

Young Researchers Seminar 2009

Torino, Italy, 3 to 5 June 2009

Warm asphalt bituminous mixtures with regards to energy, emissions and performance

Nicolas BUECHE

EPFL - LAVOC

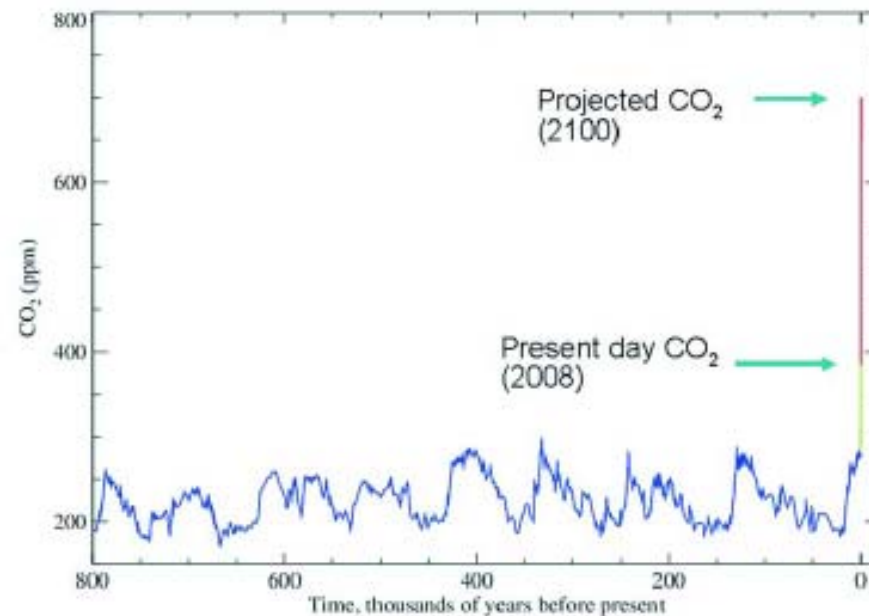


Presentation outline

- ❑ Introduction
- ❑ Research objectives & description
- ❑ Warm mix asphalt technologies and potential
- ❑ Assessment of the warm mix asphalt performance
 - ❑ Preliminary study (LAVOC)
 - ❑ Methodology for laboratory performance analysis
- ❑ Preliminary conclusions

Introduction

- Increases of global energy consumption and CO₂ emissions.
- Various governments decisions in order to decrease the environmental load.



Source: Met Office (UK)

→ Road domain has to contribute to sustainable development

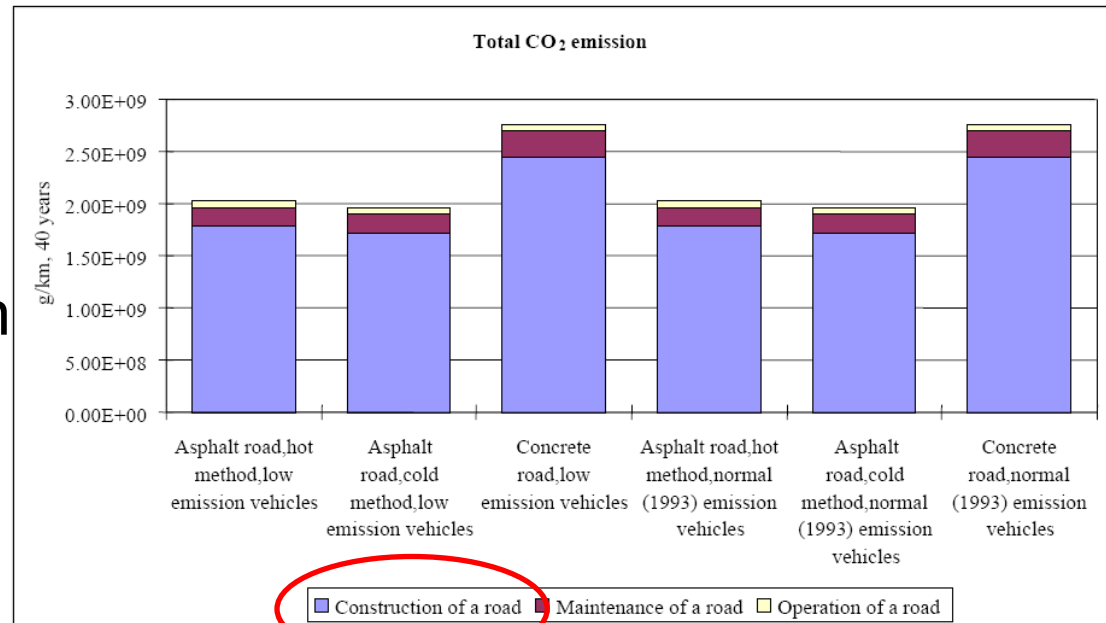
WAM with regards to energy, emissions and performance

Bueche Nicolas



Introduction

- Transportation area: major contributor for GHG emissions and energy consumption in developed countries.
- The energy used for a road (construction, maintenance, operation) represents 5-12% of the energy used for traffic on the same section.
- Construction phase of a road is the major source of emissions.

