Towards a strategy for a circular resource management system in road engineering

SSMARAGD
Smart Selection Model for innovative Application of Reclaimed Asphalt Granulate in road Design

Chairs
Prof. Dr Wim Van den bergh (Road Engineering)
Prof. Dr. Amaryllis Audenaert (Sustainability Assessment)
Why ? Closing loops for asphalt pavements

- 130 000 km roads in Belgium
- 73 000 km paved with asphalt
- Every year 4 à 5 million tons asphalt produced
Closing loops for asphalt pavement

- Construction of new roads limited: 500 km/year (of 73000 km total)
  - 1 000 000 ton needed
  - Most of asphalt production for rehabilitation of existing roads
Every year 1.5 million tons milled
- 0.9 million tons reclaimed in asphalt
- 0.6 million tons used other applications: in concrete, unbound base
Consequences:
• Accumulation of asphalt material on the road since decades
• Milled asphalt material: 40% downcycled
• Near future: a lot of material shall/must be recycled
Closing loops for asphalt pavement: 20 years experience @ UA

• Before 1997:
  • Industry: using RA because of low cost material
  • Low research output about recycling reclaimed asphalt

• Since 1997:
  • Several “un-coordinated” research projects “Recycling”
  • Road Engineering Research Section (University College of Antwerp – University of Antwerp)
  • Road Authorities:
    • Recycling rates limited
    • Quality equal
Closing loops for asphalt pavement: Ambition

Our ambition, our task as academic research group:

Improving recycling potential

How?
Criteria?
Closing loops for asphalt pavement: ROAD MAP

ROAD MAP Optimizing the recycling potential of RA

- Until 2016: No actual strategy to optimize and closing the loop
- 2016:
  - First Draft of SSMARAGD
    A global recycling model in order to improve quality and environmental impact for recycling by higher or more assigned RA to road construction
  
- Publication of strategies concerning recycling (E&E Praag)
  - LCA
  - Mechanical properties

Closing loops for asphalt pavement: ROAD MAP

Current studies: Life Cycle Analyses

- Using RAP is beneficial
- Even more than decreasing production temperature
Closing loops for asphalt pavement: ROAD MAP

Current studies: Life Cycle Analyses

- Transport is important
- New materials
- Reclaimed Asphalt
- Construction site
Closing loops for asphalt pavement: ROAD MAP

Current studies: Life Cycle Analyses

- Service life is important in LCA
- Almost equal service life necessary
- Mechanical parameters are important
  - Healing
  - Fatigue life
  - Functional performance

Can we measure in situ service life?

Using RA decreases healing
Closing loops for asphalt pavement: ROAD MAP

• Need for data about material and quality in practice

• 2015-2017 ROAD_IT project: development of a system to control and archive the production and construction process of asphalt pavements

Material data passport GPS-related
Closing loops for asphalt pavement: ROAD MAP

• Improving quality by introduction of rejuvenators

  • 2018-2020 Rejuvebit: Research in order to evaluate the use of rejuvenators for Flemish Market

  • Increasing use of RA in mixtures: 40% → 70%
  • Increasing use by expanding applications: e.g. surface layers
  • Mechanical tests, LCA and LCC
Our ambition, our task as academic research group:

Improving recycling potential

How?
Criteria?
Closing loops for asphalt pavement: Next step

Next step: kick-off SSMARAGD

initiation of a global model in order to improve quality and environmental impact for recycling by higher and more assigned RA to road construction

! we cannot do this alone!

- Need for a certain decision model to optimize the use of RA by selection best RA for a selected work
  - Counting in environmental, economic and mechanical properties
- Modular system built up one by one (easy → complex)
Objectives of the workshop

- Kick-off strategic network team for case “reclaimed asphalt”: project?
- Road map for strategy by round table workshop
  - Decision-Making Models (macro/micro)
- Cases Quality, recycling parameters, models
  - **Speakers**
    - Industry (BAM-contractors, Kraton),
    - Academic partners (UAntwerpen and TU Wien)
    - Environmental policy support services (VITO)
Closing loops for asphalt pavement: Road Map SSMARAGD

2019
• Kick-off SSMARAGD
• Selection of partners (strategic team)
• Selection project type
  • CORNET
  • H2020, Network COST ....
    • Academic partners – Research institutes: methodology
    • Government: acceptance and providing test cases
    • Industry: cases, economic (environment), logistic input (LCC)
• UAntwerp: start PhD researcher SSMARAGD (BE) (4 yrs)

