asphalt materials** Moderator: Christoff Petit, France
12:00	**Effect of blending steel slag aggregates on the polishing resistance of asphalt pavement surface.** Thavamani Andiyappan, India	**Computational and laboratory simulations for piezoelectric energy production from road.** Suelly Helena de Araújo Barroso, Brasil
12:20	**Application of non-destructive testing for the determination of the stiffness of different materials.** Jean-Claude Carrete, Brasil	**Anisotropic response of an asphalt concrete layer under superheavy vehicles: Field measurements.** Erdrick Leandro Pérez-González, Canada
12:40	Lunch	

Thursday, October 27th

	Meeting Room No 1 **Characteristics and performance of bitumens** Moderator: Andrew Braham, USA	Meeting Room No 2 **Numerical modeling for asphalt materials** Moderator: Christoff Petit, France
14:00	**Physical properties and microstructural heterogeneity of plastic waste- versus standard polymer-modified bitumen.** Laurent Porot, Netherlands	**Heterogeneous numerical length scale investigation on fatigue behaviour of bituminous composites.** Fateh Fakhari Tehrani, France
14:20	**The Solar Irradiance Coefficient as an empirical parameter in tests of accelerated aging by weathering on Costa Rican asphalt binders.** Alejandra Baldí Sevilla, Costa Rica	**Evaluation of Recycled Asphalt Mixtures with Different RAP Contents and the Effect of Recycling Agent.** Kamilla Vasconcelos, Brasil
14:40	**Evaluation of truck platooning on road structures in Europe.** Paulina Leiva-Padilla, France	**Asphalt concrete overlay bonding stiffness assessment using FWD data and artificial neural networks a case of study.** Orlando Rojas Torrico, Bolivia
15:00	**Monitoring and modelling the responses of a flexible pavement 1 test section under heavy vehicle loading.** Shafiqur Rahman, Sweden	**Asphaltene Agglomeration Through Physical-Chemical and Rheological Testing.** Pierre Hornych, Jean-Pascal Planche, Layella Ziyani, Emmanuel Chailleux, France, USA
15:20	**Sensitivity Analysis of the IDEAL-CT test using discrete element meth.** Shadi Saadeh, USA	**Resilient Pavement Materials to Mitigate Climate Change Impact in New Jersey.** Yusuf Mehta, USA
15:40	**Comparing Different Rheological Indices to Determine Rejuvenator Dosage for Blended Asphalt Binders with High RAP Binder Ratio.** Hassan Baaj, Canada	**The Application of Bio Emulsion from Soybean Oil Partially Epoxidized as a Maintenance Technique for Flexible Pavements.** Ataslina de Paula da Silva, Brasil
16:00	**Structural and chemical analysis of bitumen surface by Surface Probe Microscopy.** Aise Koyun, Austria	
16:20	Coffee Break	

	Meeting Room No 1 **Performance of asphalt pavements** Moderator: Kim Jenkins, South Africa	Meeting Room No 2 **Numerical modeling for asphalt materials** Moderator: Cedric Saucet, France
16:50	**Resilient modulus of recycled unbound granular materials.** Erdrick Leandro Perez Gonzalez, Canada	**Evaluation of the RAP Cluster Dissociation under Different Conditions.** Kamilla Vasconcellos, Brasil
17:10	**Determination and evaluation of the linear viscoelastic range of modified asphalts and mastics under different.** Laura Gonzalez, México	**Energy dissipation of bituminous mixtures with crumb rubber added by dry process: laboratory tests and numerical simulation.** Yasmina Mahmoudi, France
17:30	**Environmental impacts from asphalt plants due to aggregates moisture and fuel in the dryer.** Liseane Padilha Thives, Brasil	**Predict High and Low Temperature True Grade of Reclaimed Asphalt Pavement Binder Using the Enhanced Mortar Testing Approach.** Yu Yan, China
17:50	**Determination of Linear Viscoelastic Limit for Binders with Physical Hardening Effects.** Salvatore Mangiafico, France	**Evaluating the Rutting and Cracking Resistance of Asphalt Mixes Subjected to Different Silo Storage Times.** Mohamed Elkashef, USA
18:10	 **Achieving Pavement Resilience under a Changing Climate.** Jo Sias, USA	
18:55	**Closing Ceremony and closing dinner**	

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