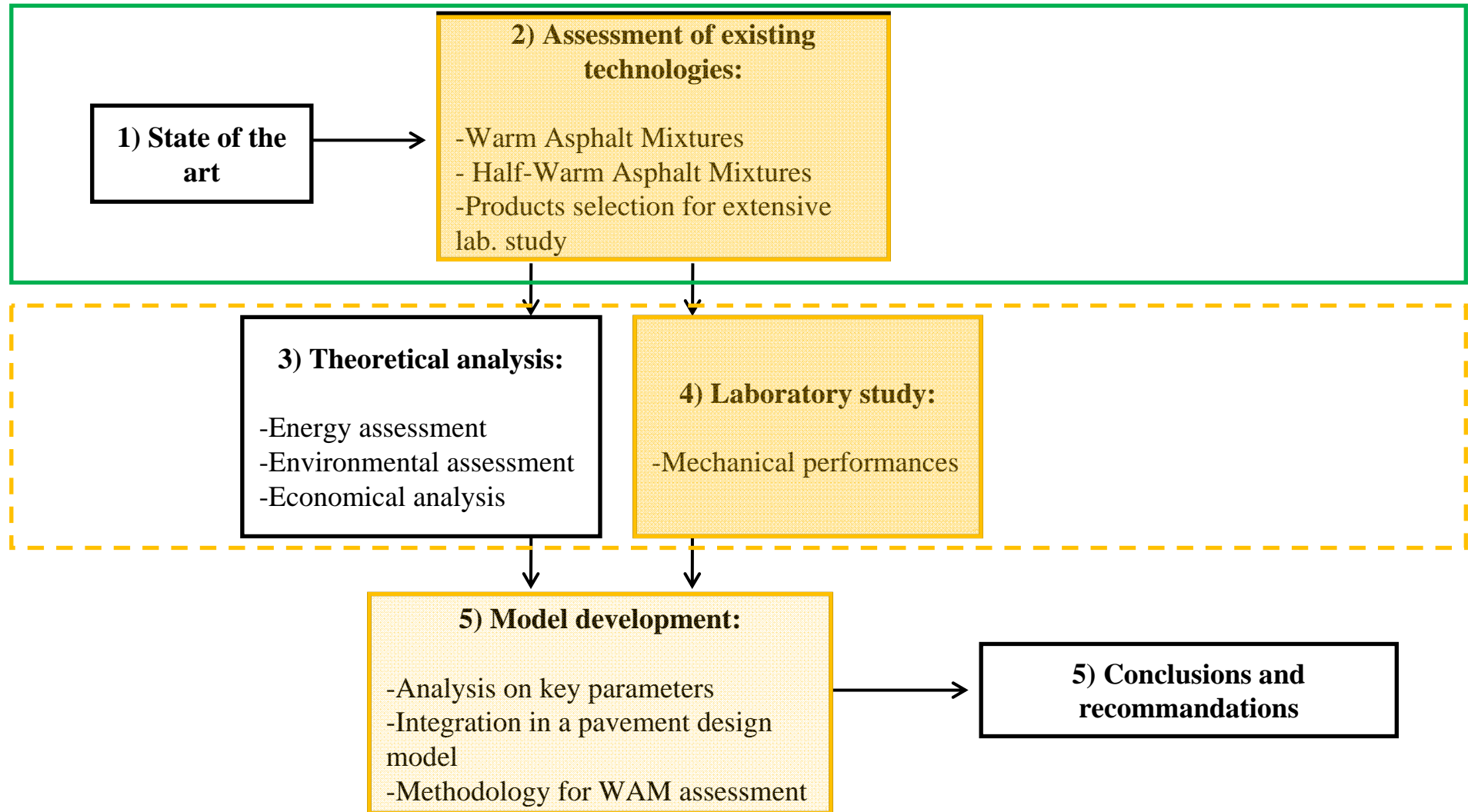


Source: H. Stripple, 2001

Research objectives

- Since the end of 1990's, research works carried out and products developed in order to reduce the asphalt mixture temperature.
- Key element: maintain a low viscosity of the mixture while decreasing the production and laying temperature.
- Main objectives:
 1. Assess the performances of techniques with reduced temperature that could be critical.
 2. Global evaluation tool of innovative asphalt mixture processes by considering specific aspects.

