59th Illinois Bituminous Paving Conference

11-12 December 2018

Champaign, Illinois

Experiences in Performance Assessment of Engineering Low Energy Asphalt Mixes

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National
Technical
University of
Athens

Outline

Low energy asphalt mix/ technologies

Status of knowledge
Experience of Low Energy Asphalt mix on site
Perspectives and challenges

Low Energy Asphalt mixes

Welfare of workers

***Goal**:* reduce exposure to bitumen and asphalt fumes

United Nations
Framework Convention on
Climate Change

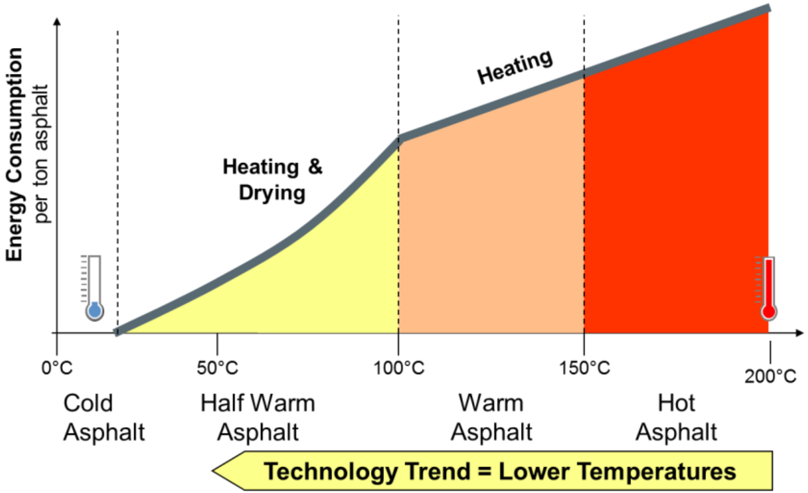
Environmental aspects (Kyoto protocol)

***Goal**:* Bring greenhouse gas emissions down to levels of 1990

Sustainable development process

Goal: Conserve resources for use by future generations

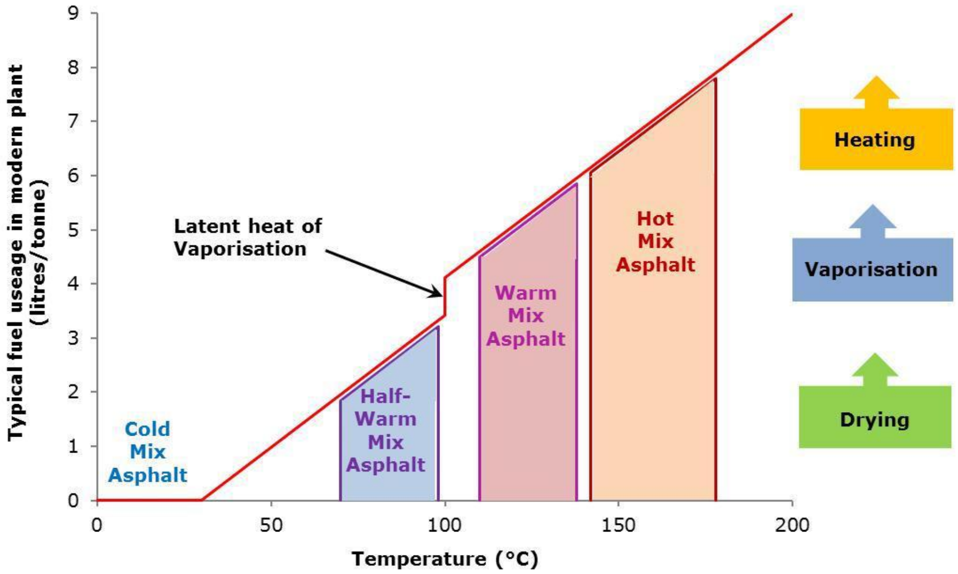
Low Energy Asphalt mixes



Low Energy Asphalt:

Incorporate technologies which **reduce the mixing** and **laying temperatures** and **energy of manufacture** of Hot Mix Asphalt

Low Energy Asphalt mixes



Warm mix asphalt (WMA): produced and mixed at temperatures of 100ºC to 140ºC

Half-warm mix asphalt (H-WMA): produced with heated aggregate at a mixing temperature (of the mixture) between approximately 70°C and roughly 100°C (below water vaporization)

Cold mix asphalt (CMA): produced with unheated aggregate and bitumen emulsion or foamed bitumen produced

Low Energy Asphalt technologies

Organic additives

- Waxes

Chemical additives

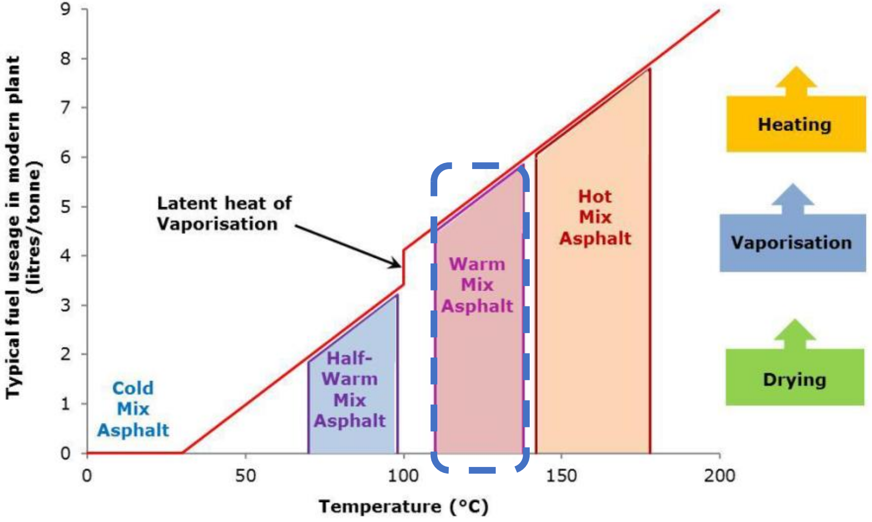
- Surfactants
- Emulsification agents
- Adhesion promoters

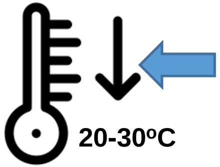
Foaming process

- Water-bearing
- Water-based coating and bitumen foaming
- Sequential aggregate coating and bitumen foaming

Emulsion

Organic additives

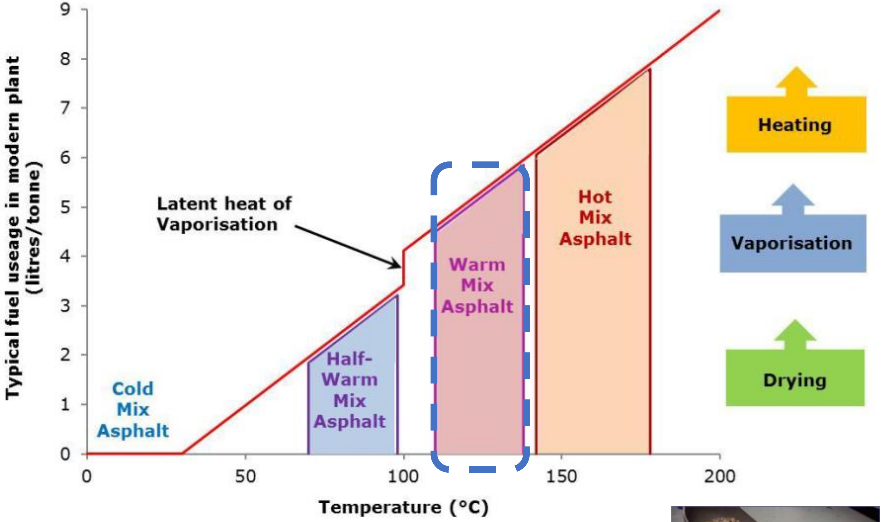


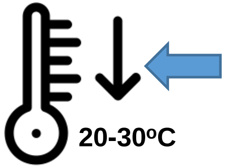


- ❑ There are several technologies available (Sasobit, Asphaltan B, LEADCAP…).
- ❑ Organic or wax additives are used to achieve the temperature reduction by reducing viscosity of binder.

Low Energy Asphalt technologies

Chemical additives

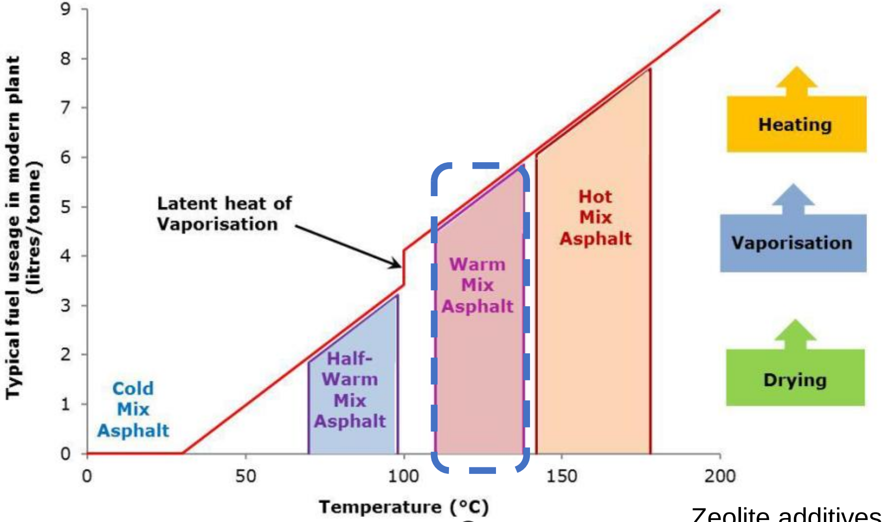


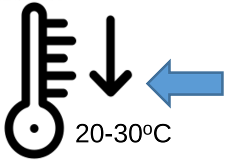


- ❑ There are several technologies available: (Evotherm, Evotherm 3G, Rediset, Cecabase…)
- ❑ These products generally include a combination of emulsification agents, surfactants, polymers, and additives to improve coating, mixture workability, and compaction, as well as adhesion promoters.

Low Energy Asphalt technologies

Foaming process

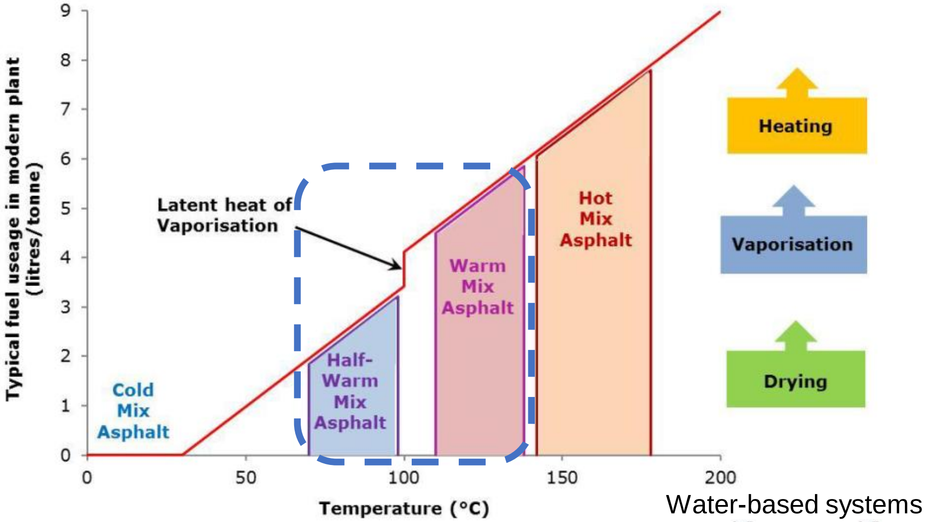


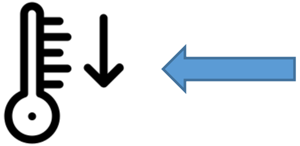


Zeolite additives

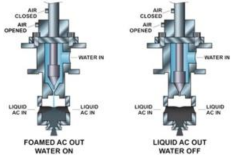
- ❑ There are several foaming technologies available that could be sub-categorised into two groups:
  - a) *water-bearing (zeolite) additives*
  - b) *water-based systems or sequential aggregate coating and binder foaming*
- ❑ The foaming action in the binder temporally increases the volume of the binder and lowers the viscosity, which improves coating and workability

Foaming process





Water-based systems



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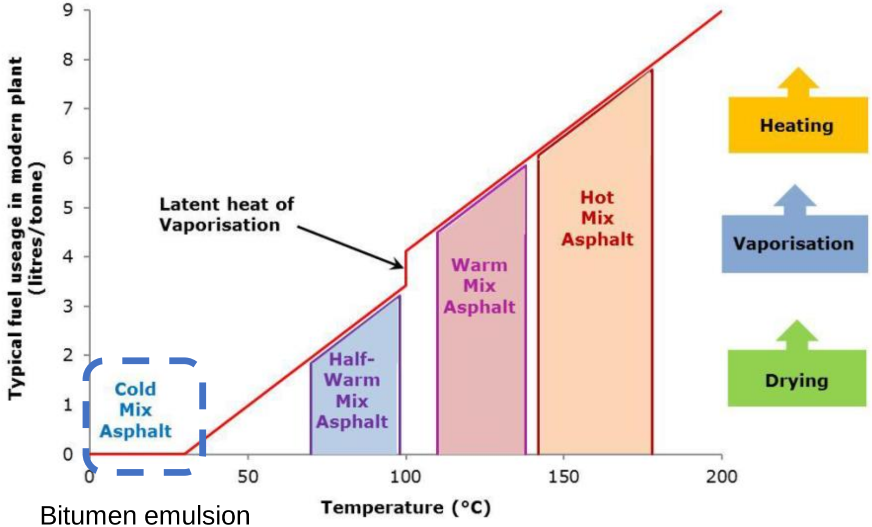
Bitumen emulsion (or Foamed bitumen)

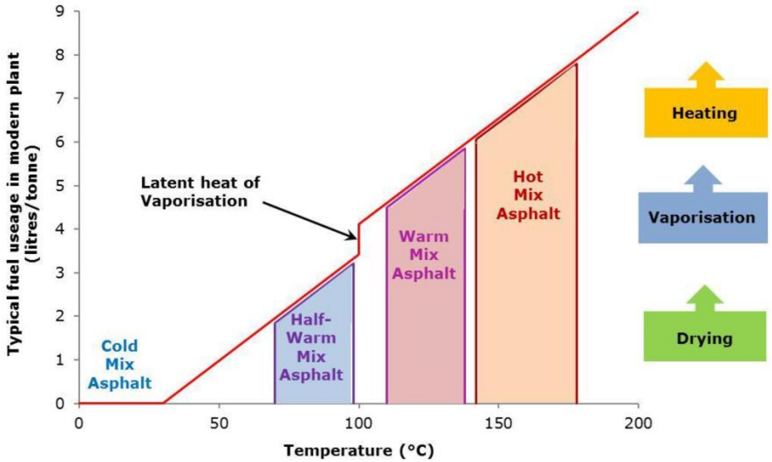


Foamed bitumen

Bitumen emulsion

❑ Bitumen emulsions (less frequently foamed bitumen) can be mixed with aggregates in ambient conditions to produce cold mix asphalt

Low Energy Asphalt mixes & technologies



Technology	Mix type application
Incorporation of organic additives	Warm Mix Asphalt
Incorporation of chemical additives	Warm Mix Asphalt
Foamed bitumen	
Water-bearing additives (such as zeolites)	Warm Mix Asphalt
Water-based/ foam generation equipment	Warm Mix Asphalt or Half-Warm Mix Asphalt
Bitumen emulsion (Foamed bitumen)	Cold Mix Asphalt

Low Energy Asphalt mixes

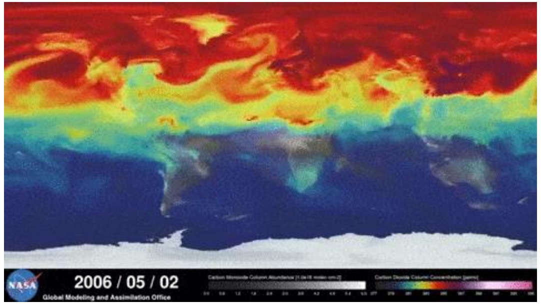
Lower energy costs

Fuel savings

Low Energy Asphalt mixes

Fumes reduction

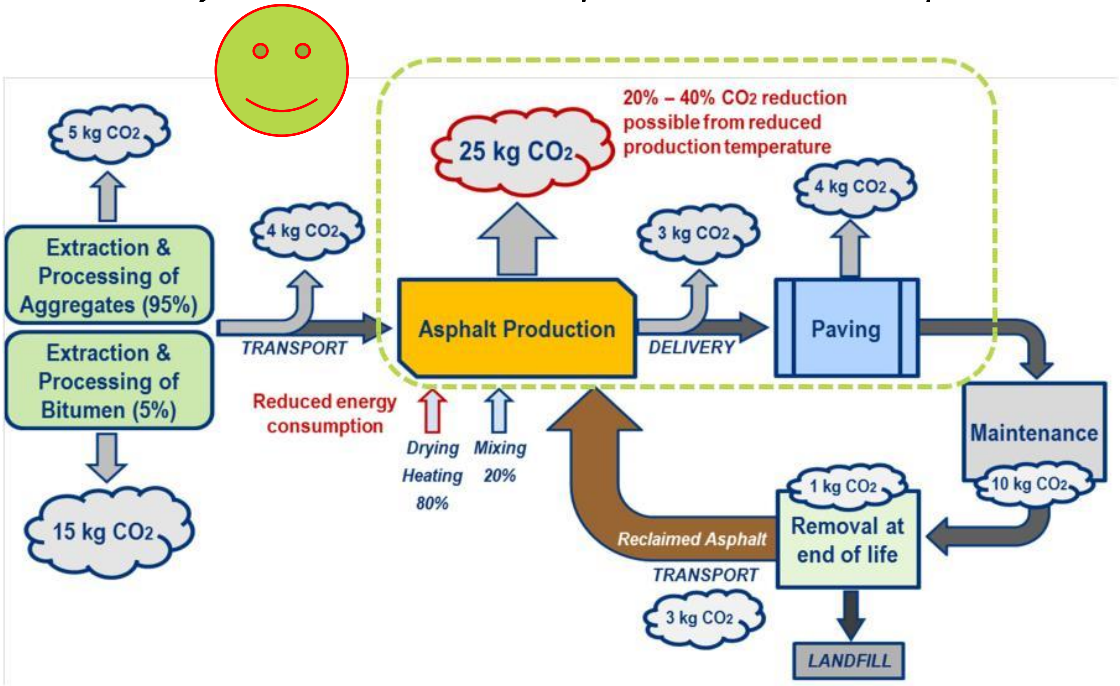
Reduced hazards for workers



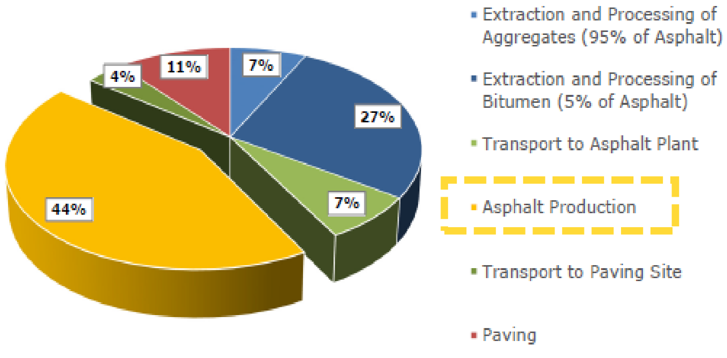
Lower carbon emissions

Low Energy Asphalt mixes

Indicative lifecycle carbon emissions for the production of one ton of asphalt



Total carbon footprint allocation for a typical road pavement project



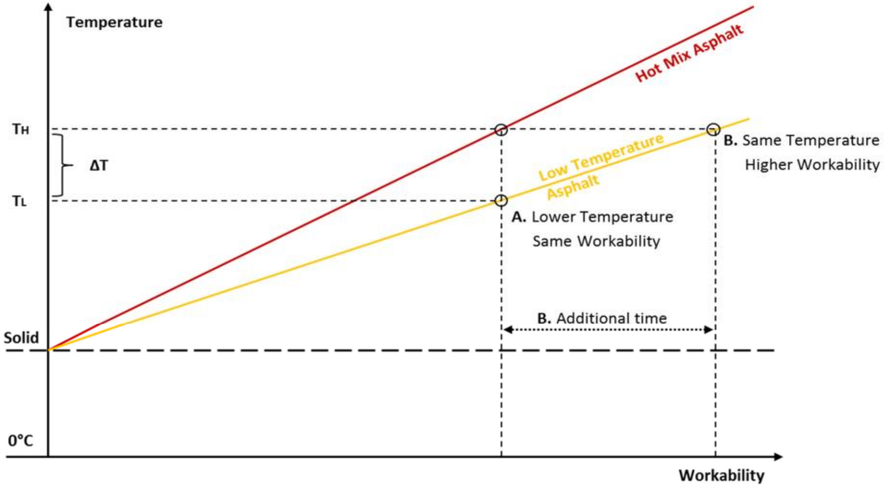
Gossling, R., and Schiavi, I. (2009) asPECT – Measuring the asphalt footprint. Presentation given at the Asphalt 2009 conference of the Asphalt Industry Alliance. Coventry, United Kingdom.

The Boston Consulting Group. (2009) Aggregates Sector Strategy Review. Final report created for the Carbon Trust. London, United Kingdom.