2020
• submittance project (preferably international and european)
Closing loops for asphalt pavement: Road Map SSMARAGD

2020
- first draft – discussion SSMARAGD 0.1

2022
- first test cases

2023
- SSMARAGD 1.0 operational
Towards a strategy for a circular resource management system in road engineering

Road map SSMARAGD

Smart Selection Model for innovative Application of Reclaimed Asphalt Granulate in road Design

Program

SSMARAGD: our first vision

16u20-17u10: Four selected cases from industry and academic research

• Bernard Hofko (TU Wien): Parameters to be taken into account, specific case Ageing
• Laurent Porot (Kraton): using rejuvenators to increase quality of recycled asphalt
• Milliyon Woldekidan (Bam Infra): LEA2P high quality recycling of asphalt
• Carolin Spirinckx (VITO): Decision modelling – cases of practices in the built environment

17u10-17u25 Discussion session with a set of hypotheses in advance and the participants can add their opinion

Closing by Prof. Amaryllis Audenaert
Towards a strategy for a circular resource management system in road engineering

Dr. Ing. Johan Blom
Prof. Dr. Ing. Wim Van den bergh

EMIB
Energy & Materials in Infrastructure & Buildings
University of Antwerp
Towards a strategy for a circular resource management system in road engineering

Road map SSMARAGD

**Smart Selection Model for innovative Application of Reclaimed Asphalt Granulate in road Design**

RA on Road

Check Conformity

- Loose base material
- Concrete
- Asphalt
Towards a strategy for a circular resource management system in road engineering

Road map SSMARAGD

Smart Selection Model for innovative Application of Reclaimed Asphalt Granulate in road Design

RA on Road

Check Conformity

Loose base material
Concrete
Asphalt
Asphalt mixture is used for (most) road pavement
Different compositions dependent on function (top and base layer)
Asphalt mixture = aggregate (stones and sand) glued together by mortar (filler and bituminous binder)
Bituminous binder (from petroleum): durability
Asphalt – the material

Current recycling:

- Reclaimed Asphalt (RAP) is accepted as a primary material
- 1.5 million ton RAP - 64% mixtures contain RAP (COPRO)
  * 0.9 million in asphalt layer
  * 0.6 million in foundation

Asphalt mixture: most used material in Belgium for road pavement, In 2015: 5 million ton (BE) for Belgian Roads

Road map SSMARAGD

Smart Selection Model for innovative Application of Reclaimed Asphalt Granulate in road Design

No use in top layers in Flanders (public works)

- Type ?
- History ?
- Composition ?
- ...

Culture/ attitude
Identification?

Insufficient

Shahin Eskandarsefat, Cesare Sangiorgi, Giulio Dondi, Riccardo Lamperti,
Recycling asphalt pavement and tire rubber: A full laboratory and field scale study.
**SSMARAGD**

**Smart Selection Model** for innovative Application of Reclaimed Asphalt Granulate in road Design

Future optimization of use of RA by upcycling: SSMARAGD by ROAD_IT tools

- **Macro model**
  - GIS-ID during construction or sensor in road
  - RA on road
- **Micro model**
  - Known quantities for each layer (type, age, binder content, …)
  - Limited tests
  - Smart stockpile management

**Conformity check**

- **Loose base material**
- **Concrete**
- **Asphalt**
  - High recycling rate and proper use of the bitumen binder
MICRO MODEL:

Additives

RAP?

Asphalt mixture

Models

ROAD IT

LCA?

LCC?

Environmental indicators
Material Depletion

Social indicators
Tire-Road Noise

Environmental boundaries
- Solar radiation
- Wind speed
- Rainfall

Traffic load boundaries
- Vertical, transverse
- Longitudinal

Environmental multiphysics
Modelling (profile in road)
- Oxygen
- Temperature
- Moisture

Mechanical multiphysics
Modelling (in asphalt layer)
- Viscoplasticity
- Viscoplasticity
- Viscofracture
- Ageing
- Stiffness
- Gradient

Durability prediction
- Rutting
- Cracking
- Moisture damage

Green Public Procurement (GPP)
MACRO MODEL
Geographical location

Mix type

Where to mill?