Research description

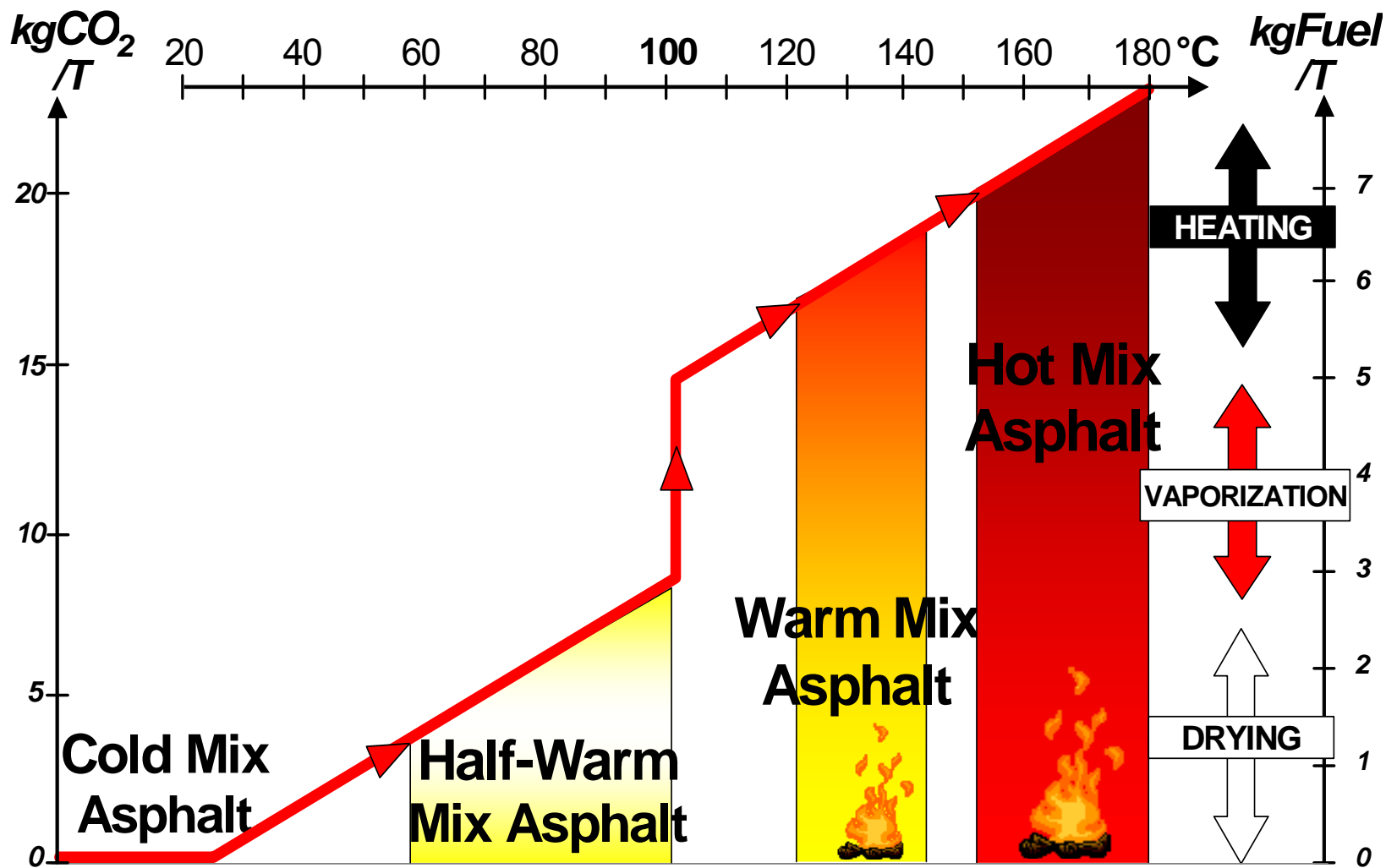


WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA technologies



Source: Workshop LAVOC 02.07.08 – Eiffage TravauxPublics

WAM with regards to energy, emissions and performance

Bueche Nicolas



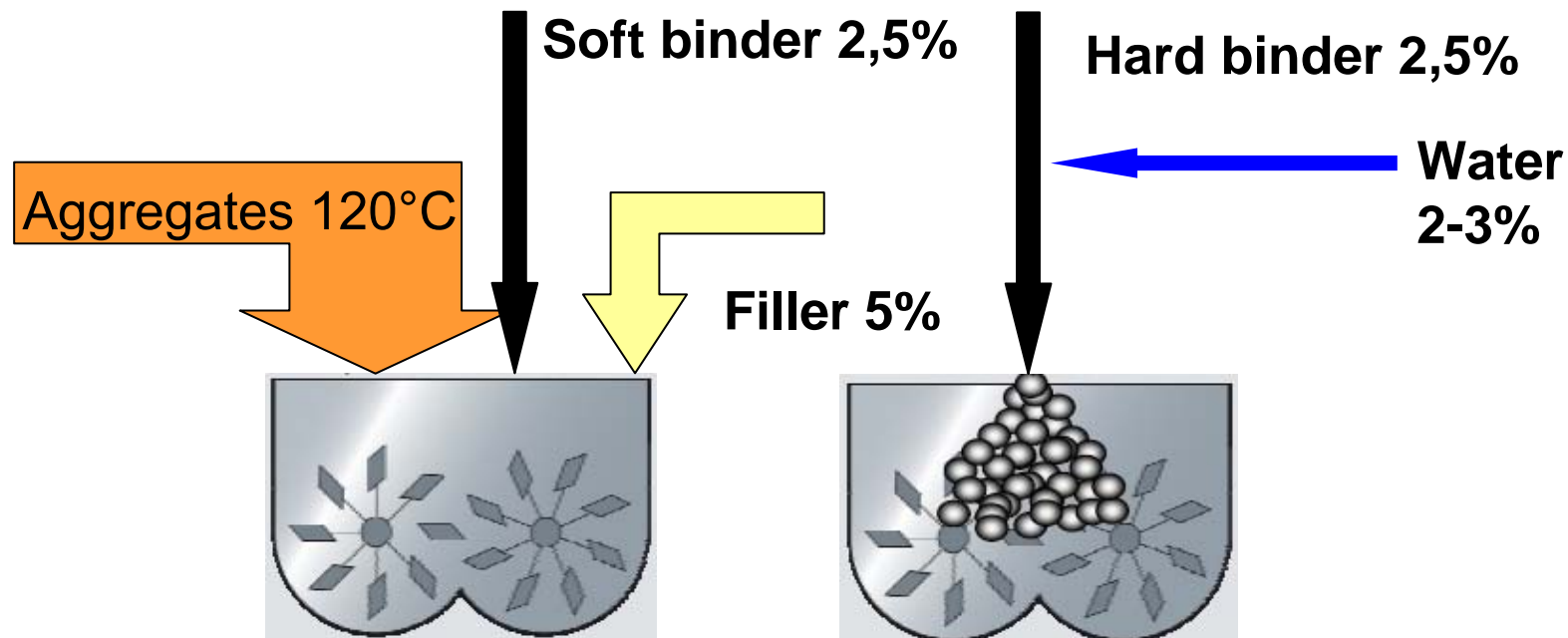
WMA technologies

A. Modification of the coating sequence:

- Sequential coating without modification of the mix components.
- Origin: KGO method (1976)
 - a. First coating with biggest aggregates and all the binder;
 - b. Remainder of aggregates, sand and filler added for the final mixture.
- Method further developed and modified (two different binders, cold water,...).

WMA technologies

- WAM-Foam[®]: sequential coating + foaming



Source: Workshop
LAVOC 02.07.2008 –
Ammann SA

WMA technologies

B. Introduction of water

- Water added to the mix or humidity of some specific particle size controlled.
- Zeolite:
 - Synthetic alumino-silicate mineral having a certain porosity.
 - Contains 20% water in crystal form.
 - Water released in contact with hot bitumen → foaming.
- Water and air injection for a foaming of the bitumen.
- Control of residual humidity:
 - Partial drying of some aggregate particle size.
 - Foaming effect at the contact with hot binder.

WMA technologies



Source: Project NR2C
(FEHRL) - Eurovia

WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA technologies

C. Processes based on chemical additives

- Dry aggregates.
- Reduced modifications of the asphalt plant.
- 2 main categories:
 1. Wax
 - High molecular hydrocarbon chains
 - Various types (artificial, partially artificial or natural)
 - Developed since the end of 1990's
 2. Chemical additive, surfactants or green binder

Some WMA and HWMA technologies....