Low Energy Asphalt mixes

Less bitumen ageing

Compaction aid



Extend paving window

Low Energy Asphalt mixes

Lower carbon emissions

Lower energy costs

Fumes reduction

Fuel savings

Reduced hazards for workers

Compaction aid

Extend paving window

Less bitumen ageing

Outline

Why Low energy asphalt mix/ technologies

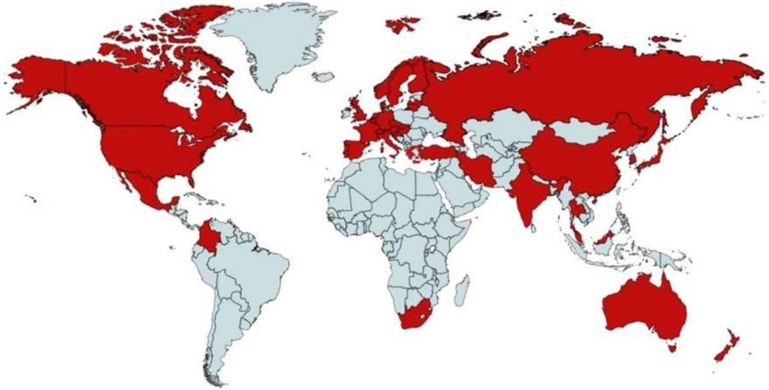
Status of knowledge

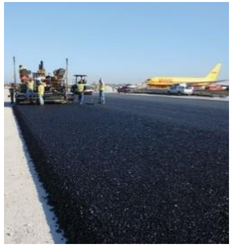
Experience of Low Energy Asphalt mix on site

Perspectives and challenges

Status of knowledge

Overview of WMA

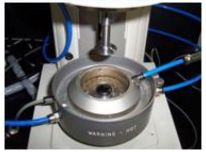


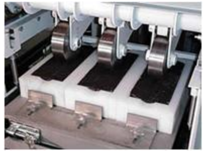


Status of knowledge

Development

- mix design and test methods (Europe, USA…)
- laboratory evaluation/ test methods

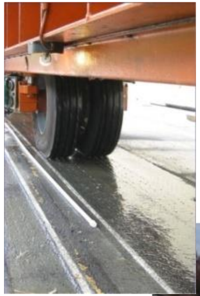
Production/ demonstration

- mixing plants
- product consistency
- contractors laying experience



Validation/ implementation

- Short- and long-term field performance
- Validate mix designs, construction standards, pavement design procedures

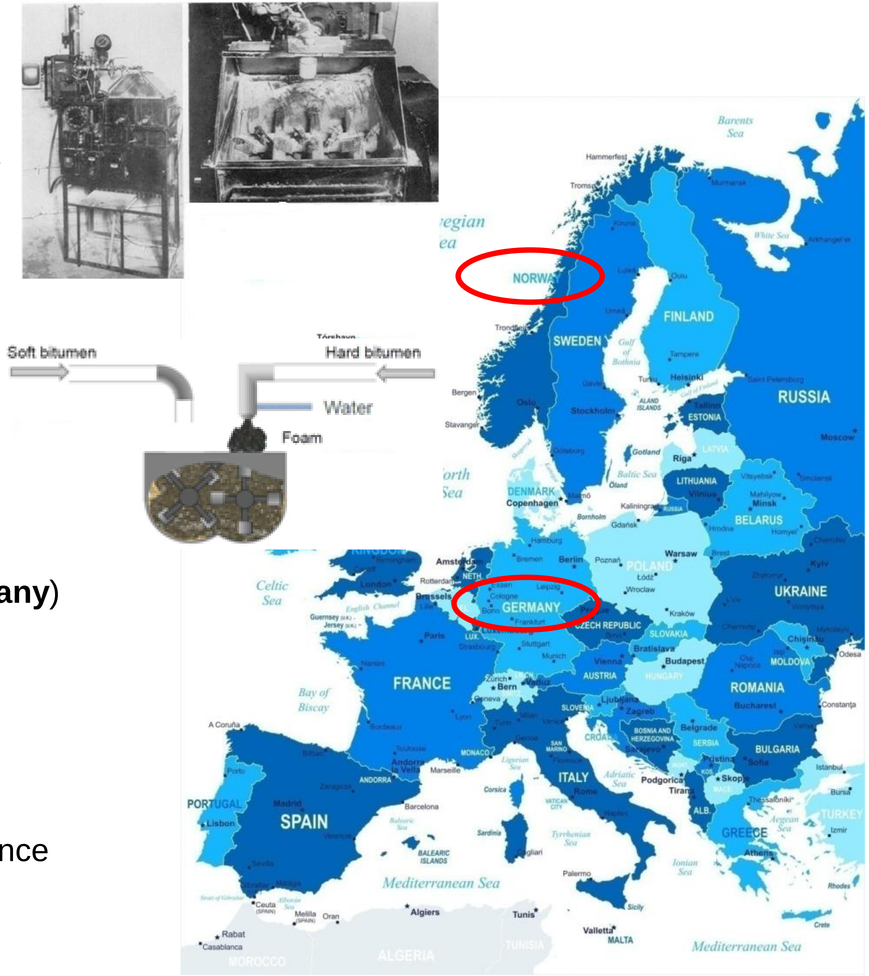



59th Illinois Bituminous Paving Conference

Status of knowledge

Brief history

- **1956**: Invention of "Foamed Asphalt" by injecting steam into hot asphalt by Prof. Csanyi (Iowa state university)
- **1968**: Mobil of Australia (Europe) acquired patent rights and modified the process by replacing it with cold water
- **1977:** Chevron developed "Mix Manual" of emulsified asphalt
- **1985:** Use of foam asphalt in RAP
- **1994:** CMA with foam asphalt
- **1995-96**: First laboratory experiments on WMA (foaming process) conducted jointly by Kolo Veidekke and Shell in Europe.
- **1997-99**: First test sections constructed in Europe (**Norway, Germany**) using WAM-Foam and organic (waxes) technologies
- **2002:** NAPA Study Tour in Europe
- **2004:** First U.S. field trials with Aspha-min
- **2007:** AASHTO/ FHWA Scan study tour in Europe
  – Visited field trial sections in Norway, Germany, and France
- **2007-17:** NCHRP initiated projects on WMA…



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Australia

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

Austroads

- ❑ Study tour in US
- ❑ Demonstration trials have been established since 2000.
  - *Typical trials include Sasobit, CECABASE and Aspha-Min.*
  - *Water-based foaming techniques (Astec Double Barrel Green, WAM-Foam).*
- ❑ Laboratory evaluation and validation trials
  - *three thin surfacings (chemical additive, polymer additive, foaming)*
  - *a hotmix asphalt 'control' surfacing*
- ❑ After 2 yrs of trafficking, no discernible difference between the WMA and HMA 'control' sections
  - *structural (strength) performance evaluation*
  - *functional (roughness, rutting, texture) performance evaluation*
- ❑ Austroads technical reports

Status of knowledge

China

- WMA was first introduced to China in 2005.
- Since 2006, WMA (mainly Evotherm) has been implemented in dozens of projects
  - *highways and dense population urban zone roads*
  - *long tunnels*
  - *bridges.*
- Reported WMA performance is satisfactory compared to HMA requirements
- WMA local specifications: 2008-2011
- National WMA specification, 2012-2013
- Challenges/ barriers
  - *No local WMA technologies*
  - *Production cost is higher than HMA/ contractors reluctancy*
  - *Need for government environmental policies/ incentives for WMA construction*

South Africa

- ❑ Warm Mix Asphalt Interest Group (WMAIG) was formulated in 2008.
  - *South African Bitumen Association (Sabita)*
  - *Road Pavement Forum (RPF)*
  - *Society for asphalt Technology (SAT)*
- ❑ Study tour in Europe
- ❑ Full-scale WMA trials (organic, chemical and foaming techniques) including HMA ‘control’ sections
- ❑ Laboratory evaluation (moisture susceptibility, rutting, modulus, fatigue) and monitoring during construction
- ❑ WMA can be produced satisfactorily using several technologies and incorporating Reclaimed Asphalt
- ❑ WMA best practice guideline based on gained knowledge and understanding

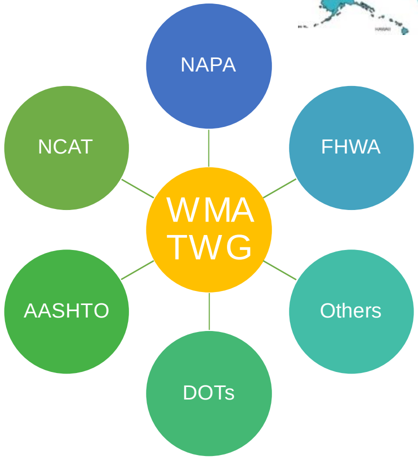
Field trials

Gained knowledge

Status of knowledge

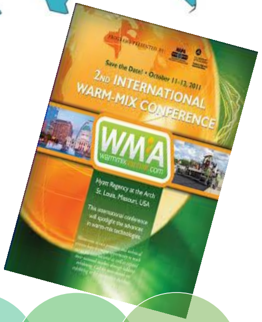
United States

- ❑ **2002** - ***NAPA Study Tour to Europe***
- ❑ 2003 - Featured at NAPA's Annual Convention
- ❑ 2004
  – Demonstration at World of Asphalt
  – First U.S. field trials (Aspha-min)
- ❑ **2005**
  – ***Warm Mix Asphalt Technical Working Group (WMA TWG)***
  – Field trials
  – NCAT reports
- ❑ 2006
  – Field trials
  – NCAT report
- ❑ **2007**
  – ***AASHTO/ FHWA Scan study tour in Europe***
  – ***NCHRP research initiated***

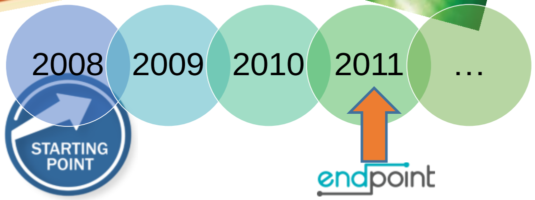


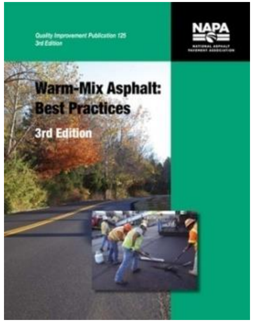
Status of knowledge

United States



- ❑ 2008
  - – Documented WMA trials in 32 states
  - – 13 WMA technologies marketed in the US
  - – *1st International WMA Conference in Nestville,Tennessee*
- ❑ 2010
  - – Documented WMA trials in 45 US States and all 10 Canadian providences
  - – 30 U.S. States and Canadian Provinces have specifications for WMA
  - – Over 20 WMA technologies marketed in the U.S.
- ❑ 2011
  - – all 50 states had conducted trials of WMA
  - – *2nd International WMA Conference in St Liouis, Missouri*
  - – ***NCHRP research programs initiated***
- ❑ 2012
  - – NAPA publications update for WMA best practices



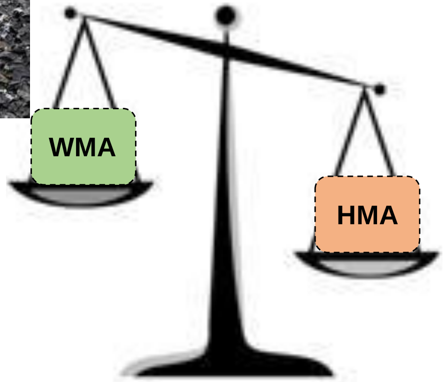


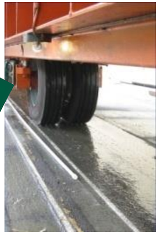
Status of knowledge

United States

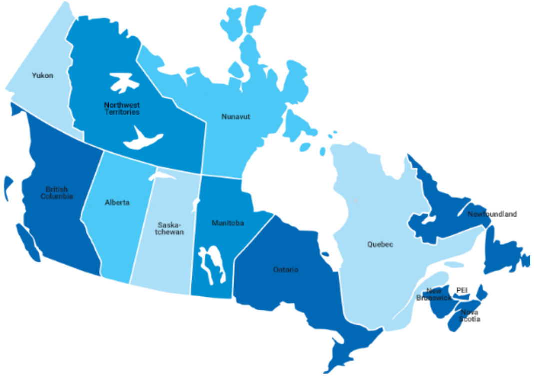
- ❑ NCHRP WMA-based research programs/ Issues addressed:
– mix design and aging conditioning protocols
– critical engineering properties: moisture susceptibility, rutting
– emissions
– short- and long-term performance in comparison with HMA
– RAP/ RAS incorporation challenge

Overall performance





Canada



- **2005**

Three trial sections of WMA were placed in Montreal, using Aspha-min zeolite

- **2006**

Three other projects were laid using Aspha-min. The first was a demonstration project, placed using 280 tons of WMA.

Other 2 projects were constructed later with temperatures ranging between 0 and 5°C. Zeolite was incorporated into the control HMA and a significant improvement in compaction was reported.

- **2005 & 2007**

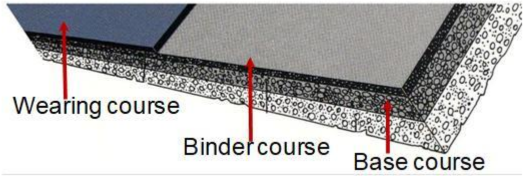
Seven demonstrations of the Evotherm technology were conducted consuming nearly 10,000 tons of warm mix.

Status of knowledge

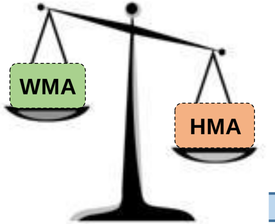
Europe

- ❑ Full-scale WMA trials including HMA 'control' sections
- ❑ Laboratory and field investigations
- ❑ WMA can be produced satisfactorily using several additives, except for foaming techniques
- ❑ Reduction of fumes and aerosoles
- ❑ Bulletin issued which lists the 'certified' additives for incorporation in different asphalt mixes types

bast
Bundesanstalt für Straßenwesen



Overall performance



		SmB 35 B (preblended Sasobit)	50/70 Pen + 4% Sasobit	50/70 Pen + Asphaltan B B193	50/70 Pen + Asphaltan B L 303	50/70 Pen + Aspha-min B3	Sübit VR 45 B283
Section Number		1	2	3	4	5	6
Field measurements	Rutting	Equal	Equal	Equal	Equal	Equal	Equal
	Post compaction densification	Equal	Better	Equal	Better	Better	Equal
	Cracking	Equal	Equal	Equal	Equal	Equal	Equal
Laboratory Investigations	Thermal stability	Better	Better	Equal	Better	Equal	Better
	Low temperature performance	Equal	Equal or Better	Equal	Equal	Equal or Better	Equal or Better
	Binder aging	Equal or Better	Equal or Better	Equal or Better	Equal or Better	Equal	Equal
	Adhesion	Equal or Better	Equal or Better	Better	Equal	Equal or Better	Equal or Better

Combined with RAP

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Europe

Frankfurt Airport example

WMA Rehabilitation

- ❑ Rehabilitation included **29cm of WMA**
- ❑ **Paving window 7.5 hours**
- ❑ **Immediately opened to jet aircraft traffic at a temperature of 85˚C without deformation**

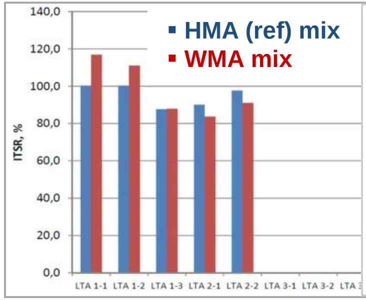
Europe

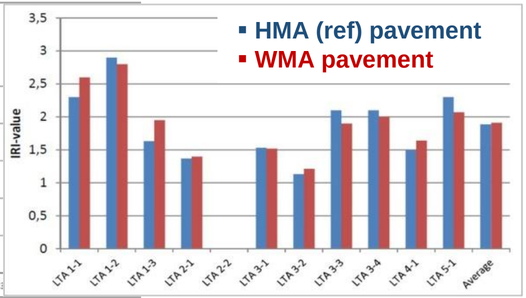
- ❑ First WMA trials using foaming techniques including HMA ‘control’ sections
  - Laboratory investigations (resistance to deformation, abrasion and fatigue)
  - Field investigations (rut depth, longitudinal smoothness and surface texture)
  - Equal performance to HMA
- ❑ Norwegian WMA project, **Low Temperature Asphalt 2011**
  - *Evaluation of asphalt quality when changing from HMA to WMA (difference 30ºC)*
  - *Analysis of working environment and ergonomic working conditions when laying WMA and HMA*

Norway

Statens vegvesen

Norwegian Public Roads Administration





- **no** significant **differences** in **mix properties**
- **no** significant **differences** in field **rutting** and **roughness**

- significant **reduction** in **asphalt fumes and vapour**
- no difference in the **mechanical exposures** (in terms of heart rate and push-and-pull forces) by hand laying of HMA and WMA

Status of knowledge

Europe

France

- ❑ Laboratory evaluation and environmental assessment

(workability, compactability, water and rutting resistance, stiffness modulus / fatigue resistance)

- ❑ Field trials are undertaken; if successful, guidance papers are prepared for use of the product

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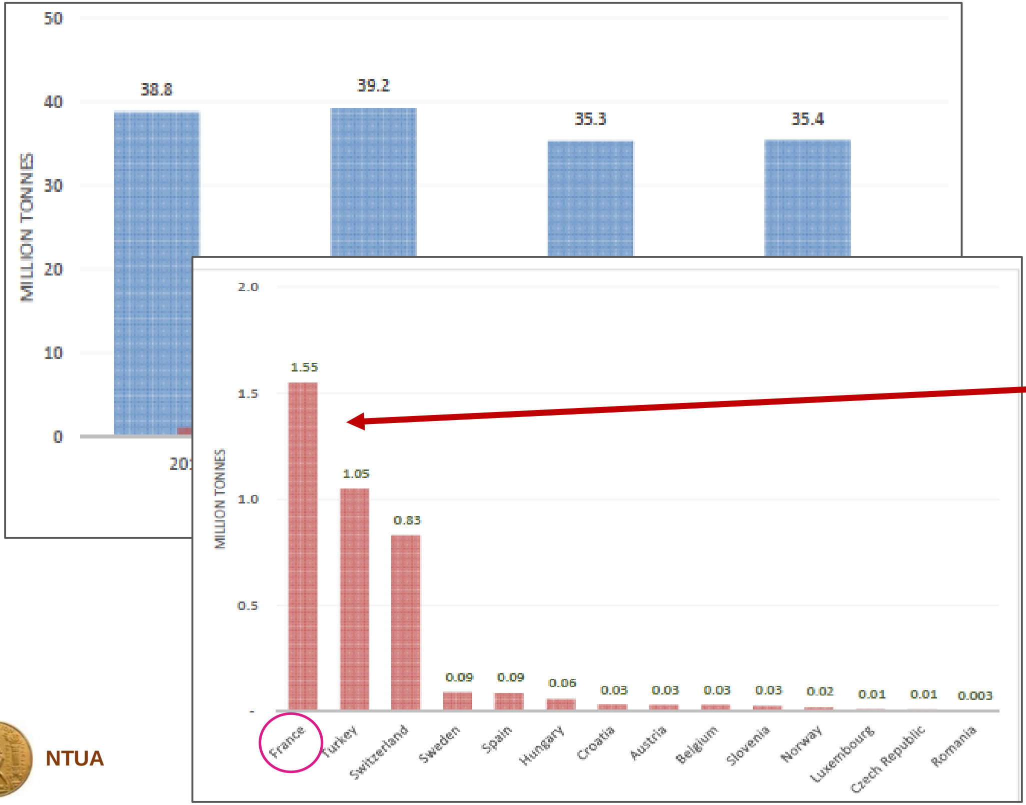
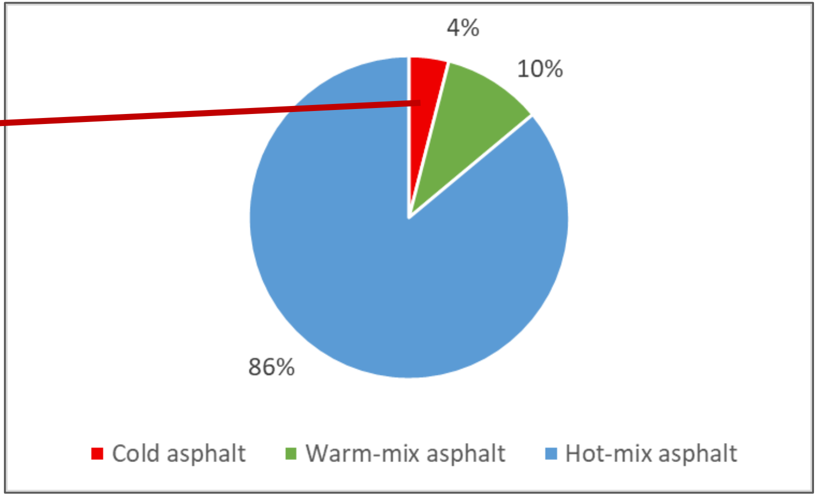
Status of knowledge

Europe

Production of warm and hot mix asphalts in France





France

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Status of knowledge

Low Energy Asphalt Mixes

Europe

1 Evidence of performance

- Technology is still under-utilized in the UK.
- Nevertheless, the use of low energy mixtures is now slowly increasing as the industry has become more familiar about its presence and performance.
- Asphalt suppliers and research organizations are increasingly confident about understanding its durability.

2 Knowledge and understanding

- New trials made on various types of road have been documented and specifications are now being developed to include lower temperature asphalt technologies.

3 Design guidance

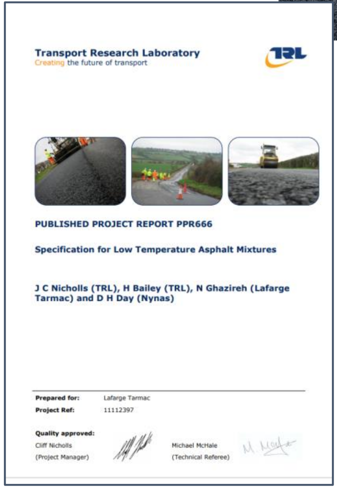
- An increasing number of documents are being released to help understand these new products.

4 Affordability

- Lower temperature asphalts could even become slightly cheaper as demand and production increase.

5 Specification

- TRL developed the new document, "**Specification for Low Temperature Asphalt Mixtures**", may assist designers and specifiers


Transport Research Laboratory
Creating the future of transport
TRL

PUBLISHED PROJECT REPORT PPR666

Specification for Low Temperature Asphalt Mixtures

J C Nicholls (TRL), H Bailey (TRL), N Ghazireh (Lafarge Tarmac) and D H Day (Nynas)

Prepared for: Lafarge Tarmac
Project Ref: 11112397

Quality approved:
Cliff Nicholls (Project Manager)
Michael McHale (Technical Referee)

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Low Energy Asphalt Mixes

Europe

Netherlands

- ✓ Local authorities use environment criteria in their bids to select asphalt. The point system was put in place by the government; CO_2 criteria weight can be up to 10%, thus increasing the chance to win tenders.
- ✓ Foaming technique is used, which is sold at the same price as HMA. Asphalt also typically contains a lot of reclaimed asphalt.
- ✓ BAM Group is currently undertaking a project part-funded by the EU (Life+ LE2AP) with the goal to pave 1 km of road containing 80% reclaimed asphalt and produced at 80°C.

Czech Republic

- ✓ Preliminary national specifications for Low Energy Asphalt Mixes published by the Czech Ministry of Transport in 2012.
- ✓ In 2013, an important road tunnel in Prague was paved using it.
- ✓ A couple of other research projects focusing on the development of Low Energy Asphalt Mixes started in 2013.