RA on Road

Transport

Life Cycle Cost Analysis

Maintenance Implications

Value vs. Risk

Past

Cost

ROAD_IT

LCA

Raw materials

End of life

Production

Distribution on the market

Transport of raw materials

ROAD_IT: combining all tools and steps into one system chain with short term and long term archive output

- Materials
- Energy
- Safety
- Efficiency

Homogeneity
Temperature
Production
Transport
Processing

Research

Assisting personnel

Improve
Process
Quality during
construction
service
recycling
Safety at work
Environmental impact
LCA / CO2 Calculation

Quality Control
intern
extern

Short term data use
Long term data archive
Road map SSMARAGD

**Smart Selection Model** for innovative Application of Reclaimed Asphalt Granulate in road Design

**Smart Selection Model**

- **MICRO level**
  - Mixtures
  - RA
  - Mechanical properties
  - LCA performance

- **Macro level**
  - Geographical
  - LCC/LCA
  - Transport
  - Boundaries

**ROAD_IT**
University of Antwerp
Faculty of Applied Engineering
https://www.uantwerpen.be/en/research-groups/emib/
Understanding Ageing of Bitumen

Key for Circular Economy in Road Infrastructure

Prof. Bernhard Hofko
Research Center for Road Engineering
Vienna University of Technology
Motivation

Operation

Recycling/Reconstruction

Traffic/Climate Loading

Maintenance

Quality

Ageing/Structural Defects
Reduce and Compensate
Chemo-Mechanics

Understanding bitumen and its ageing on relevant level
Microstructural Features

Bitumen shows distinct microstructure

Core-Shell Particle (Dispersion)
Microstructure and Chemical Composition

Linking microstructure and chemical composition

Bitumen

Fluorescence Microscopy

Saturated | Aromatics | Resins | Asphaltenes

Polarity

low polarity | high polarity

Fluorescence Intensity [p.e.u.]

Wavelength [nm]
Microstructure and Mechanics

Linking microstructure and mechanical behavior

[Graph showing stiffness gain over time with different asphaltene concentrations]

[Images of microstructure with scales]
Microstructural Model

Interaktion zwischen Mantelflächen

Asphaltene
Maltene

Matrix
Saturates
Aromatics
Resins

Mantle
Aromatics
Resins
Saturates

Micelle
Asphaltenes
Resins
Aromatics

POLARITY

DISTANCE FROM MICELLE-CENTER

TEMPORARY EMBRITTLEMENT
RELAXATION
END-OF-LIFE
UNAGED

TU WIEN
bi.ivws
Scientific Conclusion

- Linking chemical analysis and mechanical testing to understand bitumen and its ageing
- Core-Shell Model including interacting shells

Shell phase
- balances polarity gap between high polar cores and low polar maltenes
- is most prone to oxidation
  - polarity gap increases
  - increasing brittleness

- Re-filling the shell phase is the key for effective rejuvenation
  - high recycling rates
  - durable recycled asphalt mixtures
  - circular economy without down-cycling
Conclusions for Application

- **Conditions crude oil refinery are changing** – bitumen from distillation will become scarce and highly variable in quality
- It is a chance for the material: Bitumen is not just a heavy residue, it can be a tailor made product for specific application
- Role of bitumen constituents on chemical composition, microstructure and mechanics are better understood, as well as their evolution due to ageing
- Precipitated blends of constituents work
- We started to fill the toolbox for tailor made bitumen and additives
Thank you!
Questions?
Rejuvenators for asphalt recycling – an European research overview

Laurent Porot

World Resources Forum, Antwerp 24-27 February 2019

Towards a strategy for a circular resource management system in road engineering
Recycling and rejuvenators

From recycling to the reuse of RA

- Since 2007 EN 13108-8 for RA, national technical guides

The roads from today are the RA from tomorrow

- More and more hard RA, multiple recycling, surface maintenance

Need for new solutions to treat the RA

- To increase RA content, for harder RA, manufacturing

Minimum requirement for rejuvenator

- Restore flexibility at intermediate and low temperature
- Without damage high temperature, rutting resistance
- Maintain durability over time, aging
Numerous studies on rejuvenators

National or European projects

- Infravation with BioRePavation and Alterpave
- Benchmark in Germany, Czech Republic
- Towards 100% RA, Switzerland
- Full scale evaluation, Belgium
- Nordics, Spain, Italy, ...