Principle	Product	Temperatures	Potential savings	Costs	Experience
A	3E-LT ®	T _{prod} =125 °C T _{comp} =80-110 °C	GHG: 20-25%	n.a.	2004-2007: 5'000 t. (3E)
B	Advera ®	T _{comp} =120 °C	NO _x : 30% COV: 60% CO: 60%	Zeolite: 1.35 US\$/kg Asphalt plant modif: 5'000 – 40'000 US\$	USA and North Am. >10'000 t.
B	Aspha-min ®	T _{prod} =125-150 °C T _{comp} =100-130 °C	Energy: 20% CO ₂ , SO ₂ , NO ₂ : 18-25%	Aspha-min: 0.60\$/lb Asphalt plant modif: 5'000 – 40'000 US\$	2004-2008: 300'000 t. (Europe)
B*	LT Asphalt ®	T _{prod} =90-95 °C T _{comp} =60 °C	Energy: 50%	n.a.	Developed since 2004, mainly NL
B*	LEA ® (EBE)	T _{prod} =90 °C T _{comp} =60-90 °C	GHG, NO _x : 50% VOC: 80% Energy: 50%	Asphalt plant modif: 75'000 – 100'000 US\$	240'000 t. (Europe) 80'000 t. (USA)
C	Sasobit ®	T _{prod} =115-130 °C T _{comp} =80 °C	Energy: 30% Environment: 20%	2'000 €/t	1997-2007 > 10 mio t. (mainly Europe)
C	Compogreen ®	T _{prod} =120 °C T _{comp} =80-110 °C	n.a.	n.a.	2008 > 70'000 t. (WAM Sreg)
C	Rediset WMX ®	T _{prod} =120 °C	Energy: 20%	n.a.	Test sections in USA and Europe (No, Sw)
C	Evotherm ET ®	T _{prod} =100-130 °C T _{prod} =60-115 °C	CO ₂ , SO ₂ : 40-60% NO _x : 60% GES: 60% Energy: 55%	7-10% higher than conventional binder Asphalt plant modif: 1'000 – 5'000 US\$	>100'000 t. worldwide
A+B	WAM-Foam ®	T _{prod} =100-120 °C T _{comp} =80-100 °C	Energy: 35% CO ₂ : 30-40% VOC: 50-60%	Asphalt plant modif: 60'000 – 85'000 US\$	2000-2007: 100'000 t. (Europe) 2008: 15'000 t. (Australia)

WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA advantages and potential

Numerous advantages in comparison with HMA:

- Energy consumption decreases: 10-30% WMA; ~50% HWMA.
- Emissions reduction (production and laying phase): 30-40% for CO₂; 50% for VOC.
- Viscosity reduction → improved workability and compaction.
- Reduced binder aging.
- Longer haul distance and increasing of storage time. Paving season extended.

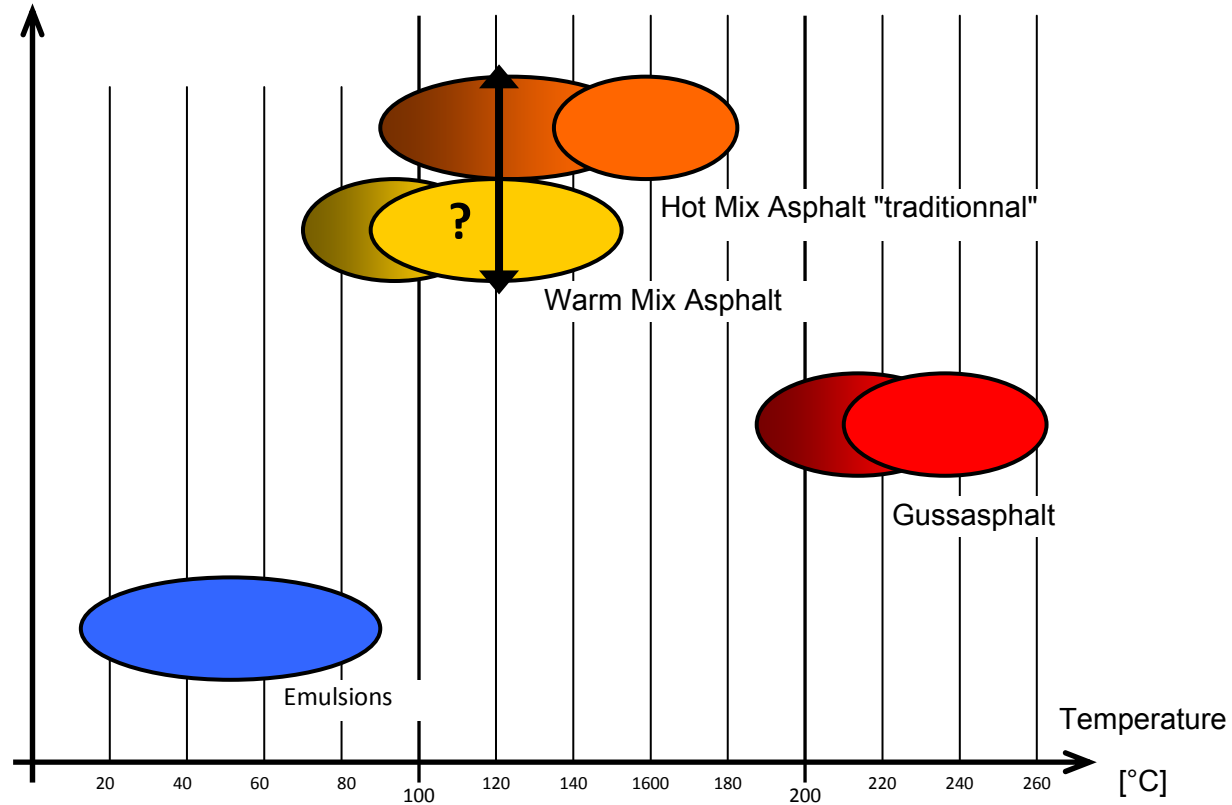
Potential benefits of WMA:

- Less exposure to asphalt fumes for workers; indicator for improved working conditions?
- Compaction aid for stiffer mixes?
- Reduced curing time?
- Binder aging and influence on performance (rutting, durability,...).
- Possibility to increase RAP content? Potential for further recycling?
- Financial assessment of the technologies (CBA).

WMA performance

Mechanical performances

[qualitative scale]



Legend :



Production temperature domain

Compaction temperature domain

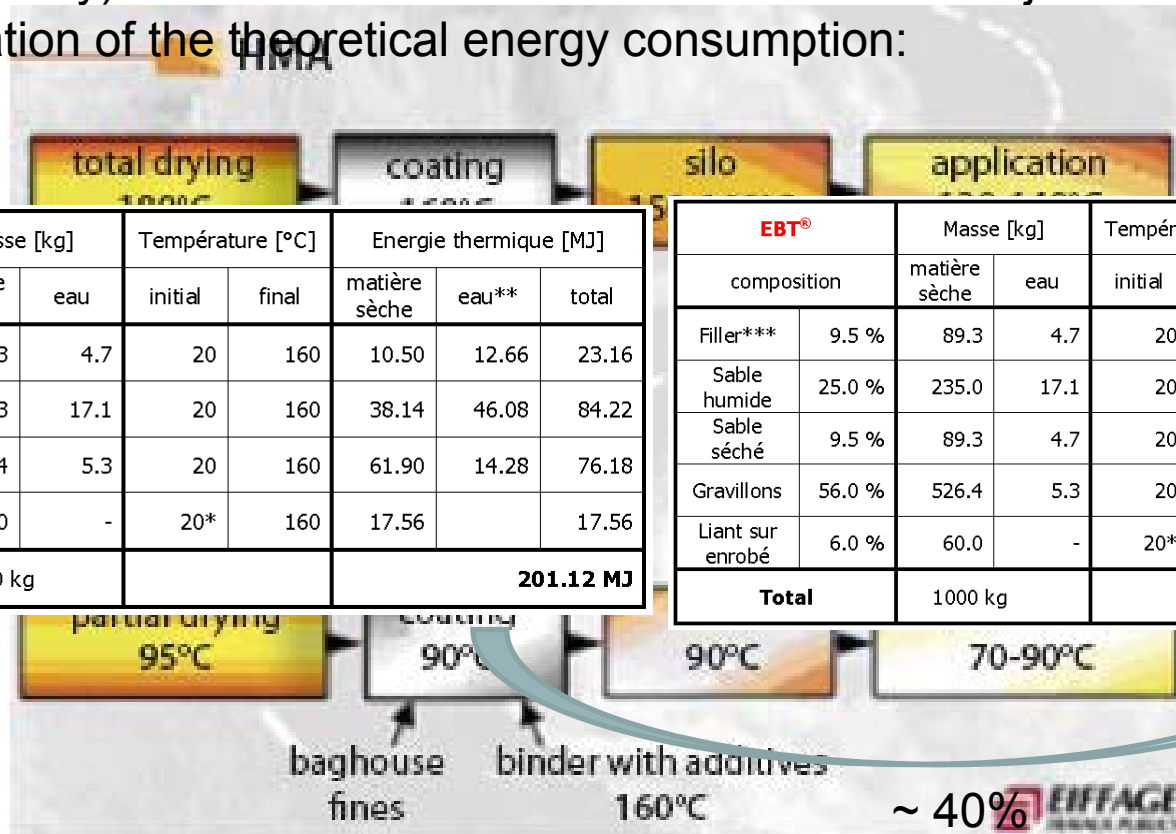
WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA performance: Case study (LAVOC)