Low Energy Asphalt Mixes

Europe

Switzerland

- ✓ Individual asphalt producers and contractors are promoting these technologies.
- ✓ In 2013, 870,000 tons of WMA and 830,000 tonnes of cold asphalt were produced in Switzerland, making the country the 2nd largest producer of lower energy asphalt mixtures in Europe.
- ✓ Research project underway to include them in the standards .

Sweden

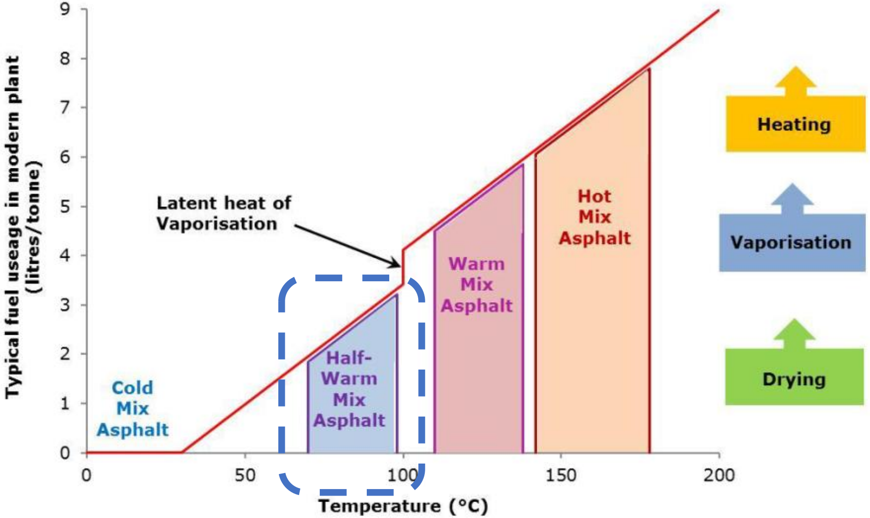
- ✓ In 2013, Sweden produced about half a million tons of them.

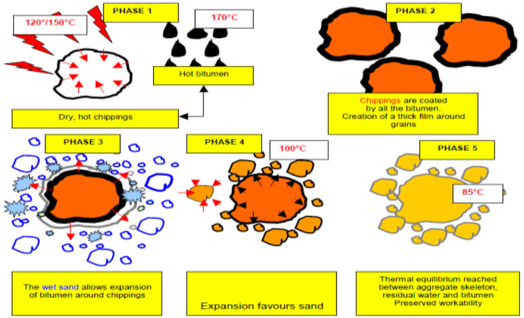
Denmark

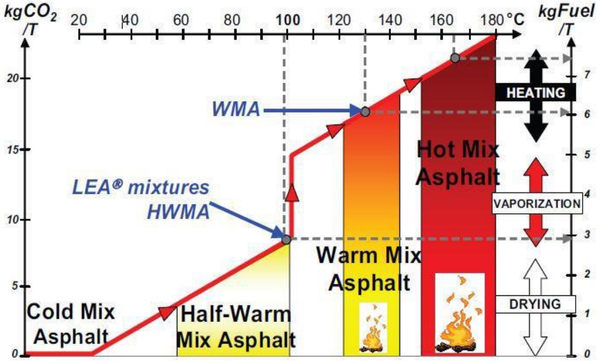
- ✓ Paved a motorway in 2012 and obtained very satisfactory results.
- ✓ NCC has paved many other sections since then.

Others …

Half-Warm Mix Asphalt







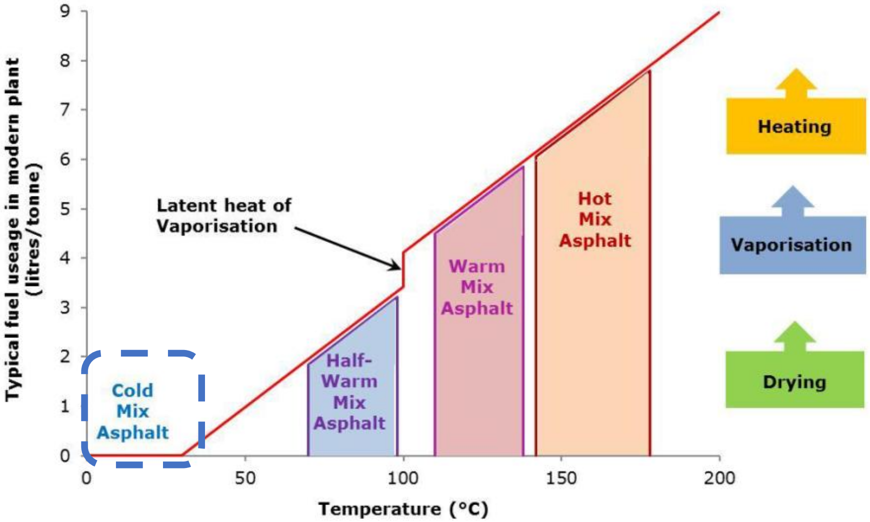
Types of asphalt technology energy consumption (Olard. F., et al., 2008)

- ❑ Generally, sequential aggregate coating and bitumen foaming process is followed for developing H-WMA.
- ❑ Use of cold and wet sand and/or aggregates partially dried/ Vaporization of water allowing bitumen foaming
- ❑ Technologies developed in France (Low Energy Asphalt: LEA), but limited use (France, Netherlands…)

Cold Mix Asphalt

Foamed bitumen

Bitumen emulsion

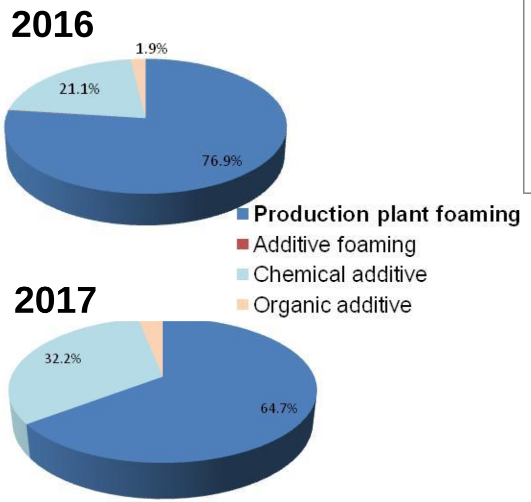


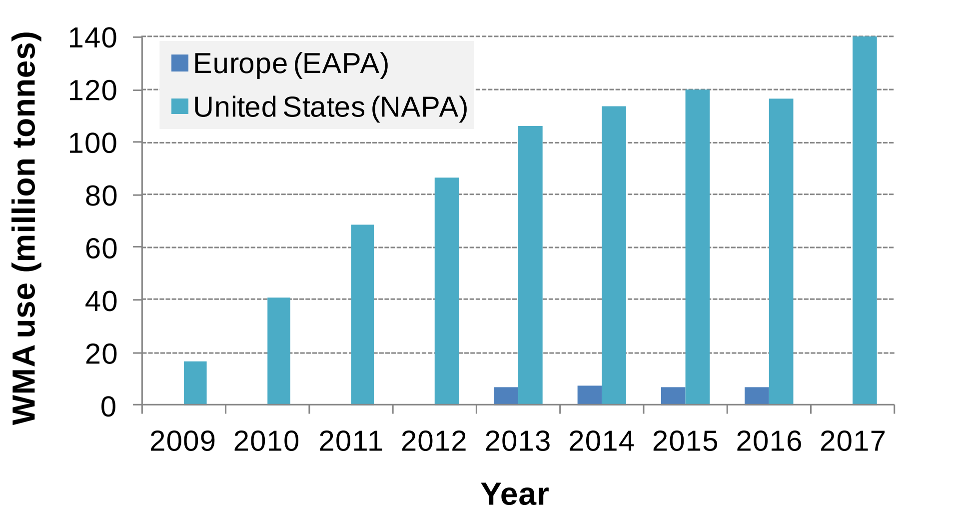
- There are still concerns (e.g. high air-void, moisture damage resistance, long curing times required to achieve maximum performance etc) which reduce its widespread usage in asphalt layers
- General use for preservation/ surface dressings or for light traffic roads
- More research is needed to develop high-quality CMA towards enhance applicability due its greatest environmental impact

59th Illinois Bituminous Paving Conference

Status of knowledge

Low Energy Asphalt Mixes





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Status of knowledge

Low Energy Asphalt Mixes

Europe

Chemical and organic additives were initially mainly used

Typically add about $3 per ton to the cost of asphalt, thus **making these methods more expensive in the long term**

USA

Mainly focused on foaming techniques

- ✓ *Today, almost **90% of the US market uses foaming**.*

An initial capital investment **usually ranging between $30,000 and $70,000** per plant

Criteria for asphalt performance

Status of knowledge

Low Energy Asphalt Mixes

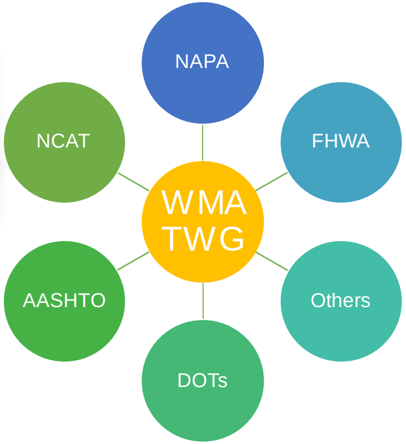
Incentives	Disincentives
Strategic research projects and multiple stakeholders	National level projects
Multiple implementation & validation test sites/ Short- and long-term performance evaluation	Industry-driven demonstration sites/ limited evidence of durability
Dissemination (conferences, meetings…)	Limited data and information exchange
Guidelines and specifications	CE performance-based mandate/ Absence of CEN specifications (ref. HMA)
Additional production cost is compensated from field compaction-based bonuses	No cost affordability

59th Illinois Bituminous Paving Conference

Status of knowledge

Low Energy Asphalt Mixes

Strategic policy



EAPA

cen

FEHRL

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Outline

Why Low energy asphalt mix/ technologies
Status of knowledge
Experiences of Low Energy Asphalt mix on site
Perspectives and challenges

International Conference

BCRRA 2017

www.bcrra2017.com

Feasibility study on a thermoset polymer-coated emulsified warm-mix asphalt mixture
Yoo, P.J., Ohm, B.S., Park, K.S. and Al-Qadi, I.L.

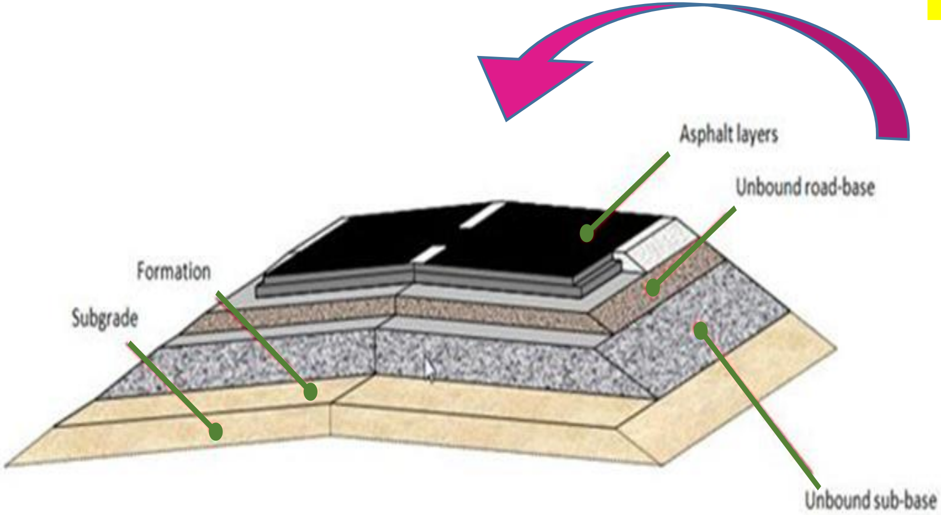
Effect of compaction temperatures on the warm mix asphalt volumetrics and stability
Ozturk, H.I., et al.

- ✓ *Turkey experience*

Performance evaluation of a 100% recycled asphalt pavement mixture using a polymer binder: A pilot study
Hajj, E.Y. , et al.

- *Also others in Conferences and International Journals….*

Experience on Low Energy Asphalt mix on site



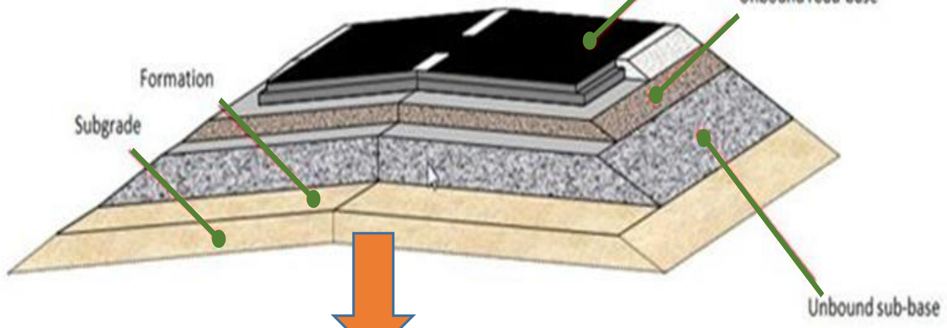
Materials/ technologies used

Lab performance assessment

Accelerated tests

Experience on Low Energy Asphalt mix on site

Material performance / technique usability



Performance concerns

- ❑ Moisture susceptibility
- ❑ Rutting potential
- ❑ Cracking resistance ?

Incorporation of RAP

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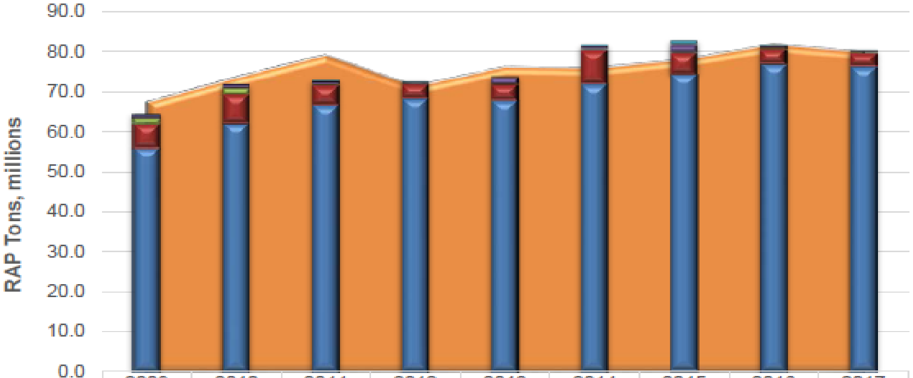
Use of RAP

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage, 2017

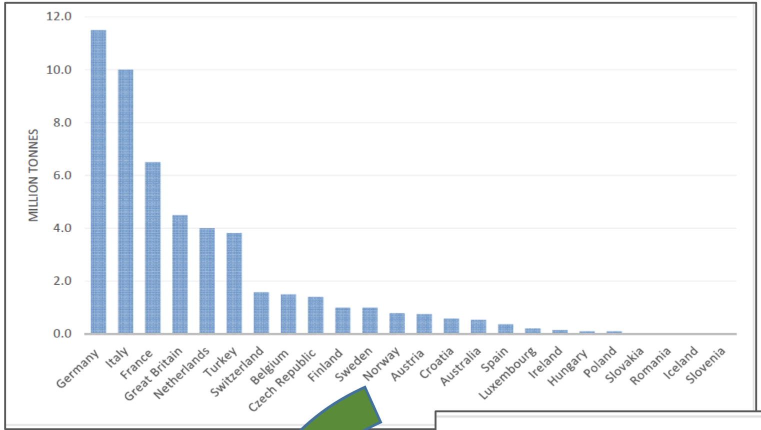


	2009	2010	2011	2012	2013	2014	2015	2016	2017
Accepted	67.2	73.5	79.1	71.3	76.1	75.8	78.0	81.8	79.9
Landfilled	0.1	0.0	0.3	0.2	0.1	0.2	1.0	0.1	0.0
Used in Other	0.7	0.8	0.7	0.2	1.5	0.6	1.6	0.4	0.2
Used in Cold Mix	1.5	1.6	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Used in Aggregate	6.2	7.3	4.9	3.6	4.0	8.5	5.5	3.7	3.4
Used in HMA/WMA	56.0	62.1	66.7	68.3	67.8	71.9	74.2	76.9	76.2

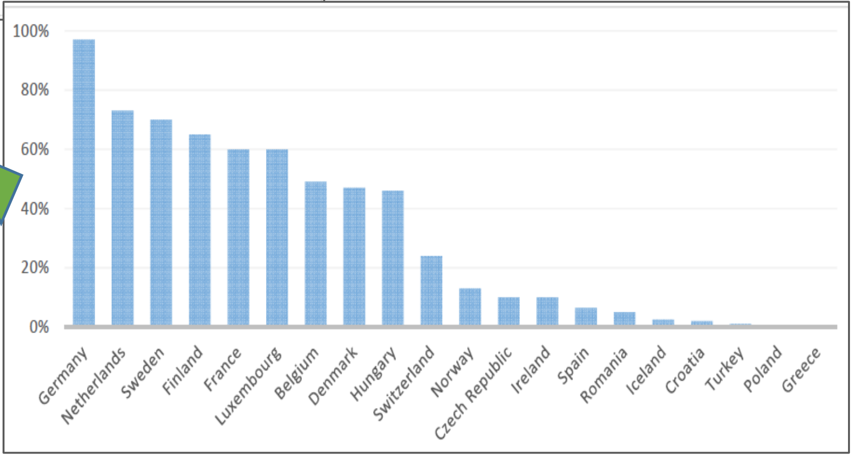
Experience on Low Energy Asphalt mix on site

Use of RAP

RAP in Europe in 2012



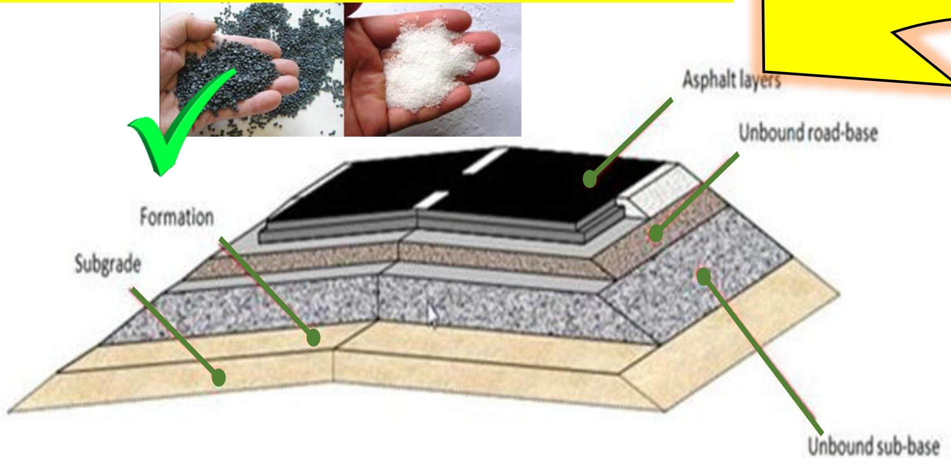
% RAP used for HMA/ WMA production (2012)



- ✓ Germany and the Netherlands have the highest recycling rate of available reclaimed asphalt in Europe.

Experience on Low Energy Asphalt mix on site

Material performance / technique usability



Long term performance assessment

?

Field

❑ Laboratory evaluation

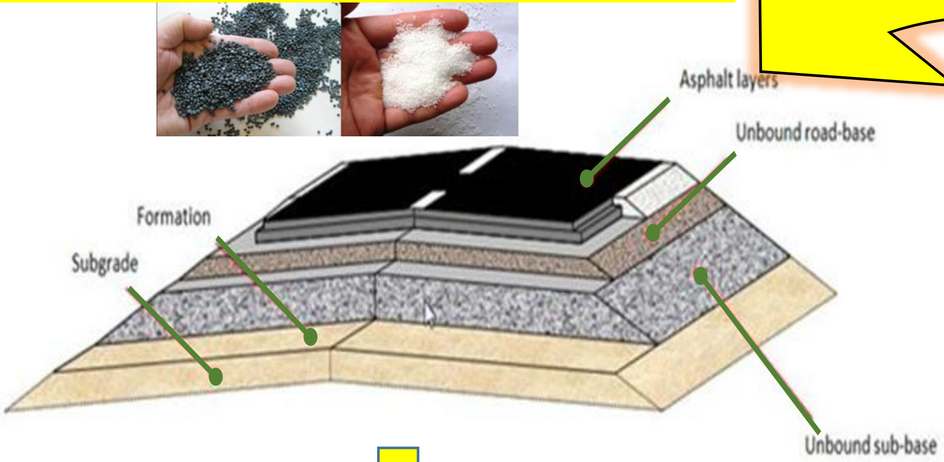
- *Mix design (RAP/RAS)*
- *Samples fabrication and conditioning (ageing regimes)*
- *Performance criteria*

❑ M-E Pavement design

- *Performance indicators prediction*

Experience on Low Energy Asphalt mix on site

Material performance / technique usability



Long term performance assessment

Field

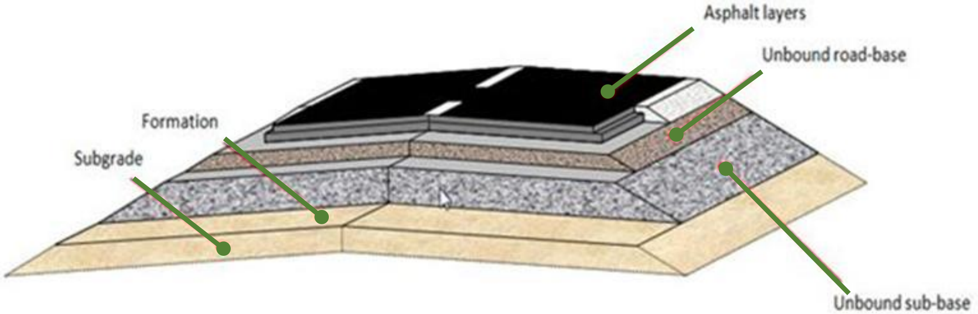
?