Also across the world

- Japan, US, New Zealand
- RILEM TC 264-RAP
Recycling status in Japan

Asphalt recycling in Japan, a long story

- First investigation in 1982,
- First technical guide in 1992
- Now up to 80% RA for base layer

Use of rejuvenators is a standard practice

- Standard for rejuvenator based on viscosity, mostly petroleum based
- Spread on RA before mixing chamber

Current trends

- Already 3rd or even 4th recycling cycle
- RA binder getting harder and harder needs new solutions
BioRePavation – European project

Towards a more environmentally friendly pavement

Part of Infravation scheme, co funded by EU and US

- Academic and industry consortium with 6 partners
- Duration of 36 months (2015-2017) from lab to full-scale evaluation

Project on recycling with bio-based materials

- Bio-based rejuvenator to increase RA content up to 100%
- Bio-based additive to increase RA compatibility with virgin binder
- Bio-bitumen as total replacement of bitumen in recycling

Aim at building a demonstrator to validate feasibility of high content in asphalt mix thanks to bio materials

http://biorepavation.ifsttar.fr
BioRePavation – Results

Materials

- Very hard RA out of specifications (penetration < 70.1 mm)
- Asphalt mix made with 50% RA compared with high performance EME asphalt mix as reference

Testing on binder and mix with EU and US specifications

Full scale accelerated experiment

- No or limited cracks as compared to
Rejuvenator benchmark – Czech Republic

Evaluation of rejuvenators (ZETA project, Brno university, 2016-2018)

- Benchmark on 13 products in lab including multiple-aging
- Road trial with 6 rejuvenators

Outcomes

- All products are not equal, most important is aging
- Dosage calculation tool (http://rejuvenator.cz)

The use of rejuvenators as an effective way to restore aged binder properties
Rejuvenated binders, Reclaimed binders and Paving bitumens, are they any different?
Towards 100% recycling - Switzerland

Maximising the use of RA (Empa, 2015-2017)

- Threes rejuvenating agents evaluated on binder
- Full scale plant production 100 % RA Mix

Outcomes

- DSR to address aging and rejuvenation on binder, aging is key indicator
- Addition location of rejuvenator at mix plant is important, hot vs cold
- Use of balanced mix design

Effect of ageing on the mechanical and chemical properties of binder from RAP treated with bio-based rejuvenators
Comparing different rejuvenator addition locations in asphalt plant based on mechanical and chemical properties of binder
Full scale evaluation – Belgium

Rejuvenation of Reclaimed Asphalt in a Circular Economy, Re-RACE (BRRC*, 2017-2019)

- Plant mix production with 50 % RA surface layer and 70 % RA base layer
- Extensive binder and mix lab evaluation
- Rejuvenator helps for high RA content

RejuveBIT (Antwerp University 2018-2020)

- Consortium with academic, industry and road authority
- A total of 5 full scale projects with 3 different rejuvenators

Outcomes to come soon

* BRRC, Belgian Road Research Centre

www.ocw.be/nl/rejuvenator
EAPA guide on rejuvenators

Synthesis & methodology to evaluate rejuvenators

Content

- Characterisation of rejuvenators
- Characterisation of RA
- Characterisation of final binder
- Characterisation of asphalt mix
- Usage at mix plant

A pragmatic approach by steps

- Evaluation on binders
- Depending of degree of knowledge

Example of rejuvenator

SYLVAROAD™ RP1000 Performance Additive from Kraton

- Biobased additive from Pine chemistry

Restore essential lost properties of aged binder

Shear modulus over temperature range (DSR)

Limited changes over aging (Original/RTFOT/PAV)

Validations on asphalt mix

Full scale productions and applications

Effectiveness of a Bio-based Additive to Restore Properties of Aged Asphalt Binder

Asphalt and binder evaluation of asphalt mix with 70% Reclaimed Asphalt
Outcomes

Moving from Recycling to Reuse of RA needs solution

Rejuvenators take recycling to the next step
- For high RA content, very hard RA, processing at mix plant

Subject of numerous researches and trials across Europe
- Effect and benefits of rejuvenators
- Methodology to evaluate and specify product and usage

Technology and industry ready for more RA

Need specifications to allow and promote more
References

About Japan recycling

About BioRePavation
- BioRePavation: innovation in bio-recycling of old asphalt pavements, comparison between EU and US mix design specification systems, ISAP 2018, Fortaleza, Chailleux E. et al

About Brno’s rejuvenator benchmark study
- The use of rejuvenators as an effective way to restore aged binder properties, TRA 2018 Wien, Koudelka T., Porot L., Coufalik P., Varaus M.
- Rejuvenated binders, Reclaimed binders and Paving bitumens, are they any different?, Rilem CMB, Braunschweig, Koudelka T., Coufalik P., Varaus M., Coufalikova I.