- First laboratory study performed in LAVOC in order to test a warm mix asphalt process.
- EBT[®] (Enrobé Basse Température – Low Energy Asphalt LEA[®]) – Aggregates (hot and dry) mixed with wet sand before hot bitumen injection.
- Calculation of the theoretical energy consumption:



Hot Mix Asphalt		Masse [kg]		Température [°C]		Energie thermique [MJ]		
		matière sèche	eau	initial	final	matière sèche	eau**	total
Filler	9.5 %	89.3	4.7	20	160	10.50	12.66	23.16
Sable	34.5 %	324.3	17.1	20	160	38.14	46.08	84.22
Gravillons	56.0 %	526.4	5.3	20	160	61.90	14.28	76.18
Liant sur enrobé	6.0 %	60.0	-	20*	160	17.56		17.56
Total		1000 kg				201.12 MJ		

EBT [®]		Masse [kg]		Température [°C]		Energie thermique [MJ]		
		matière sèche	eau	initial	final	matière sèche	eau**	total
Filler***	9.5 %	89.3	4.7	20	20	-	-	-
Sable humide	25.0 %	235.0	17.1	20	20	-	-	-
Sable séché	9.5 %	89.3	4.7	20	160	10.50	12.66	23.16
Gravillons	56.0 %	526.4	5.3	20	160	61.90	14.28	76.18
Liant sur enrobé	6.0 %	60.0	-	20*	160	17.56		17.56
Total		1000 kg				116.90 MJ		

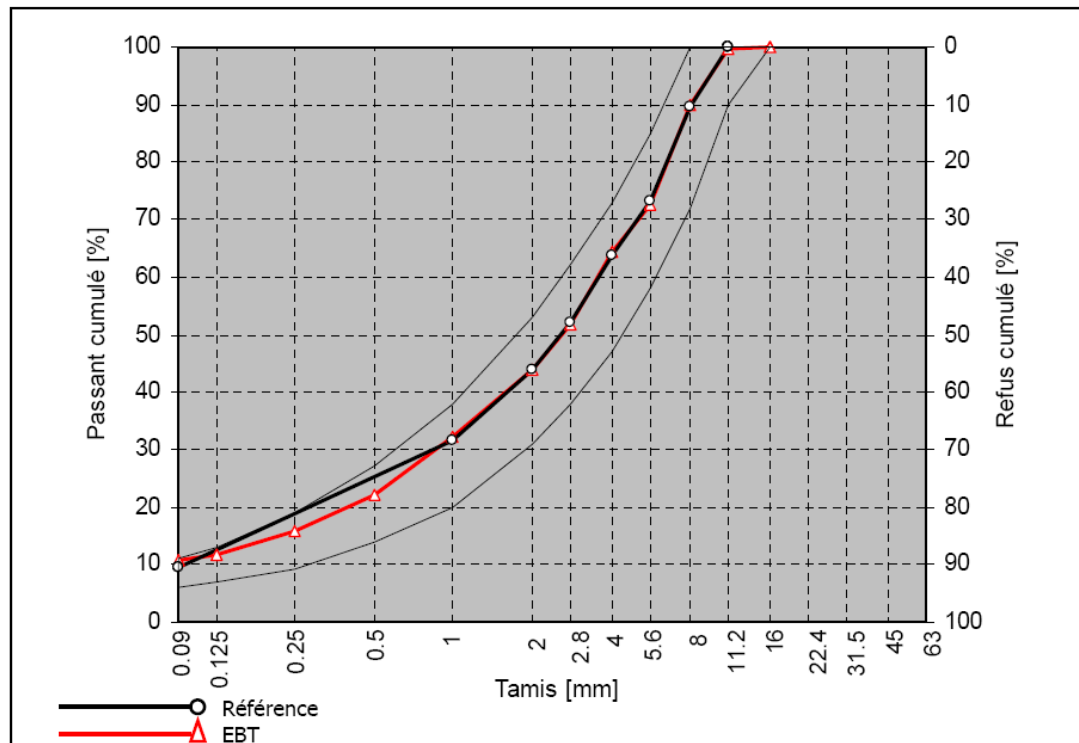
WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA performance: Case study (LAVOC)

- 2 different mix design tested in laboratory (2006 & 2008):
 - Top layer AC 11S binder 80/100 in 2006 ←
 - Base course AC T 22S binder 50/70 in 2008
- Reference mix design provided by a previous laboratory experience (AC 11S 80/100).