Structural performance + **Functional performance** =

Pavement Condition Assessment

Pavement Sustainability

Long-life pavements

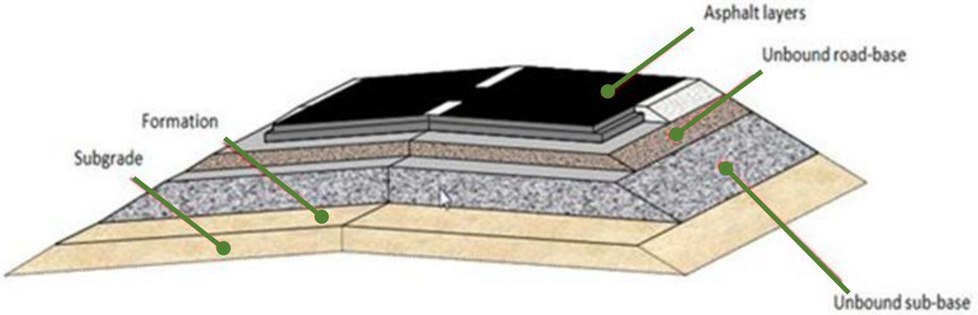


A sustainable pavement may be defined as "*a pavement that minimizes environmental impacts through the reduction of energy consumption, natural resources and associated emissions while meeting all performance conditions and standards*."

Low Energy Asphalt mixes ?

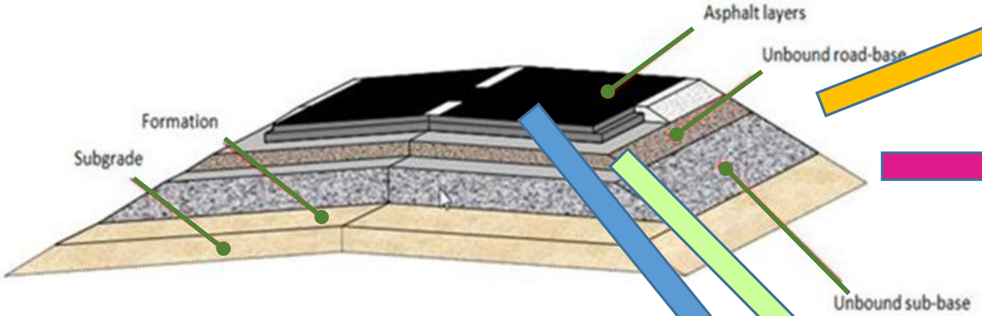
Pavement Sustainability

Long-life pavements



Pavement Sustainability

Long-life pavements



Limit distresses
on surface layer

Pavement structure
- ✓ low energy
- ✓ cost-effective
- ✓ durable & highest-performing

Suitable materials selection
- ❑ asphalt layers
- ❑ base-subbase layers

Low energy mix with foamed bitumen (foamix) suitability ?

Outline

Why Low energy asphalt mix/ technologies

Status of knowledge

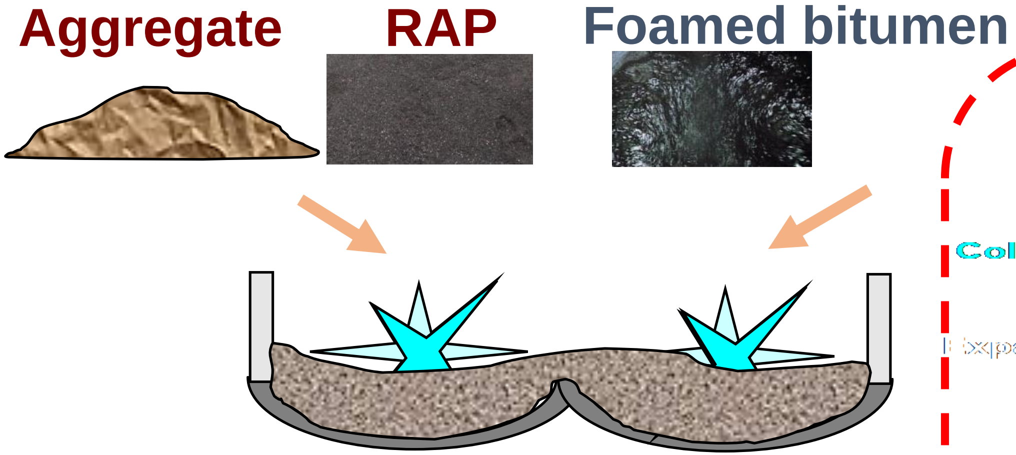
Experience of Low Energy Asphalt mix on site

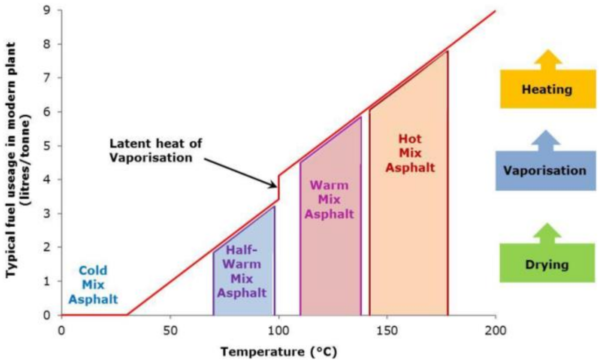
- **Foamed Asphalt mix**

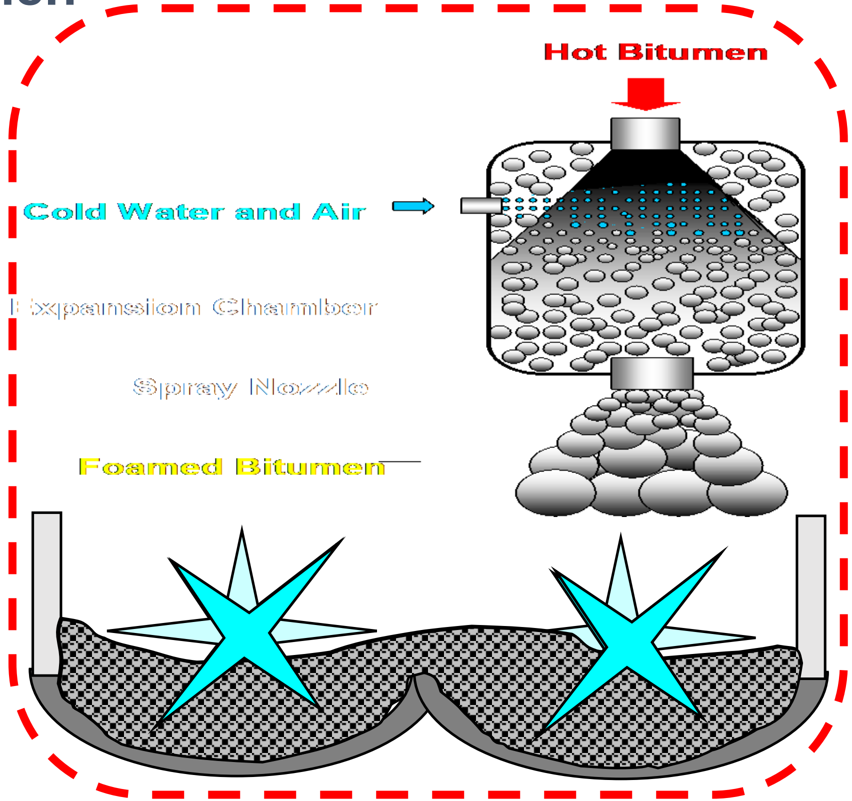
Perspectives and challenges

Experience on Low Energy Asphalt mix on site

Foamed Asphalt mix (Foamix)







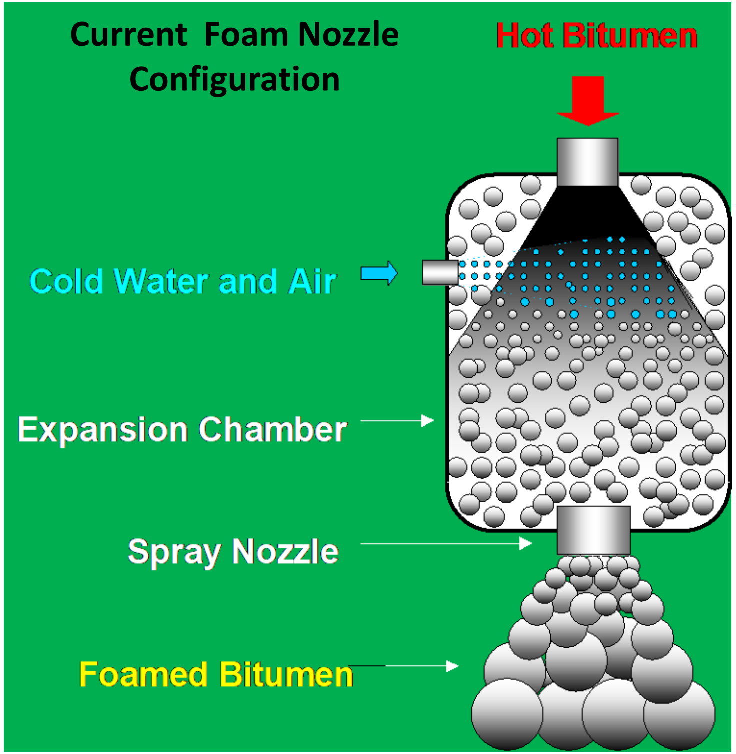
Foamed bitumen/ Foamed Asphalt mix

- ❑ Produced by a process in which water (typically 2 %) is injected into the hot bitumen, resulting in spontaneous foaming and temporary alteration of physical properties of bitumen

- ❑ Water, on contact with hot bitumen is turned into vapour, which is trapped in thousands of tiny bitumen bubbles

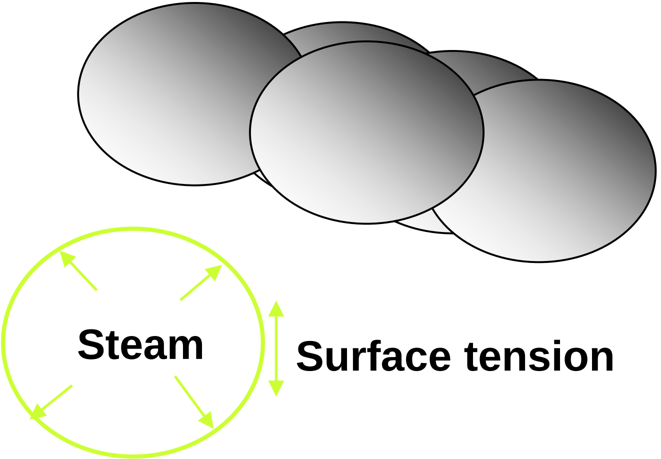
- ❑ Foam dissipates in a very short time in less than a minute and the original properties of bitumen are regained

- ❑ Incorporating foamed bitumen into the aggregates produces foamed asphalt mix (foamix)



Foamed bitumen

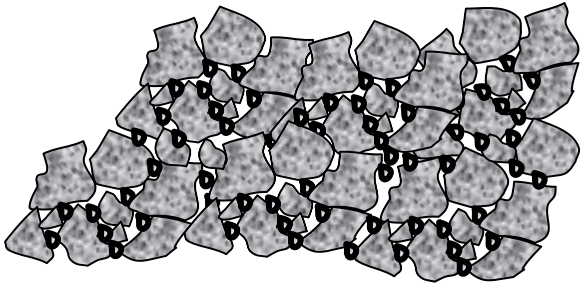
BUBBLES - as in "bitumen cappuccino"



Foamed Asphalt mix (foamix)

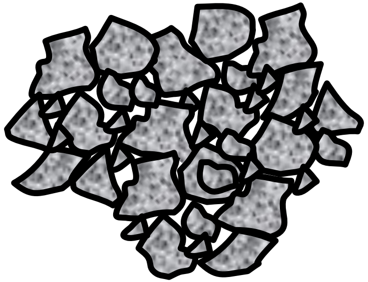
Foamed Asphalt mix

Non-continuously bound



Asphalt mix

Continuously bound



DIFFERENT BEHAVIOUR PATTERNS

- *Non-continuously bound (spot welds)*
- *Millions of individual visco-elastic points*
- *Stress dependent behaviour (granular)*
- *Fine particles immobilised (durability)*

Outline

Why Low energy asphalt mix/ technologies

Status of knowledge

Experience of Low Energy Asphalt mix on site

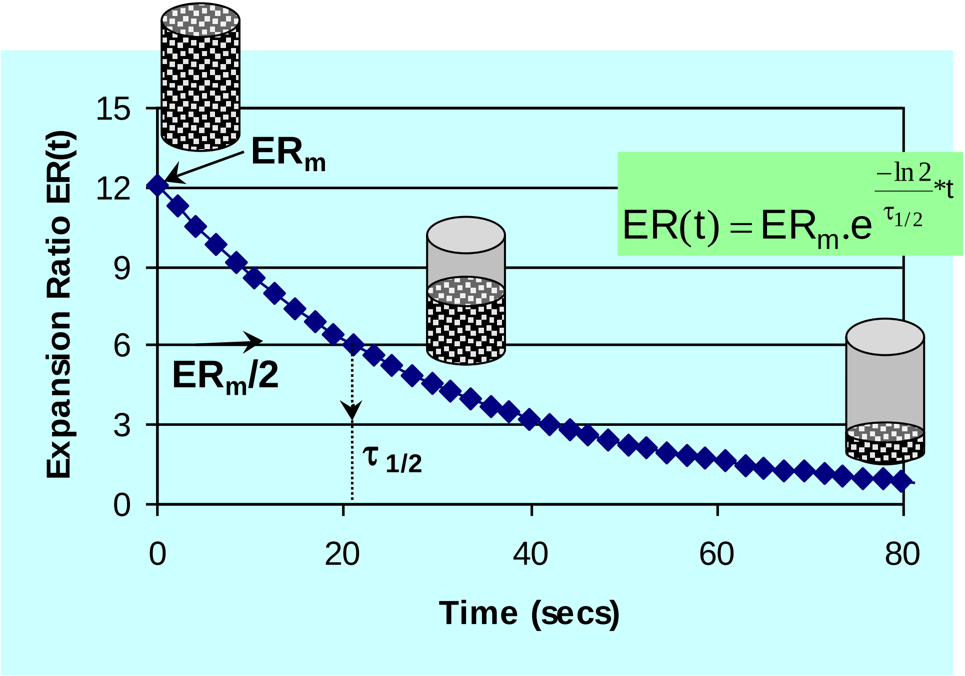
- Foamed Asphalt mix
- **Laboratory design and mix optimization**

Perspectives and challenges

Experience on Low Energy Asphalt mix on site

Laboratory design and mix optimization

Foamability



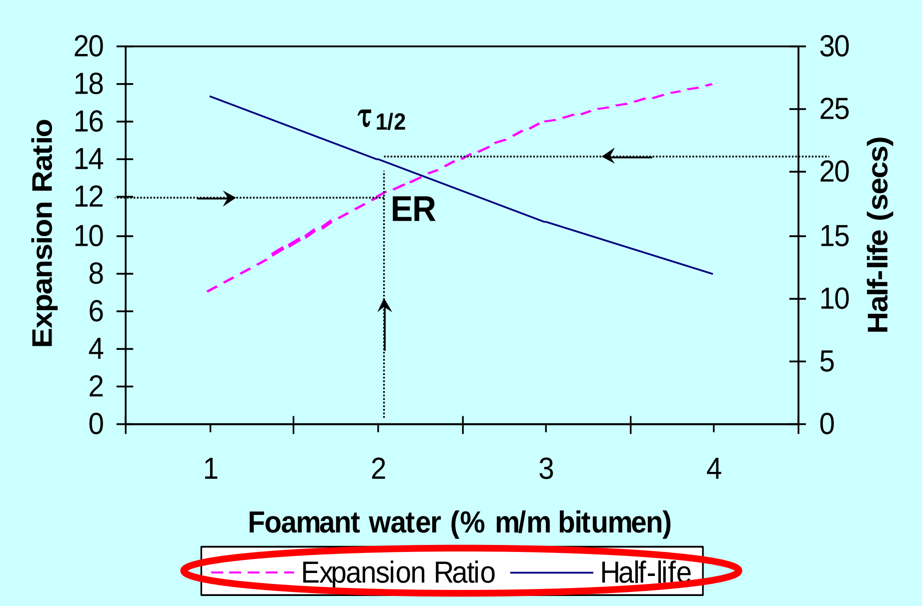
<u>Foamability</u> of bitumen is characterized in terms of **expansion ratio (ER)** and **half-life (HL)**

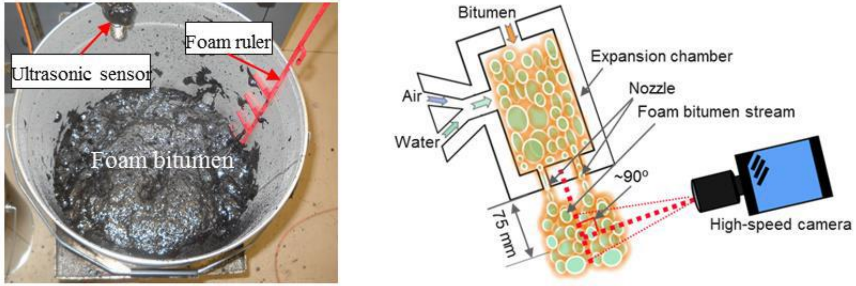
- ***ER***: *Ratio between the maximum volume achieved in the foam state and the initial volume of the binder*
- ***HL ($\tau_{1/2}$)***: *Time between the moment the foam achieves maximum volume and the time it dissipates to half of the maximum volume*

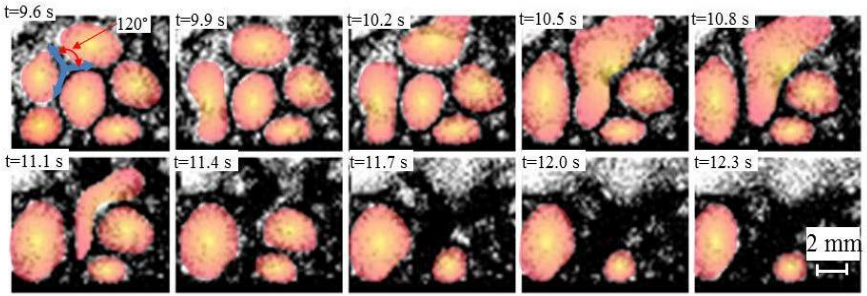
Experience on Low Energy Asphalt mix on site

Laboratory design and mix optimization

Foamability optimization





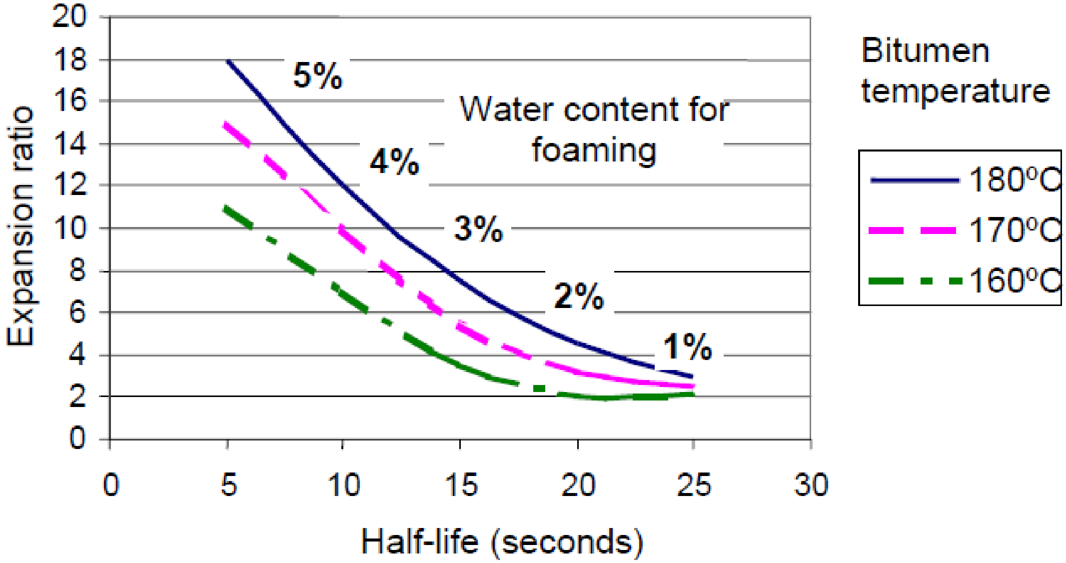


Hailesilassie B.W., Thesis, Stockholm, Sweden, April 2016

"Morphology Characterization of Foam Bitumen and Modeling for Low Temperature Asphalt Concrete"

Laboratory design and mix optimization

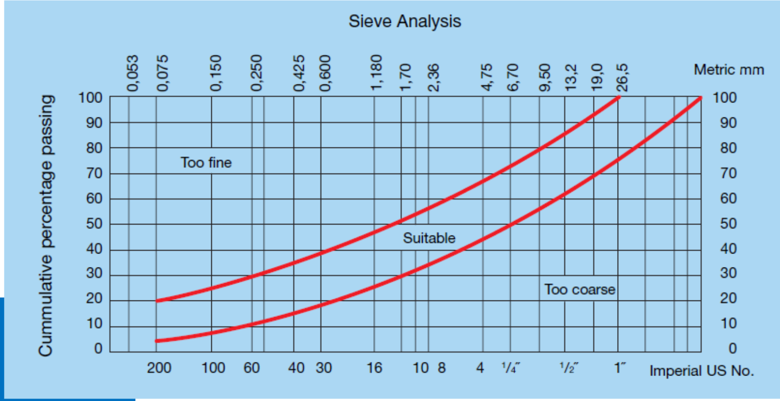
Foamability optimization- Effect of water content and bitumen temperature