About Empa’s 100% recycling study
- https://www.empa.ch/web/s301/fully-recycled-asphalt
- Comparing different rejuvenator addition locations in asphalt plant based on mechanical and chemical properties of binder, TRB 2018, Zaumanis M., Chiara Cavalli M., Poulikakos L.

About Belgium’s full scale evaluation studies
- Re-RACE project www.ocw.be/nl/rejuvenator

About EAPA’s recommandation

About Sylbvaroad™ RP1000 Performance Additive from Kraton
- Asphalt and binder evaluation of asphalt mix with 70 % Reclaimed Asphalt, EATA 2017 Dubendorf, L. Porot, D. Broere, M. Wistuba, J. Grönniger
Thanks for your attention

Laurent Porot
Kraton Chemical
16 Transistorstraat 1322 CE, Almere – Pays Bas
laurent.porot@kraton.com
Legal Disclaimer

Kraton Corporation and all of its affiliates, including Kraton Chemical, believe the information set forth herein to be true and accurate, but any recommendations, presentations, statements or suggestions that may be made are without any warranty or guarantee whatsoever, and shall establish no legal duty on the part of any Kraton affiliated entity. The legal responsibilities of any Kraton affiliate with respect to the products described herein are limited to those set forth in Kraton’s Conditions of Sale or any effective sales contract. NOTE TO USER: by ordering/receiving Kraton product you accept the Kraton Conditions of Sale applicable in the region. All other terms are rejected. Kraton does not warrant that the products described herein are suitable for any particular uses, including, without limitation, cosmetics and/or medical uses. Persons using the products must rely on their own independent technical and legal judgment, and must conduct their own studies, registrations, and other related activities, to establish the safety and efficacy of their end products incorporating any Kraton products for any application. Nothing set forth herein shall be construed as a recommendation to use any Kraton product in any specific application or in conflict with any existing patent rights. Kraton reserves the right to withdraw any product from commercial availability and to make any changes to any existing commercial or developmental product. Kraton expressly disclaims, on behalf of all Kraton affiliates, any and all liability for any damages or injuries arising out of any activities relating to the use of any information set forth in this publication, or the use of any Kraton products.

*KRATON, the Kraton logo and SYLVAROAD are either trademarks or registered trademarks of Kraton Corporation, or its subsidiaries or affiliates, in one or more, but not all countries

©2019 Kraton Corporation
Low Emission$^2$ Asphalt Pavement

Milliyon Woldekidan

M. Huurman, E. Demmink, J. Qiu, B. de Bruin
Historical trends

Road expansion and RA availability (EAPA & VBW)

Climatic trends...

“in 2030 fully circular and climate & energy-neutral.”
Research focus

R&D efforts on:

- Recycle surface layers
- Temperature reduction
- Reduction of emissions
- Noise reduction

Surface layer: PA, TLPA, SMA

Base: RAP (current practice)
**LE2AP project goals:**

Noise reduction: >7 dB

Recycling rate: >80%

Temperature: ≈100°C (was <80°C, not feasible)

Energy and Emissions:

- CO - 35%
- CO₂ - 35%
- Nox - 50%
- CxHy - 80%
- SO₂ - 30%
- Energy - 35%

Test section: 1 km

Grant by European Commission: 1,3 M€

Contribution of Royal Dutch BAM: 1,3 M€
LE2AP Recycling concept

- Decompose asphalt into components

- Mortar-sand 0/2
- PA 8/16, 5/8
Mortar Design & Performance

- High quality mortar:
  - Addition of fresh Bitumen, Rejuvenators
  - Use of advanced testing methods
Mixture design

Control at 3 levels of scale:

1. Bitumen
2. Mortar
3. Mixture:

PA16 with close to 95% re-use performs better than its fresh equivalent. (Surface mixture!)
1 km long test sections (production & laying)

Gelderland: N338, 1 km

Noord Brabant: N279, 1.3 km
Future: Mortar feed unit for asphalt plants

Existing asphalt plants

BEAMER Project
Full scale mortar production & feed unit
Achievements

Noise reduction:  >7 dB 8.3-8.4 dB
Recycling:       >80% 80-93%
Temperature:    ≈100+°C (<80°C, not feasible) 100-110°C
Energy & Emission:

- CO - 35% -72%
- CO2 - 35% -51%
- Nox - 50% -85%
- Odour / CxHy - 80% -77%
- SO2 - 30% -64%
- Energy - 35% -51%

Test section: 1 km 2 x 1 km