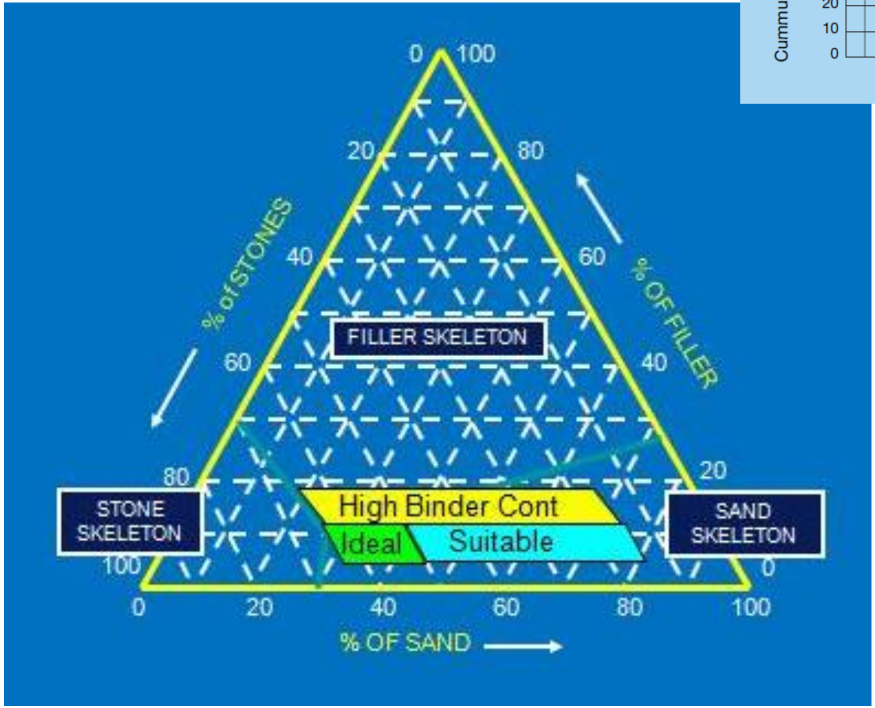


Experience on Low Energy Asphalt mix on site

Laboratory design and mix optimization

Aggregate Skeleton Composition





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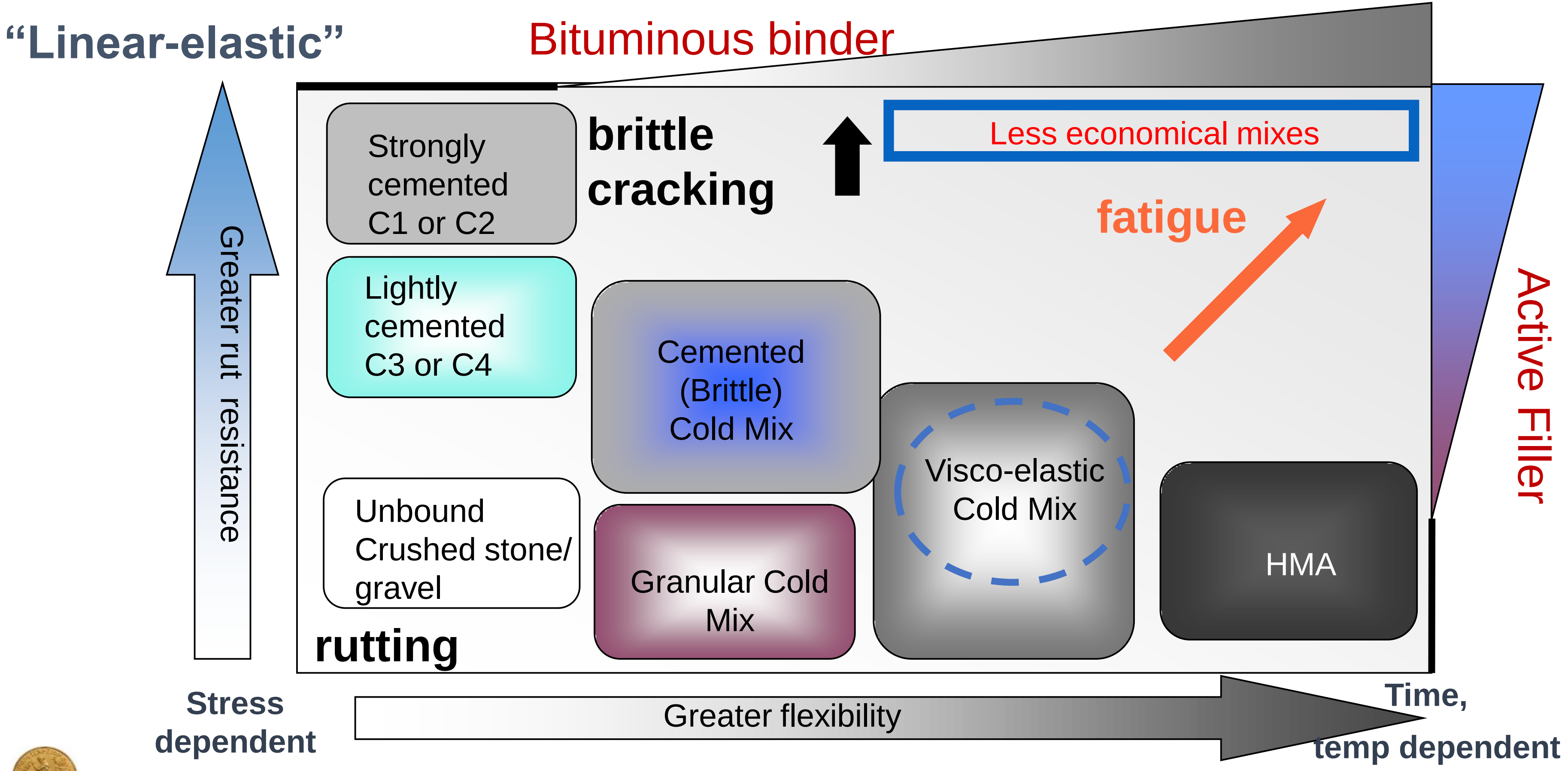
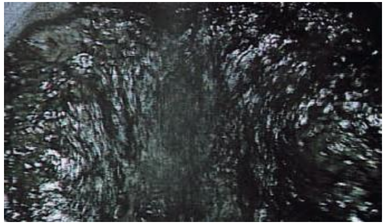
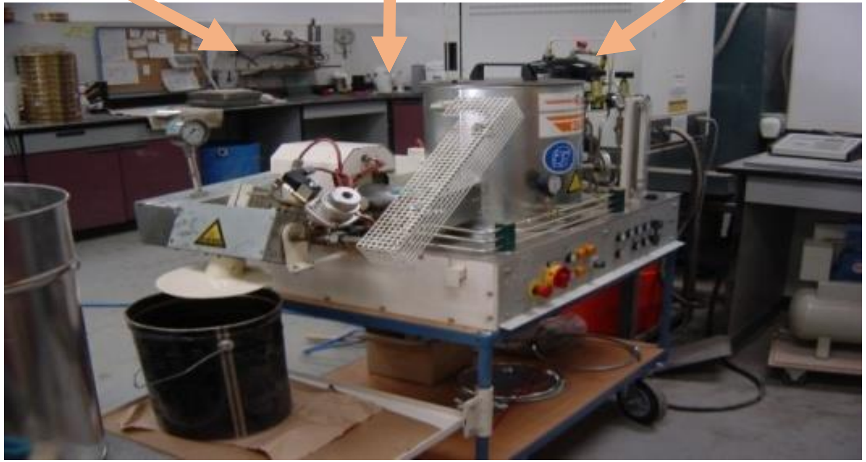
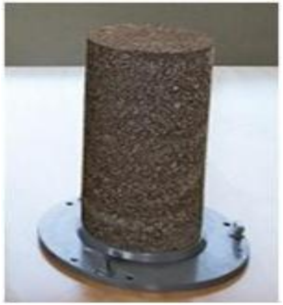
Experience on Low Energy Asphalt mix on site



Experience on Low Energy Asphalt mix on site

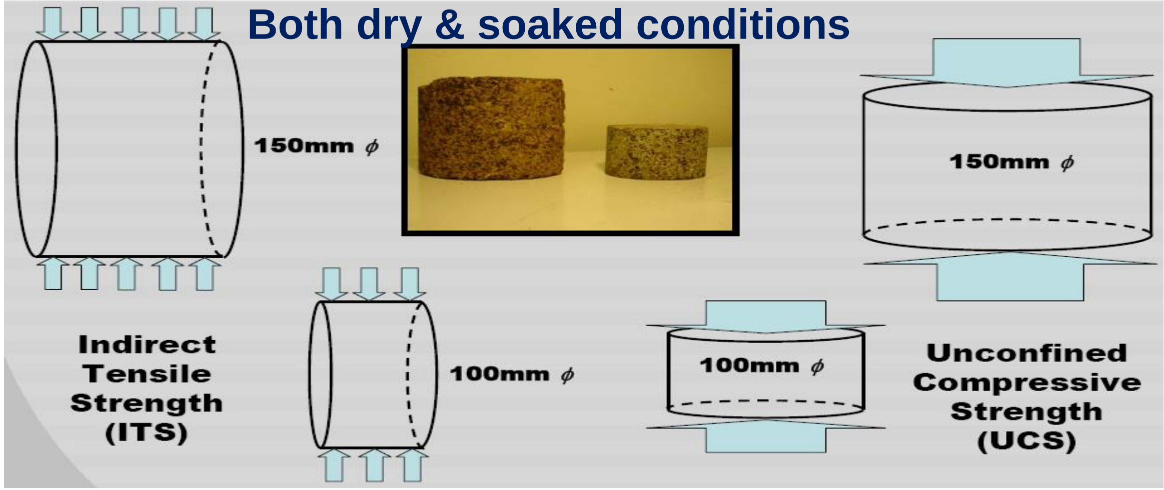
Laboratory design and mix optimization



Experience on Low Energy Asphalt mix on site

Laboratory design and mix optimization



Tensile Strength Retained (TSR)

$$TSR = \frac{ITS_{soaked}}{ITS_{dry}}$$

Outline

Why Low energy asphalt mix/ technologies

Status of knowledge

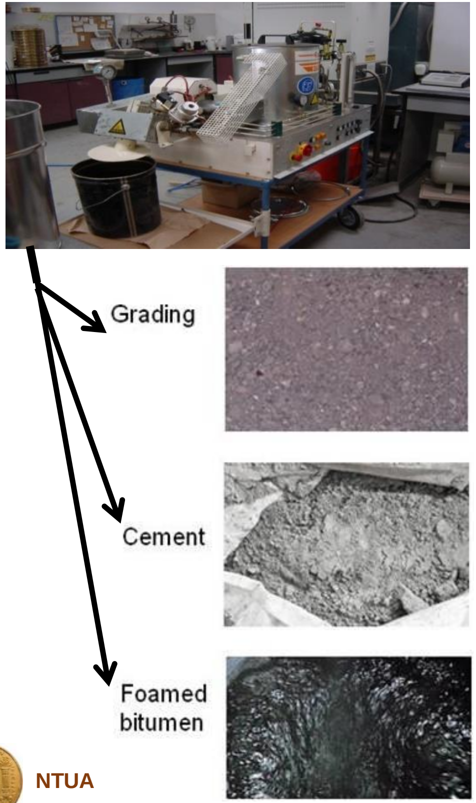
Experience of Low Energy Asphalt mix on site

- Foamed Asphalt mix
- Laboratory design and mix optimization
- **Implementation**

Perspectives and challenges

Implementation

Laboratory mix design



Pavement design

Asphalt concrete friction course mix (semi-open graded)

Dense graded asphalt concrete mix

Foamed bitumen treated RAP + aggregate

Implementation

Construction process

Implementation

Construction process

Outline

Why Low energy asphalt mix/ technologies

Status of knowledge

Experience of Low Energy Asphalt mix on site

- Foamed Asphalt mix
- Laboratory design and mix optimization
- Implementation
- **Early-stage performance**

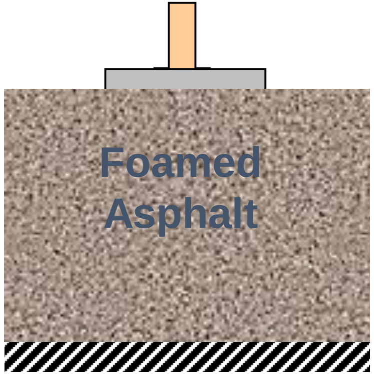
Perspectives and challenges

Early-stage performance

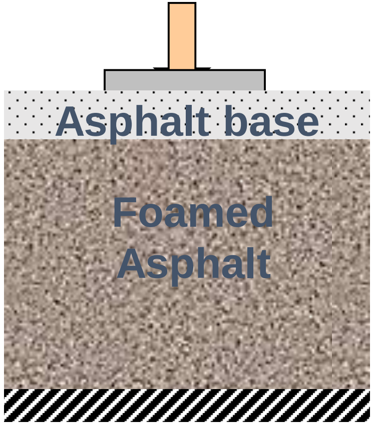
NDT assessment

1-2 days → 5 days → 3 weeks-18 months

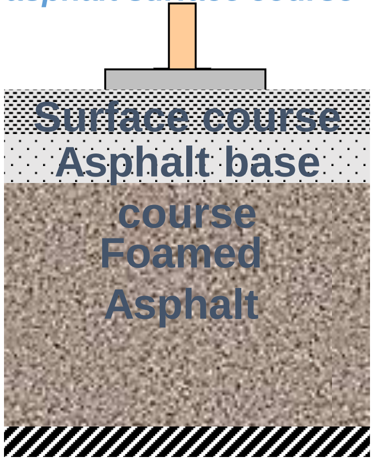
Measurements on the foamix layer



Measurements on the asphalt base course



Measurements on the asphalt surface course



Early-stage performance

Surface course compaction density assessment

$$\varepsilon_{HMA} = \left(\frac{1 + \frac{A_0}{A_p}}{1 - \frac{A_0}{A_p}} \right)^2$$

+

Density / Air voids algorithms
- ALL
- PANK
- Regression based

=

In-situ HMA density

Experience on Low Energy Asphalt mix on site

Al-Qadi, I. L., Wang, S., & Zhao, S. (2018). **Non-linear Optimization of GPR Data to Predict Thin Overlay Thickness and Density.** *European Geosciences Union (EGU) General Assembly 2018, Vienna, Austria.*

CHALLENGE

- **To eliminate the effect of surface moisture based on the "frequency-selective" effect:**

ALL Model:
(Al-Qadi, Lahouar, and Leng)

$$G_{mb} = \frac{\dfrac{\varepsilon_{HMA} - \varepsilon_b}{3\varepsilon_{HMA} - 2.3\varepsilon_b} - \dfrac{1-\varepsilon_b}{1-2.3\varepsilon_b + 2\varepsilon_{HMA}}}{\left(\dfrac{\varepsilon_s - \varepsilon_b}{\varepsilon_s - 2.3\varepsilon_b + 2\varepsilon_{HMA}}\right)\left(\dfrac{1-P_b}{G_{se}}\right) - \left(\dfrac{1-\varepsilon_b}{1-2.3\varepsilon_b + 2\varepsilon_{HMA}}\right)\left(\dfrac{1}{G_{mm}}\right)}$$

Correction Algorithm

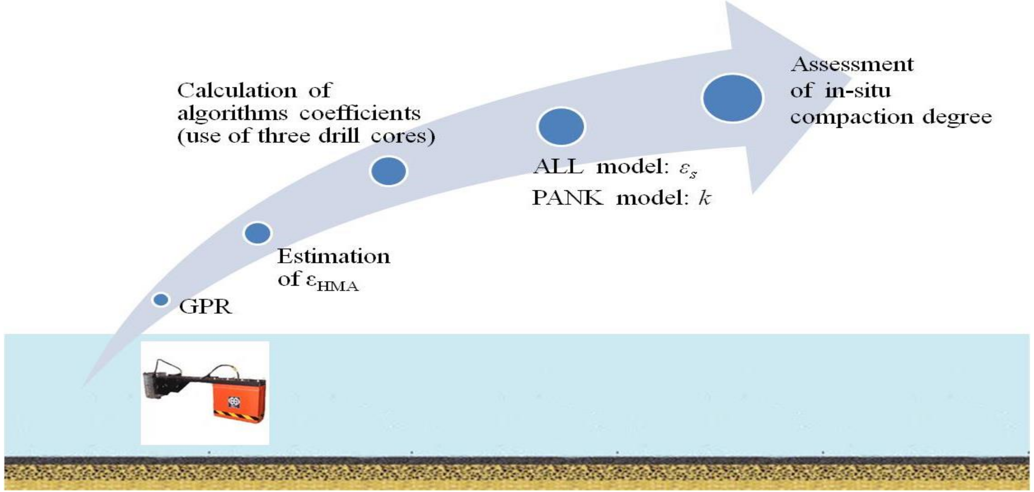
Density Model

GPR Data on Wet Pavement → GPR Data on Dry Pavement → Density of Pavement

- **Density Model: Al-Qadi, Lahouar, Leng (ALL) Model**
- **ALL model – AC dielectric constant is extremely important for real-time density monitor.**
- **Correction Algorithm: Nonlinear optimization based on gradient descent.**
- **Simulation using Finite Difference Time Domain – gprMax.**

Early-stage performance

NTUA methodological approach

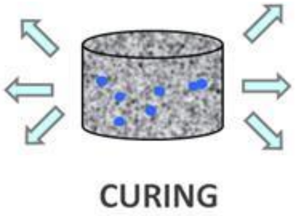


Georgiou, P. & Loizos, A. (2015). **Assessment of in-situ compaction degree of HMA pavement surface layers using GPR and novel dielectric properties-based algorithms.** *European Geosciences Union (EGU) General Assembly 2015, Vienna, Austria.*

VS

Early-stage performance

'Curing issues'



- ❑ Discharge of water from compacted material due to:
  - *Evaporation*
  - *Particle charge repulsion*
  - *Pore-pressure induced flow paths*
- ❑ Curing is associated with strength gain

Early stage – no possibility for coring due to curing process

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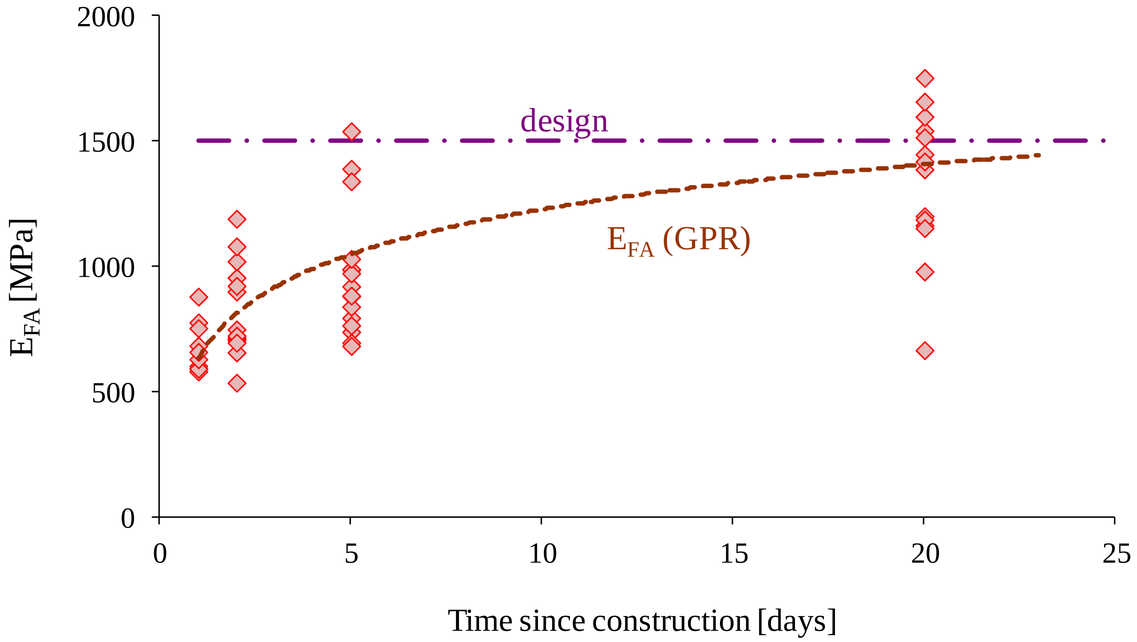
Early-stage performance

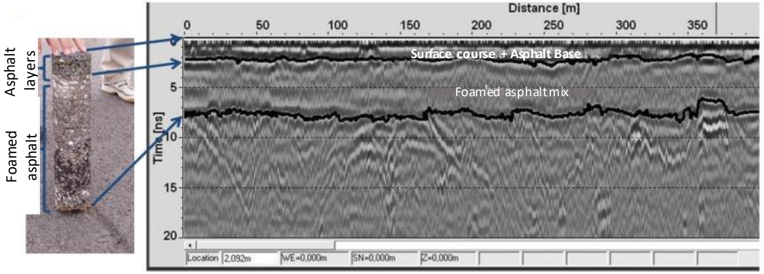
Back-analysis results

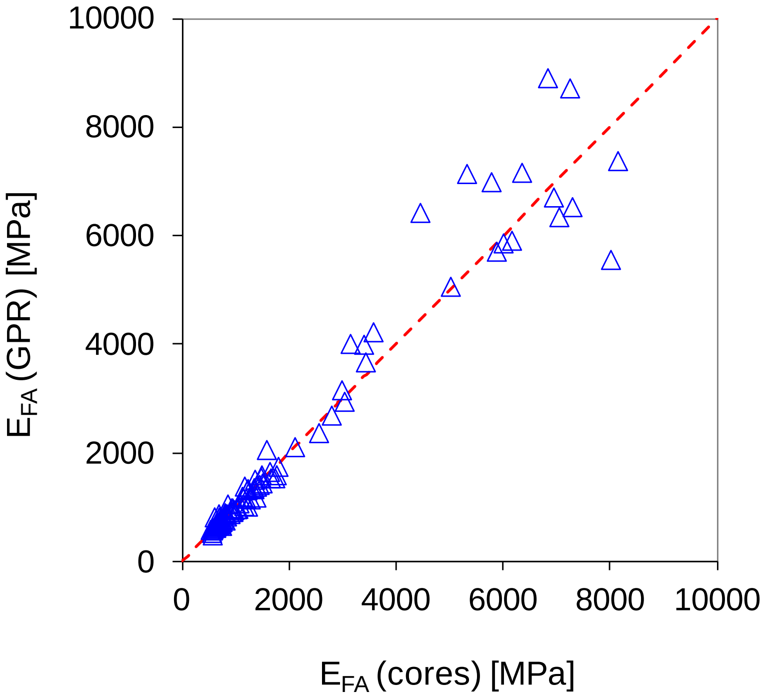


Early-stage performance

Back-analysis results

Cores extraction after curing (>6 months period)

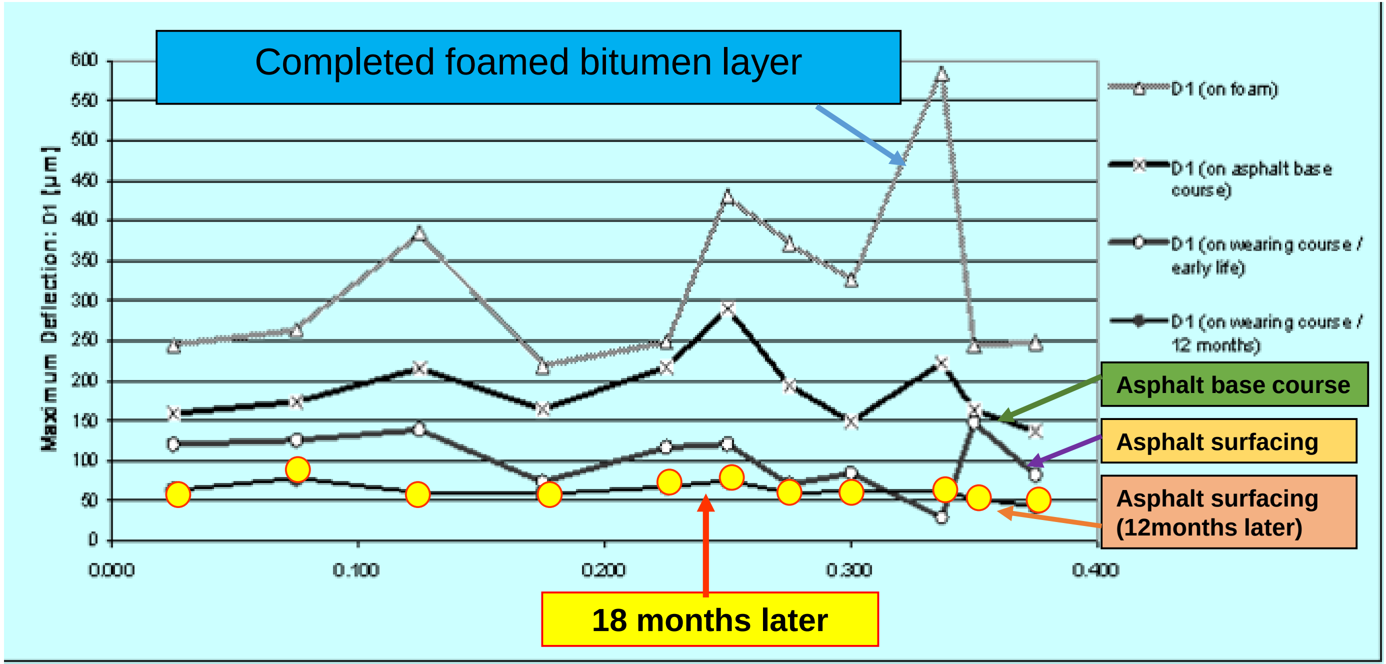




Very good correlation between GPR and cores-based backcalculated FA moduli

Early-stage performance

FWD deflections over time



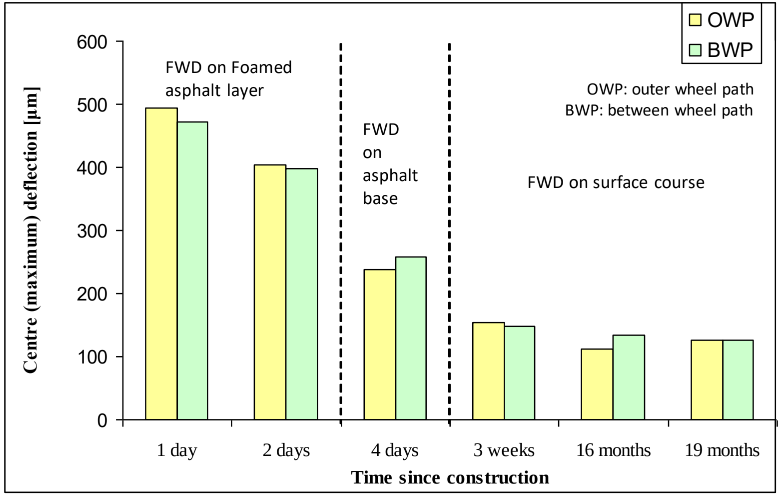
Increase in modulus of foamed asphalt layer

Outline

Why Low energy asphalt mix/ technologies
Status of knowledge
Experience of Low Energy Asphalt mix on site
- Foamed Asphalt mix
- Laboratory design and mix optimization
- Implementation
- Early-stage performance
- **Long-term performance**

Perspectives and challenges

Long-term performance



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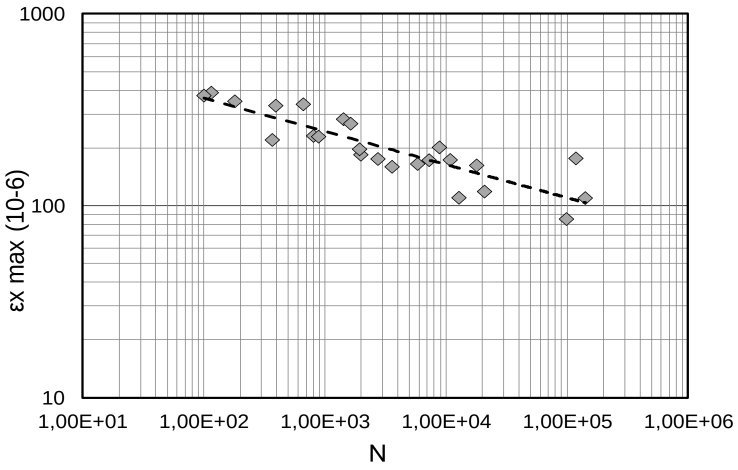
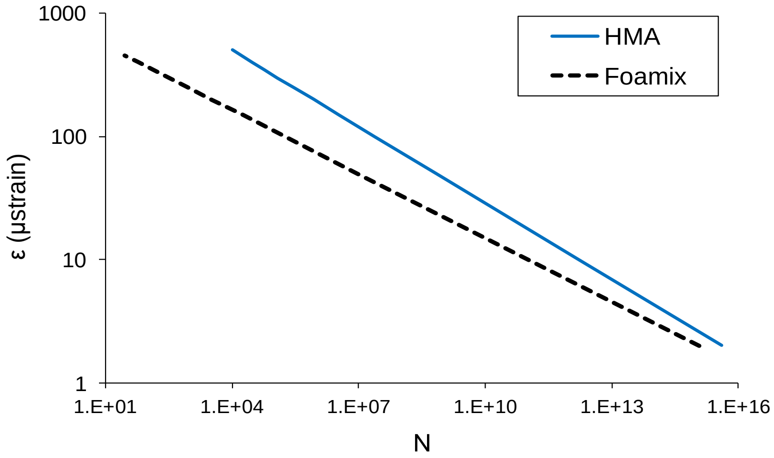
Long-term performance

Fatigue test results (Foamix)



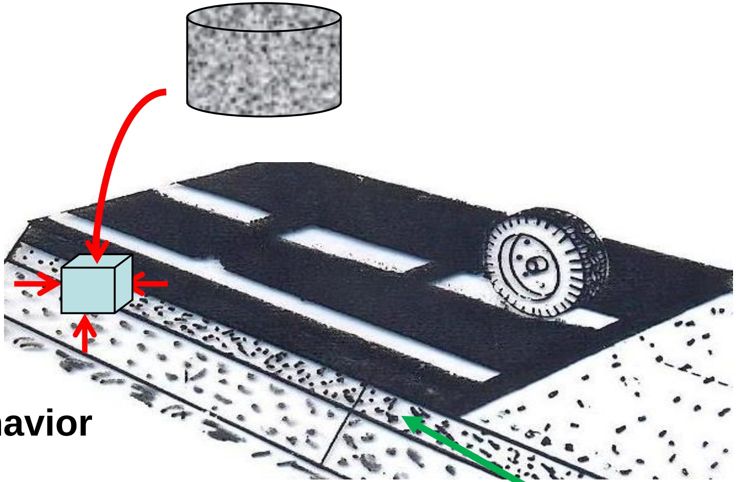


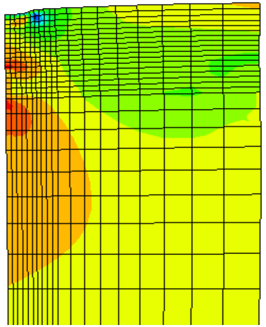
Cycles to failure $N = a * \varepsilon_{r\max}^{\ b}$

Papavasiliou, V. and Loizos, A. (2013). **Field performance and fatigue characteristics of pavement materials treated with foamed asphalt**, *Construction and Building Materials, Volume 48: 677-684.*

Long-term performance

Laboratory tests

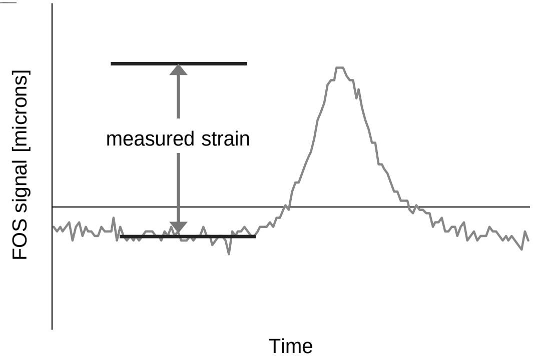




Strain analysis

Field behavior

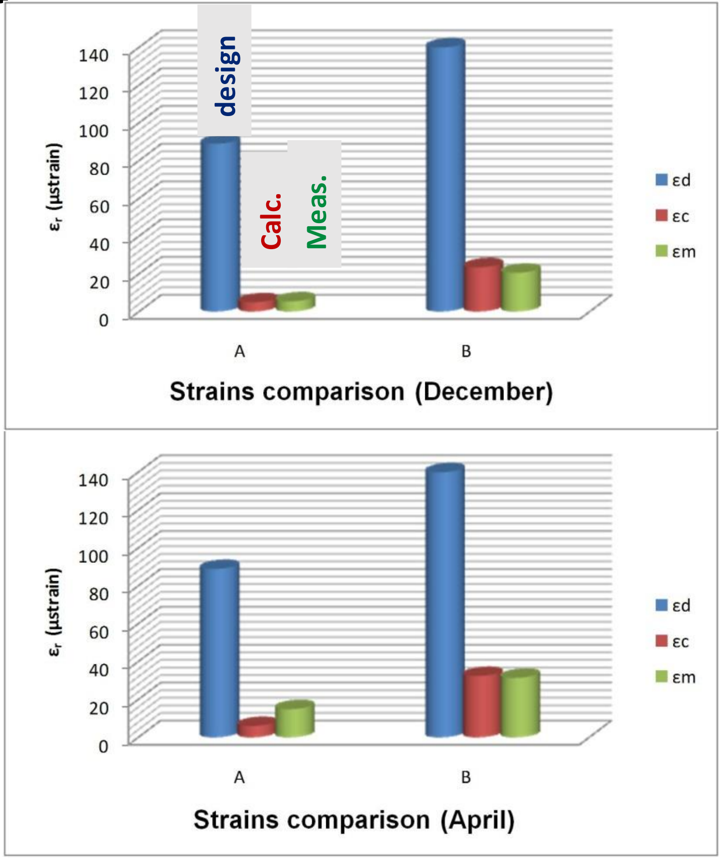
Instrumentation
(Fiber Optic Sensors)



Long-term performance

Location A

Location B



Assessment of strains using Fiber Optic Sensors

Unlike pavement design, fatigue of foamed bitumen mix may not be considered a critical performance indicator

Loizos et al. (2013), *International Journal of Pavement Engineering, Volume 14 (2): 125-133.*

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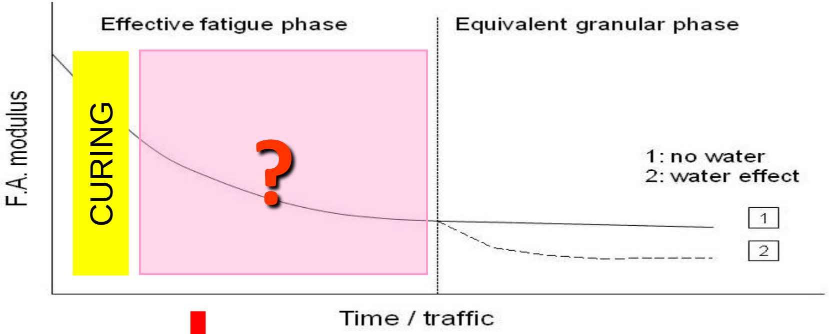
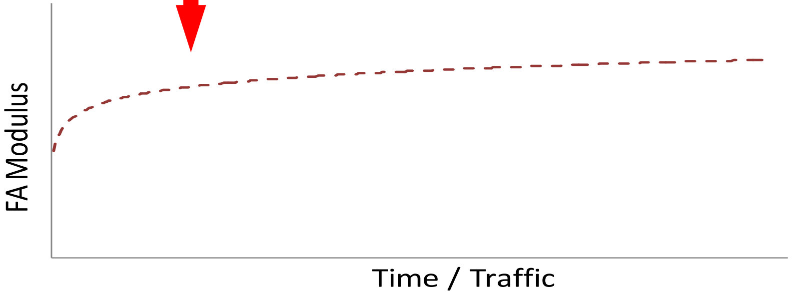
Long-term performance

Assessment of field behavior

Heavy Vehicle Simulator (HVS)

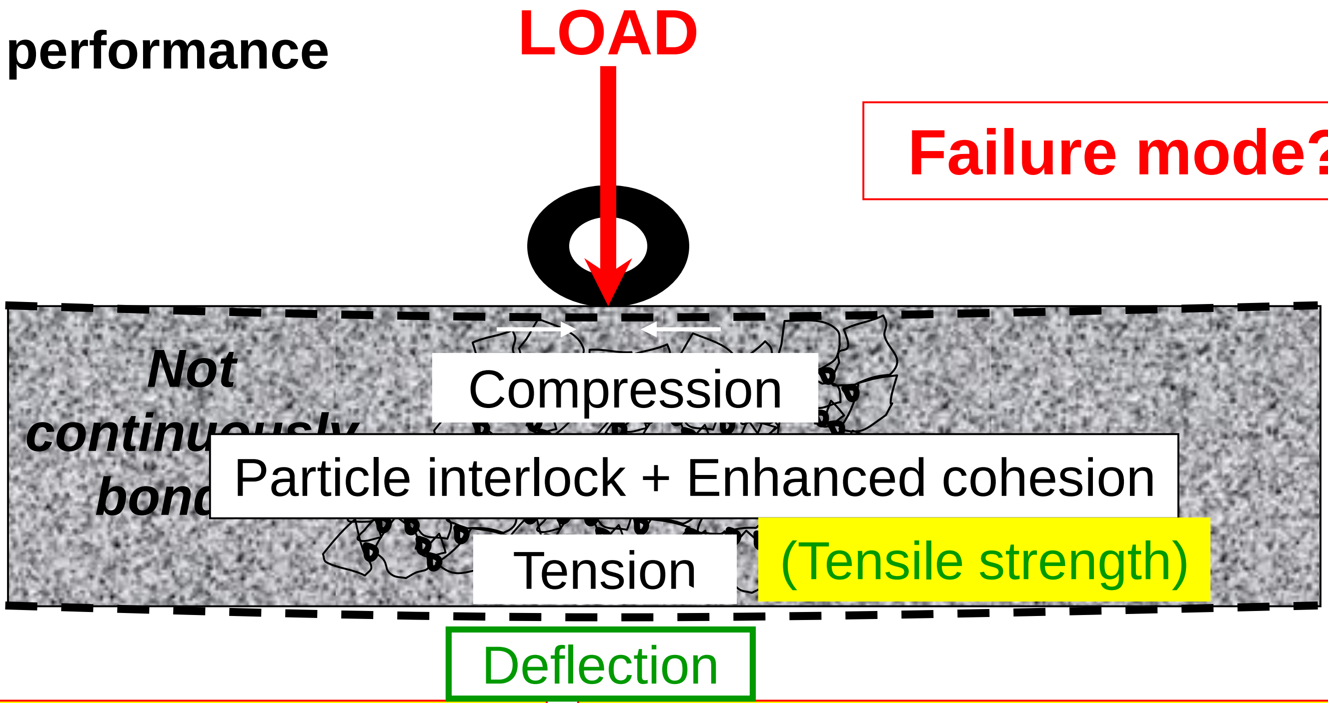


Real Loading Testing (RLT)



Long-term performance

Failure mode?



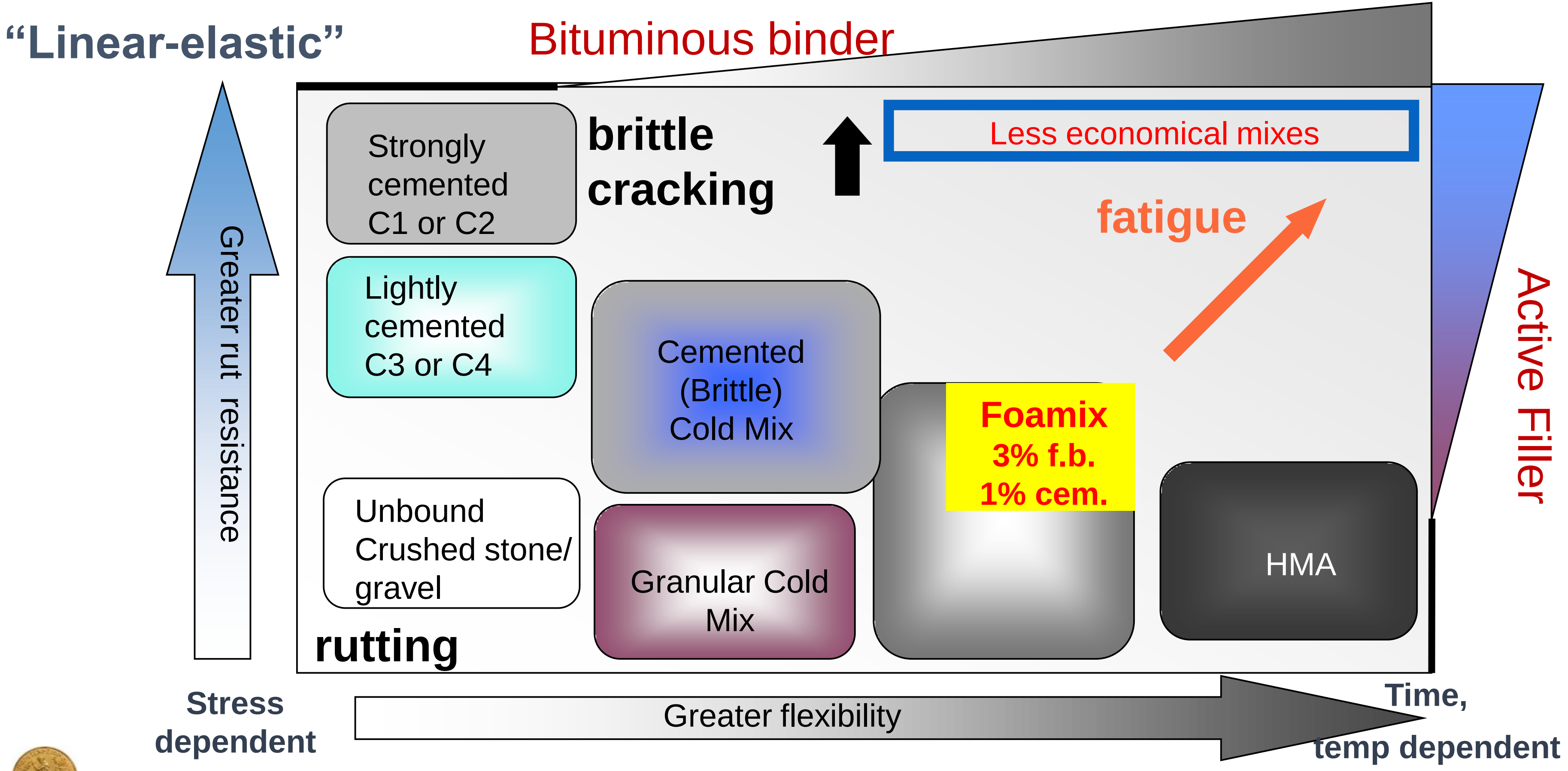
NOT "bottom-up" cracking

All particles not bound together

NOT "Permanent deformation"

Rut depth criterion

Experience on Low Energy Asphalt mix on site



Environmental impact

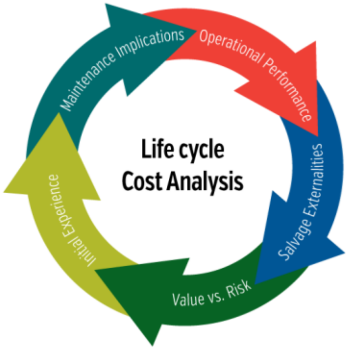
- ❑ Up to 100% of existing materials reused
- ❑ Limited need of new materials
- ❑ Keeps reusable materials out of the landfill

Social impact

- ❑ Quick implementation
- ❑ Road open for traffic same day
- ❑ High safety consideration

Economic impact- Construction benefits

- ❑ Resistive to moisture intrusion
- ❑ Flexible base –holds up well to overloading
- ❑ Virtually no maintenance for +10 years
- ❑ Inexpensive make up materials can be added to roads that don't have good mix of materials for structural design



Experience on Low Energy Asphalt mix on site

Research is ongoing…

Long Term Pavement Performance

Outline

Why Low energy asphalt mix/ technologies

Status of knowledge

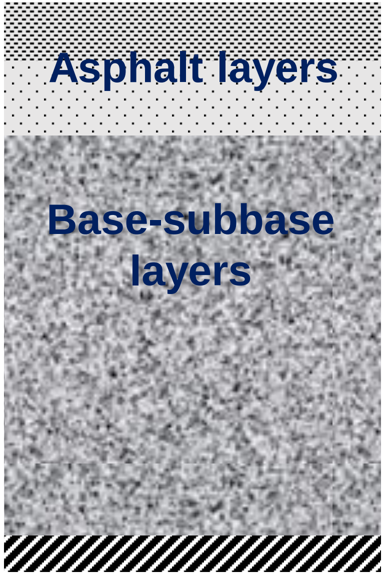
Experience of Low Energy Asphalt mix on site

- Foamed Asphalt mix
- Laboratory design and mix optimization
- Implementation
- Early-stage performance
- Long-term performance
- **Our Goal**

Perspectives and challenges

Our Goal

Low energy and long-life pavement



Pavement structure criteria
- low energy
- cost-effective
- durable & highest-performing

Suitable materials selection
- asphalt courses
- base-subbase courses

Low energy and long-life pavement

Near future

Warm Mix Asphalt-RAP based asphalt layers

Foamed asphalt treated-RAP base-subbase layers

Suitable materials selection

- ❑ asphalt layers
- ❑ base-subbase layers

Our Goal

Research project:
Performance evaluation of Low Energy Asphalt mixes and their impact on Pavement Sustainability (LEAPS)

The **goal** of this **research project** is to develop:

- ❑ **a ‘green’**
- ❑ **energy-efficient** and
- ❑ **durable asphalt-based product**

for implementation in pavement construction and maintenance activities.

Dr. Panos Georgiou
Email: georgp@central.ntua.gr

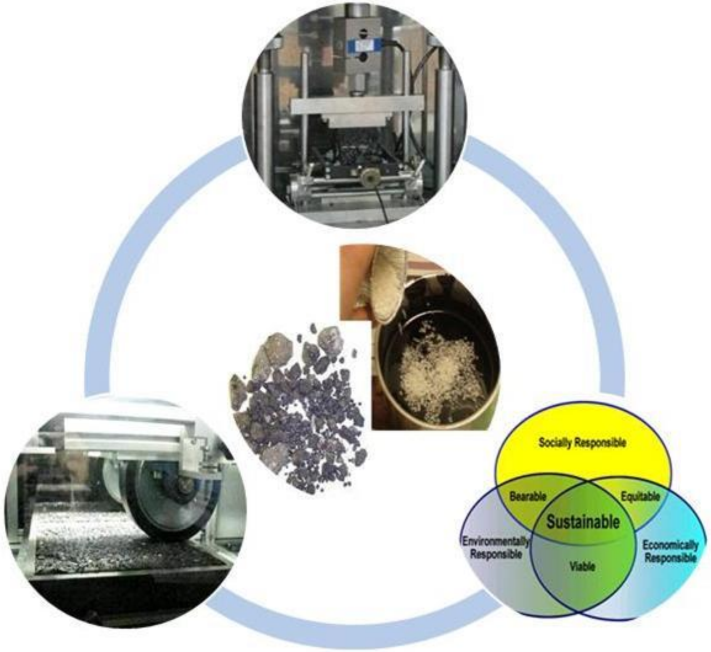
Our Goal

HFRI Hellenic Foundation for Research & Innovation
GSRT General Secretariat for Research and Technology
European Investment Bank — The EU bank

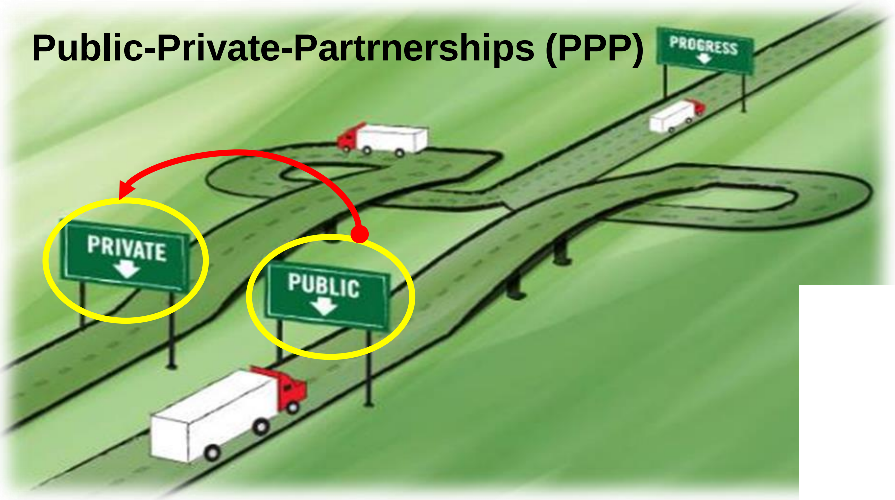
Research project:
Performance evaluation of Low Energy Asphalt mixes and their impact on Pavement Sustainability (LEAPS)

Methodology tasks

- Optimization of mix design of WMA-RAP mixtures
- Laboratory performance testing and evaluation
- Sustainability impact

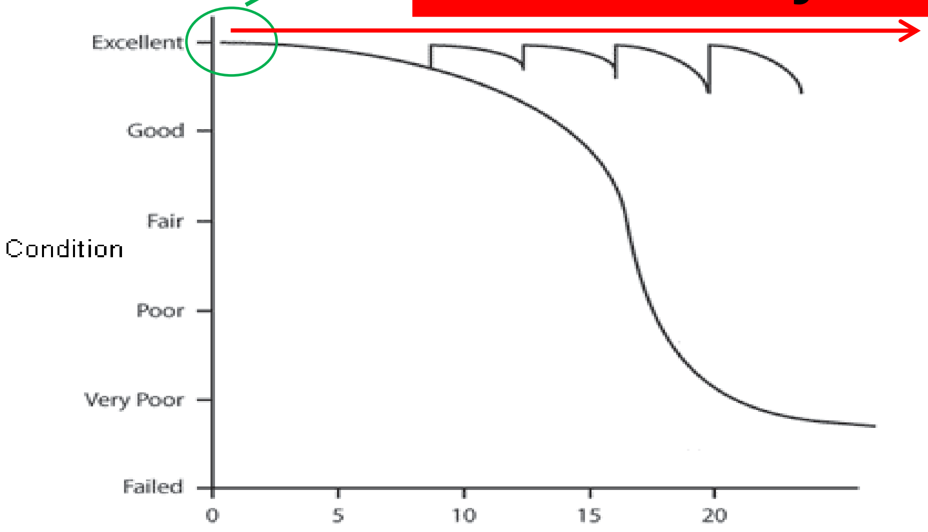


Public-Private-Partrnerships (PPP)



Construction cost

Cost analysis



Outline

Why Low energy asphalt mix/ technologies
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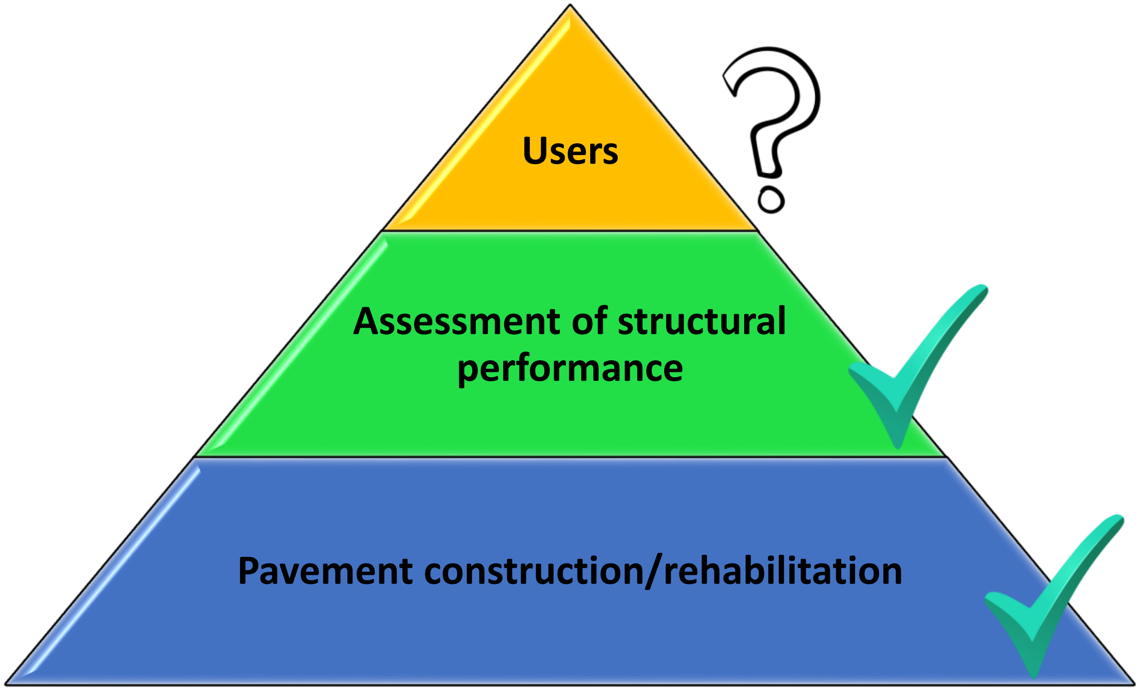
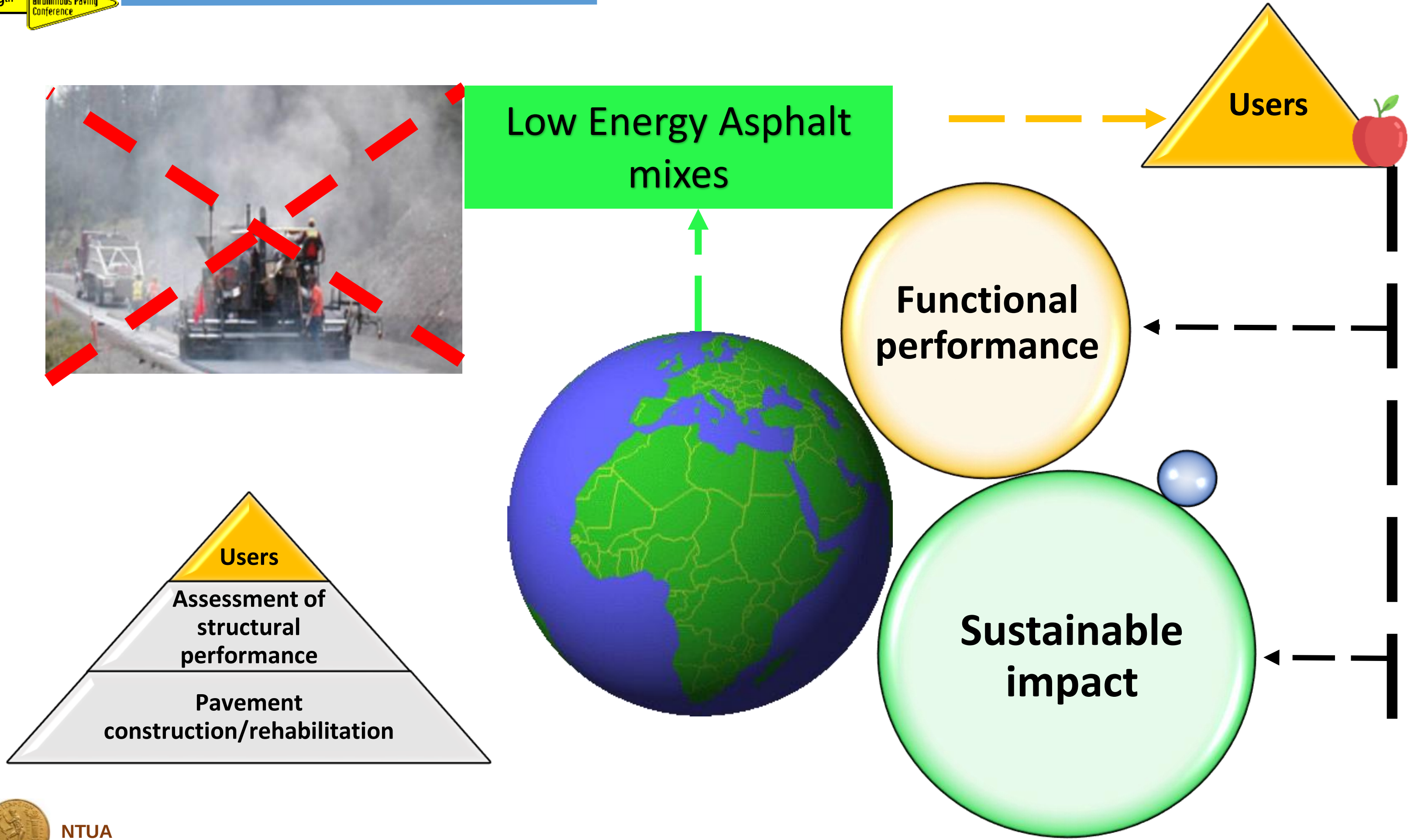
Perspectives and challenges

Perspectives and challenges



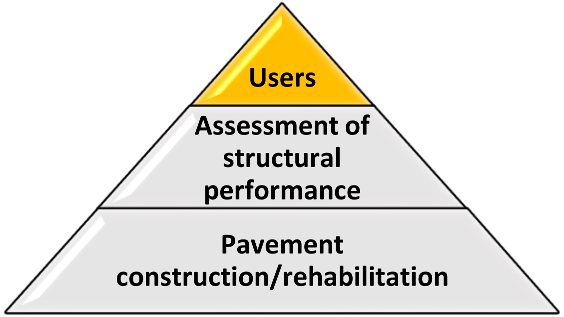
Perspectives and challenges

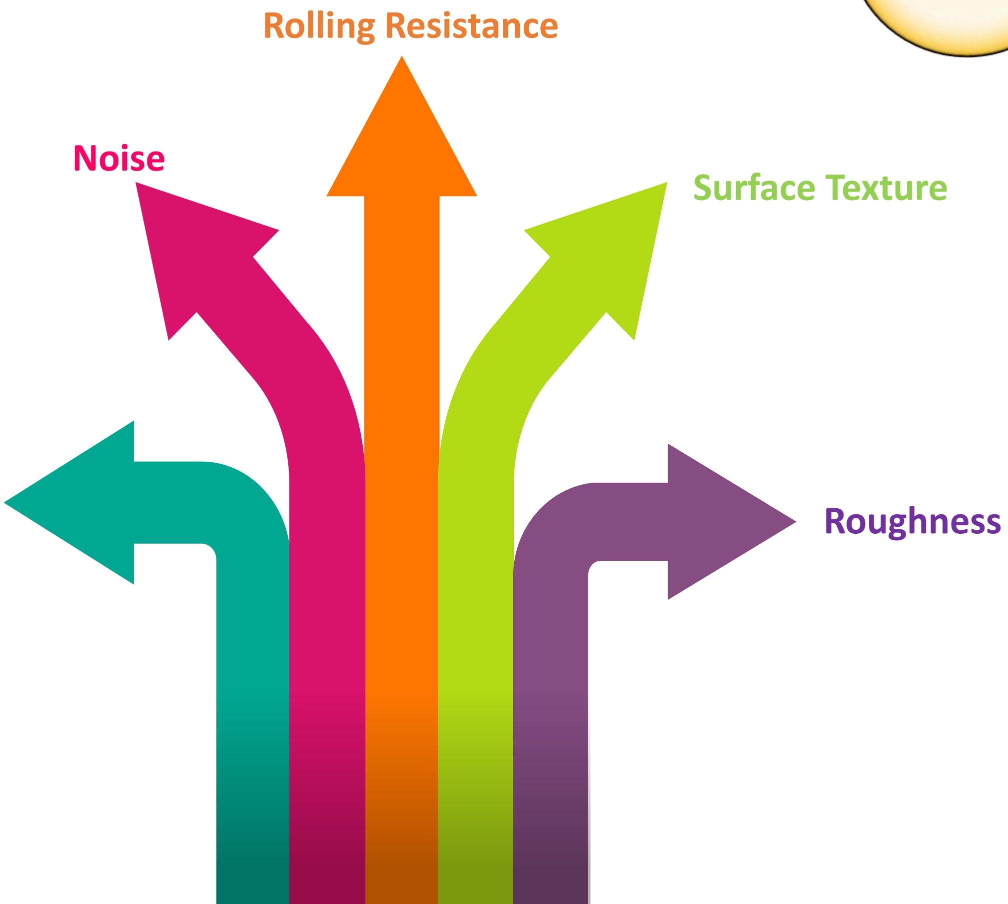


Perspectives and challenges

Functional performance

Functionality
- ✓ Safety
- ✓ High Quality

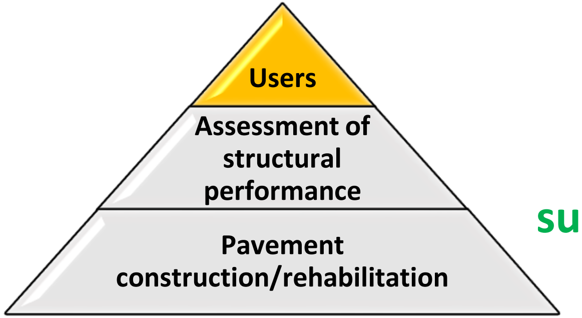




Sustainable impact

Sustainability of pavement engineering

Developing environmental friendly and energy efficient asphalt paving technologies coincides with the concept of Global Sustainable Development



In recent years, significant efforts are being made to realize the **sustainability of pavement engineering** in a **more systematic and scientific way**

Perspectives and challenges

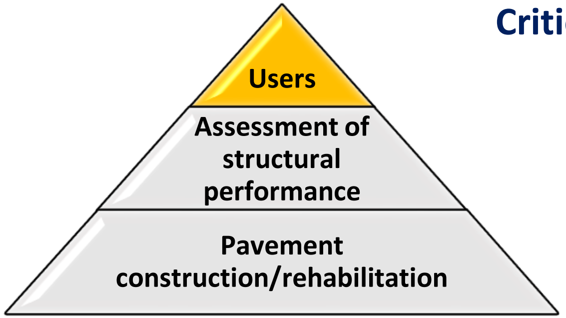
Sustainable impact

Sustainable pavement is one that achieves its specific engineering goals, while, on a broader scale:

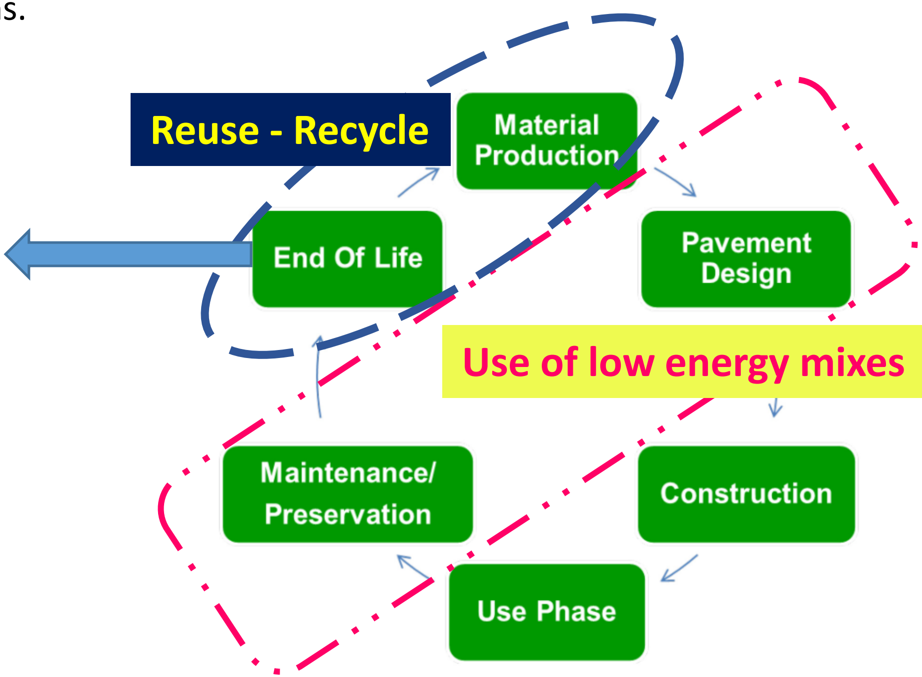
(1) meets basic human needs,

(2) uses resources effectively, and

(3) preserves/restores surrounding ecosystems.



Critical phase

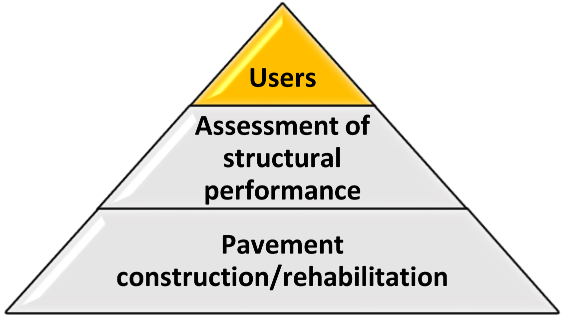


Sustainable impact

Some End Of Life perspectives

Some approaches to improving sustainability with regard to pavement recycling at the end of its life along with associated environmental benefits:

- ***Use in-place and plant recycling of asphalt pavement materials*** following best practices for candidate locations, mix and structural design, and construction quality.
- ***Manage RAP stockpiles following best practices***, including fractionation and moisture control.
- ***Leaching control ?***

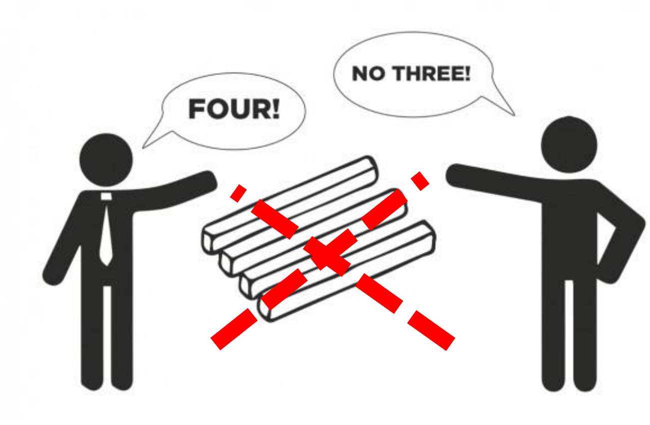


Need for more End Of Life perspectives

Reuse

Perspectives and challenges

Sustainable impact



Need for

Global Environmental Assessment Tool (like for other techniques)

Assessment of fumes on site and correlate with laboratory

Job sites surveys (check specs in field performance)

Common Assessment Tools

LCA

Indicators

Decision making

Assess real life performance

Life Cycle Analysis

Sustainable impact

Indicators

- Global warming potential
- Depletion of resources
- Air pollution
- Leaching potential
- Noise
- Skid resistance
- Financial cost
- Recyclability
- Performance
- Responsible sourcing
- Traffic congestion

New Visions

Perspectives and challenges

New Visions ?

HOW

Sustainable impact

Kyoto Protocol

1997

Nations to apply

legally bound

Effect

Commits state parties to reduce greenhouse gas emissions, based on the scientific consensus that global warming is occurring by human-made CO2.

Target

Nations to apply

Consensus-building, allows for voluntary and ***nationally determined targets***

Paris Agreement

4th November 2016

dealing with greenhouse-gas-emissions mitigation, adaptation, and finance

Low energy mixes reduce greenhouse gases from transport sector

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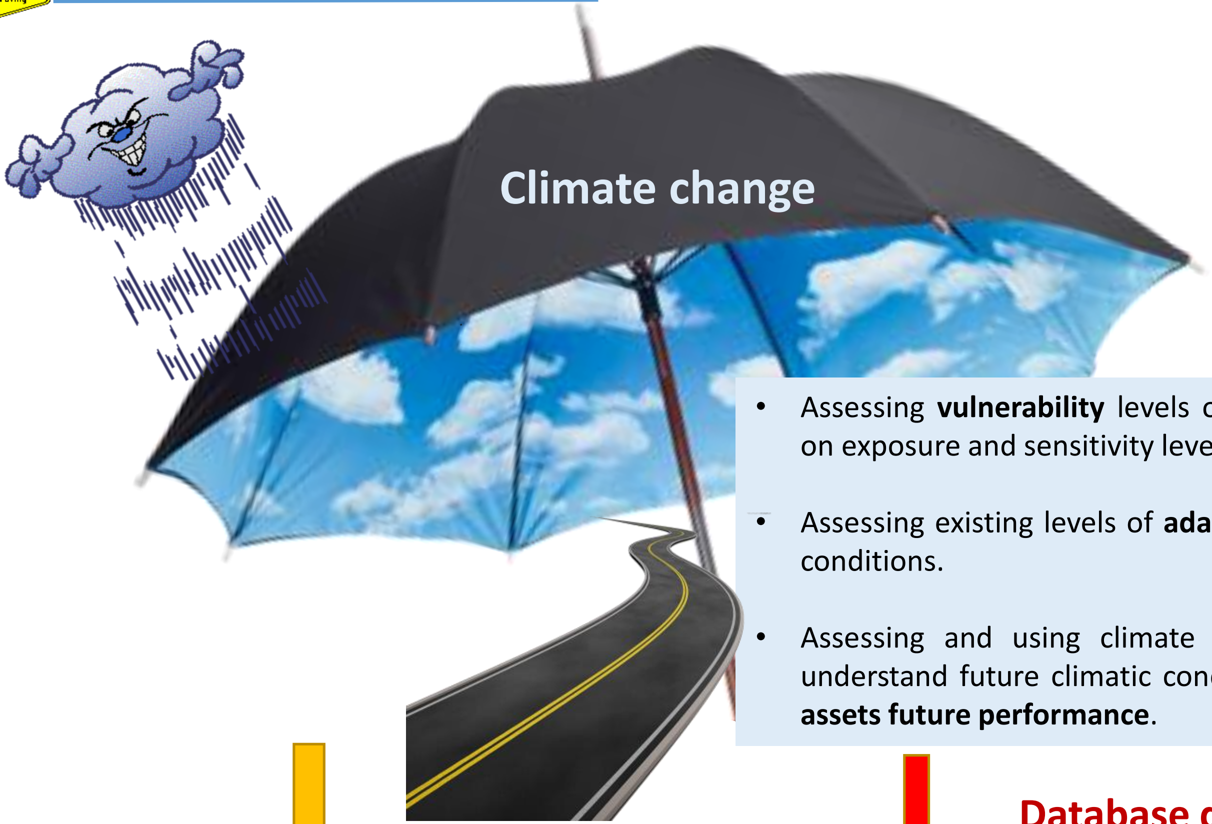
Perspectives and challenges



Sustainable impact

- Assessing **vulnerability** levels of different assets and locations, based on exposure and sensitivity levels.
- Assessing existing levels of **adaptive capacity** of the assets to extreme conditions.
- Assessing and using climate change **projections** and scenarios to understand future climatic conditions and **change risk and impact on assets future performance**.

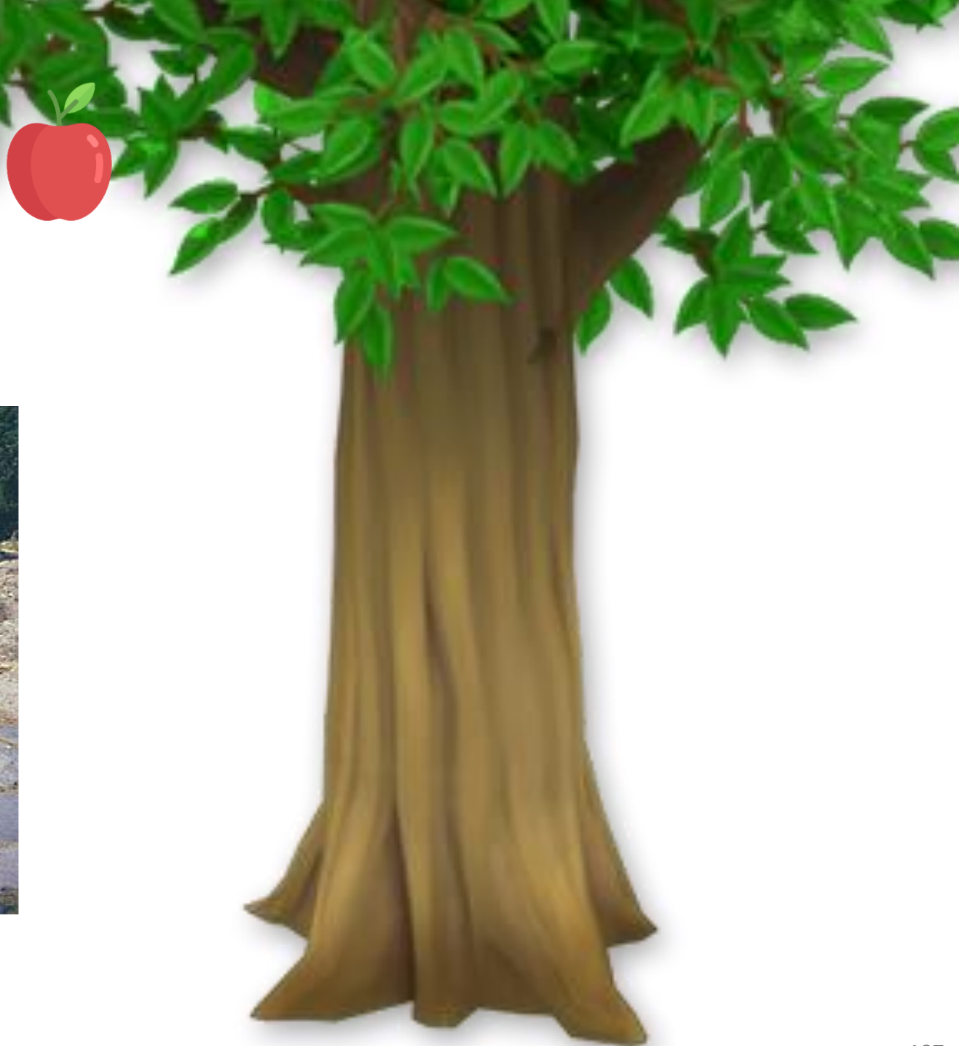
Low energy mixes are resilient to climate changes?

Database development

Sharing experience

Harmonize Criteria International Level

Mature enough to move on...?



Let's develop our future !

NTUA

Prof. Andreas Loizos

Perspectives and challenges

FEHRL

Brussels

Decision making and excellence

Greek FEHRL Group (since 2004):

Κ Ε Δ Ε

Ministry of Infrastructure and Transport

Central Public Works Department

Laboratory of Pavement Engineering of School of Civil Engineering of NTUA

NATIONAL ROAD RESEARCH CENTRES IN PARTNERSHIP

59th Illinois Bituminous Paving Conference

Perspectives and challenges

European platform

We need infrastructure to be more efficient:

- ✓ Much cheaper – 30% less cost
- ✓ Ensuring much more reliable traffic
- ✓ Much safer and more secure
- ✓ Minimal footprint
- ✓ Fully ICT integrated
- ✓ Enhancing new mobility concepts
- ✓ Enhancing social inclusion/accessibility
- ✓ Resilient to climate change effects

FEHRL

FOREVER OPEN ROAD

Redefining Road Transport for the 21st Century

FEHRL's Flagship Programme

New pavements

Perspectives and challenges

FOREVER OPEN ROAD
Redefining Road Transport for the 21st Century
FEHRL's Flagship Programme

FEHRL

Forever Open Road will tackle global challenges such as climate change, carbon reduction, energy saving, as well as the increasing need for journey time reliability in response to rising demand both for private car travel and the delivery of goods by road.

Meet societies goals to provide transport infrastructure :

- **Safe and secure**
- **Sustainable, cleaner, quieter and more energy efficient**
- Supported by **innovative and competitive industry and private sector**
- Provide **reliable mobility** based on user needs and expectations
- Based on the need to **take into account the shrinking public-sector budgets**

Perspectives and challenges

FOREVER OPEN ROAD

Redefining Road Transport for the 21st Century

FEHRL's Flagship Programme

Forever Open Road

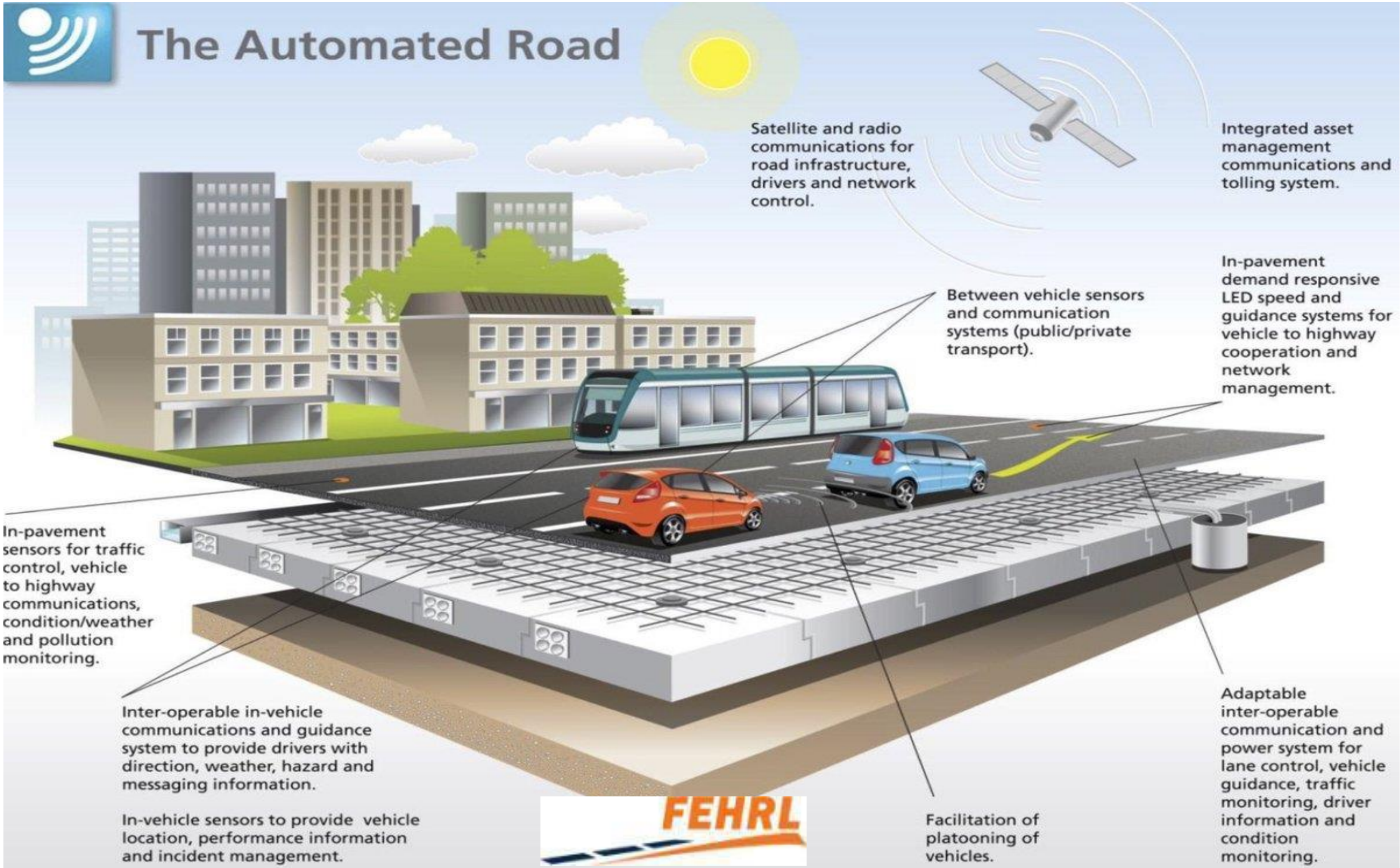
- Less traffic delay
- Fast repair
- Climate resilient

Next generation pavements

- ✓ The Automated Road
- ✓ The Adaptable Road
- ✓ The Resilient Road

FEHRL

Perspectives and challenges



Perspectives and challenges

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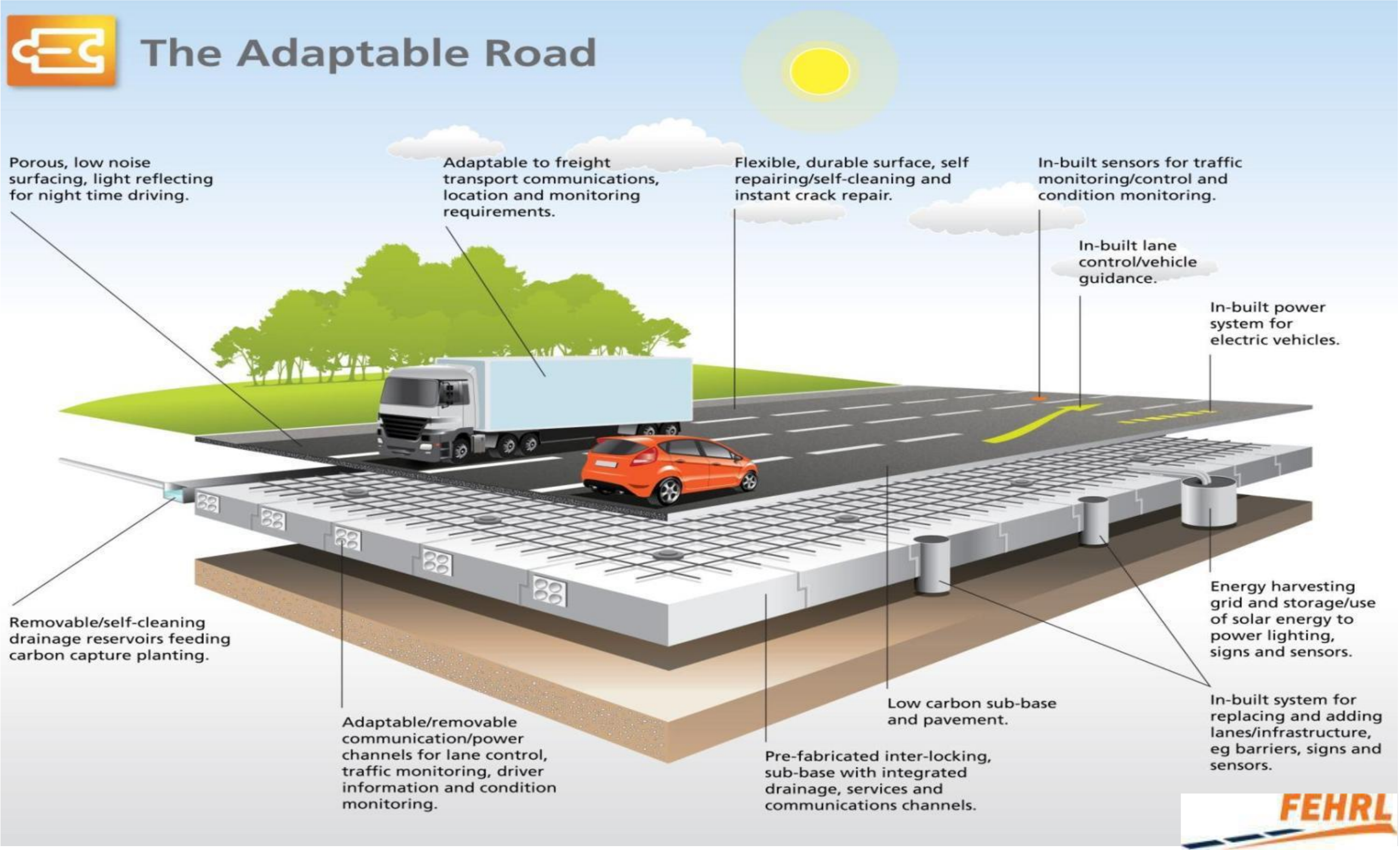

Perspectives and challenges

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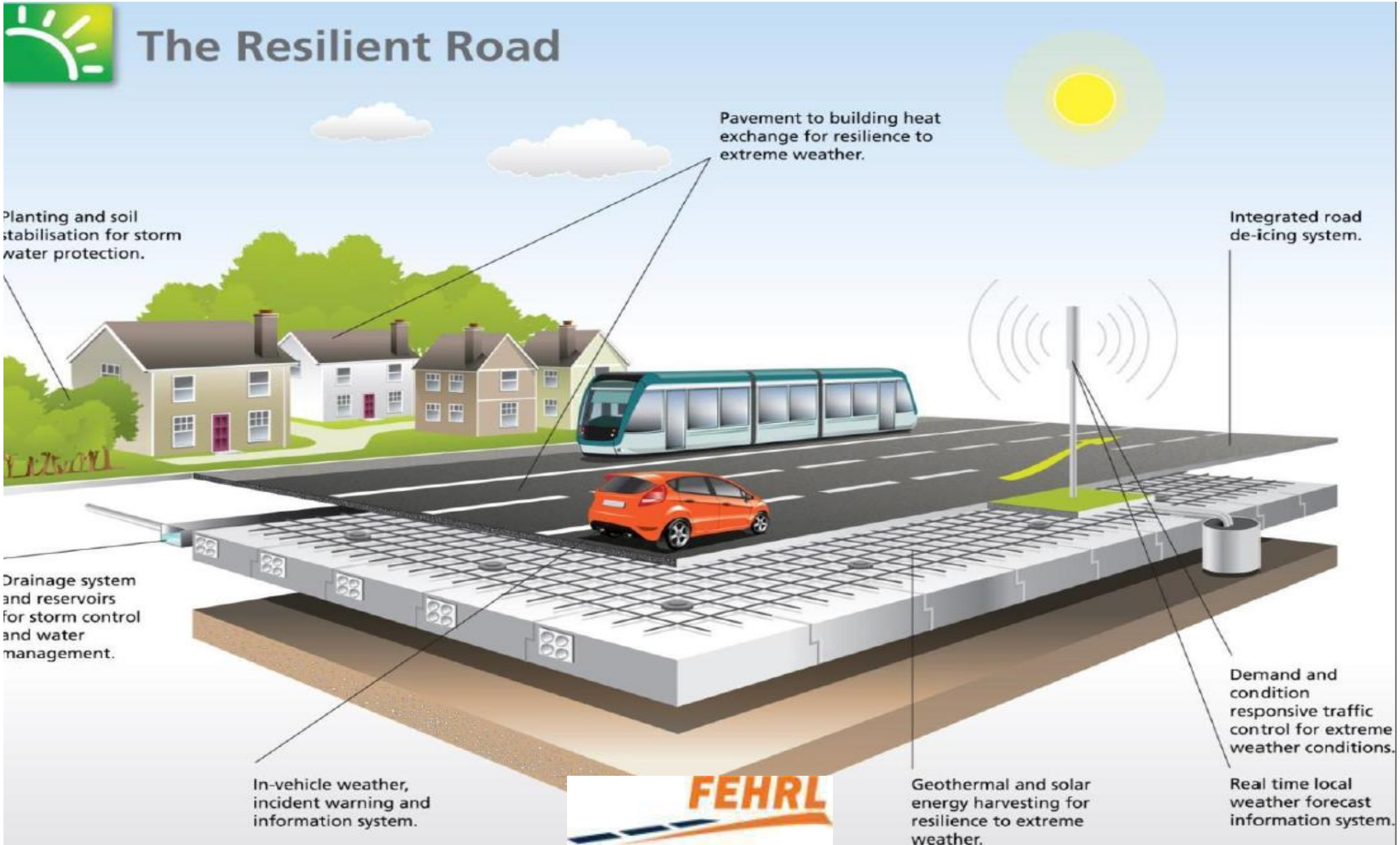

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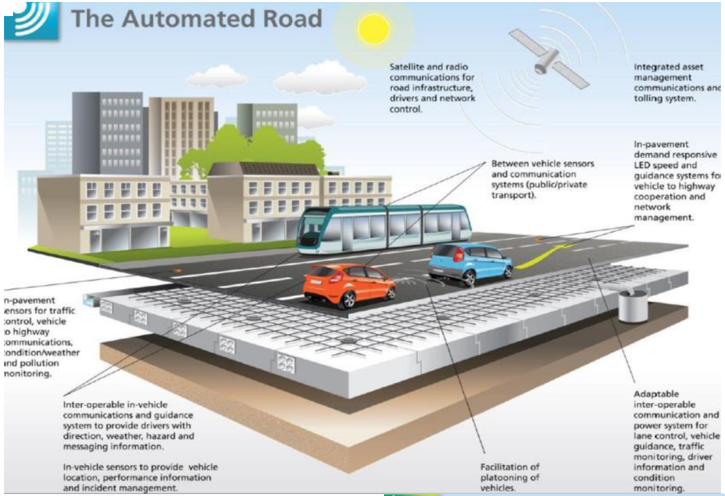

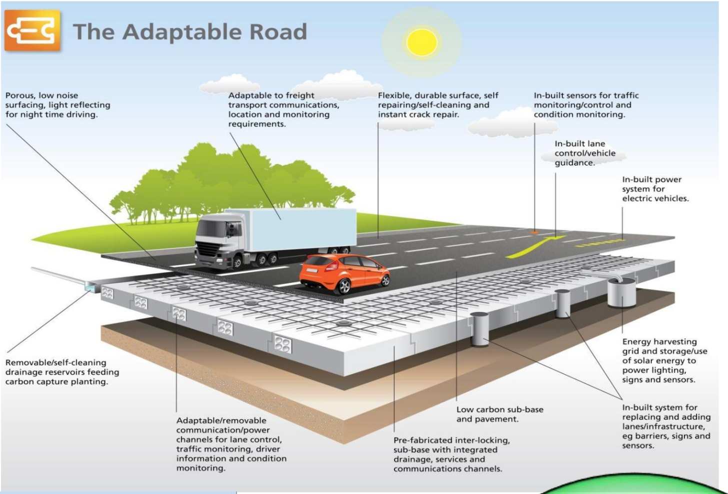

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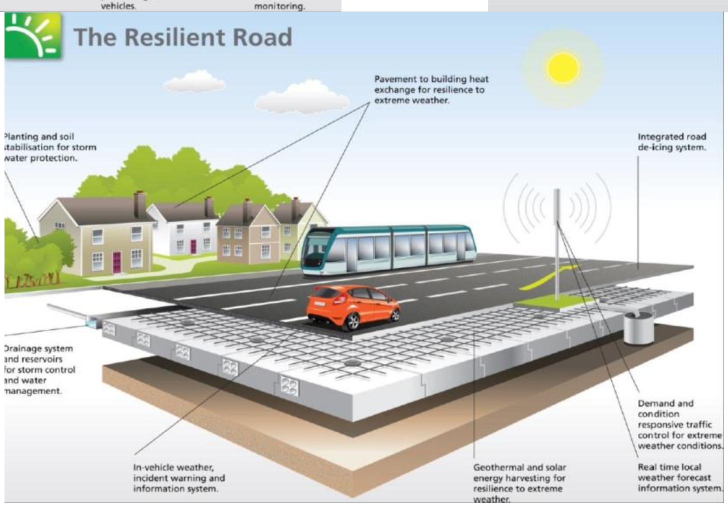

Including **low energy mixes in new vision pavements**

EU Innovation – Concepts

Various papers and more information within

- ❑ **Performance of asphalt mixes with additives**
- ❑ **Stabilization and reinforcement**
- ❑ **Recycled materials and techniques**

Focused:

✓ **Road pavements**

✓ **Airfield pavements**

59th Illinois Bituminous Paving Conference

Laboratory of Pavement Engineering

Andreas Loizos

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