EBT (AC 11S):
Binder content: 6.15% (80/100)
Additive: 0.3% binder mass

WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA performance: Case study (LAVOC)

- Tests performed (AC 11S)
 - Marshall (void content, stability, creep test);
 - Gyratory compactor;
 - Indirect Tensile Strength (ITS);
 - Rutting susceptibility.
- First laboratory tests;
- Higher binder content and lower void ratio for EBT than the reference mix;
- Good workability below 100 °C;
- Apparently no specific water sensitivity (ITSR);
- Reduced binder aging;
- Reference mix very sensitive (mix design);
- Relatively low performance of EBT (rutting resistance, ITS).

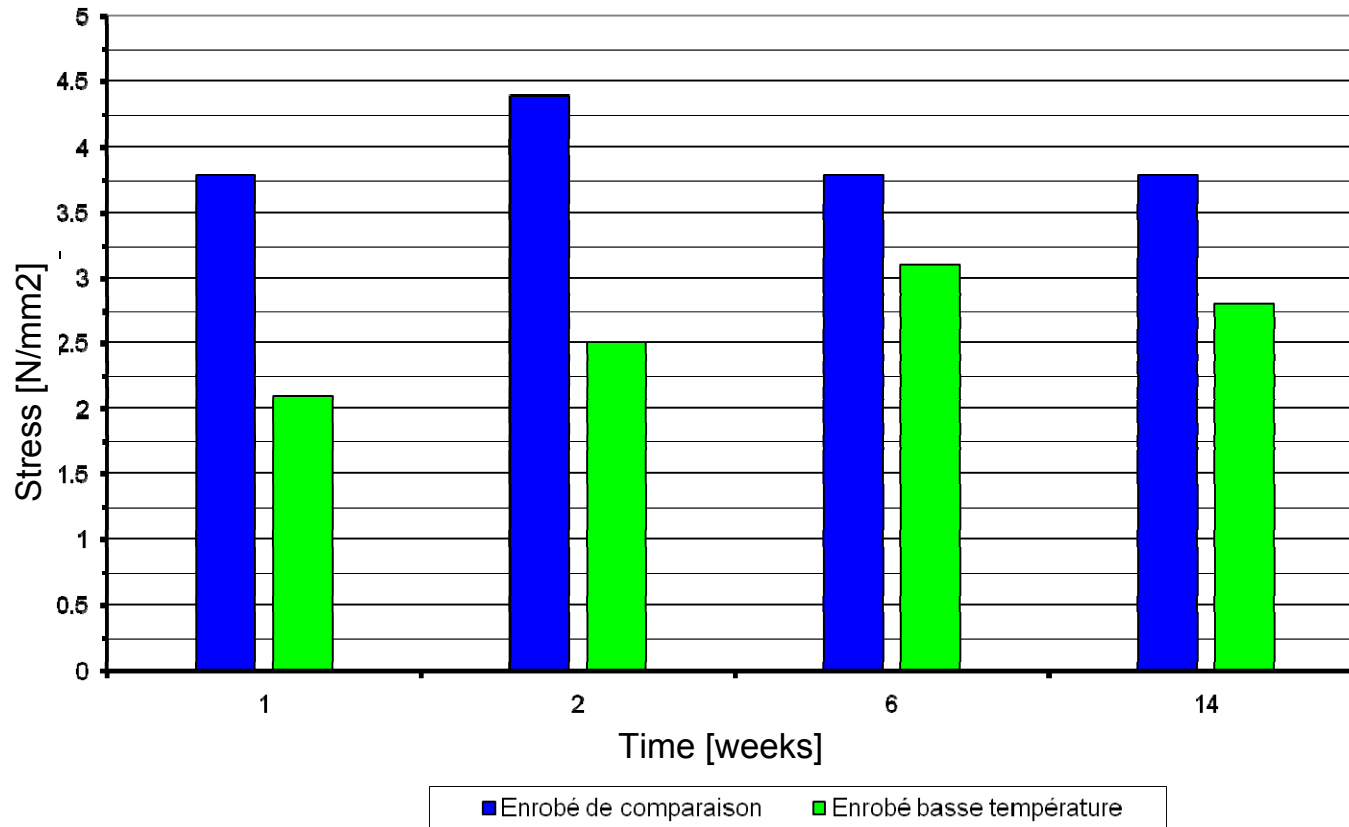
Second mix design for laboratory testing (AC T 22S)

Tests performed after 1, 2, 6 and 13 weeks :

- Indirect Tensile Strength;
- Rutting;
- Asphalt mixture analysis (grading size, binder recovery).

WMA performance: Case study (LAVOC)

Tests results (base course): Indirect Tensile Strength (ITS) ; -10 °C



- Higher void content for WMA.
- Curing effect of the WMA more important than for HMA.
- Tensile strength resistance lower for WMA.

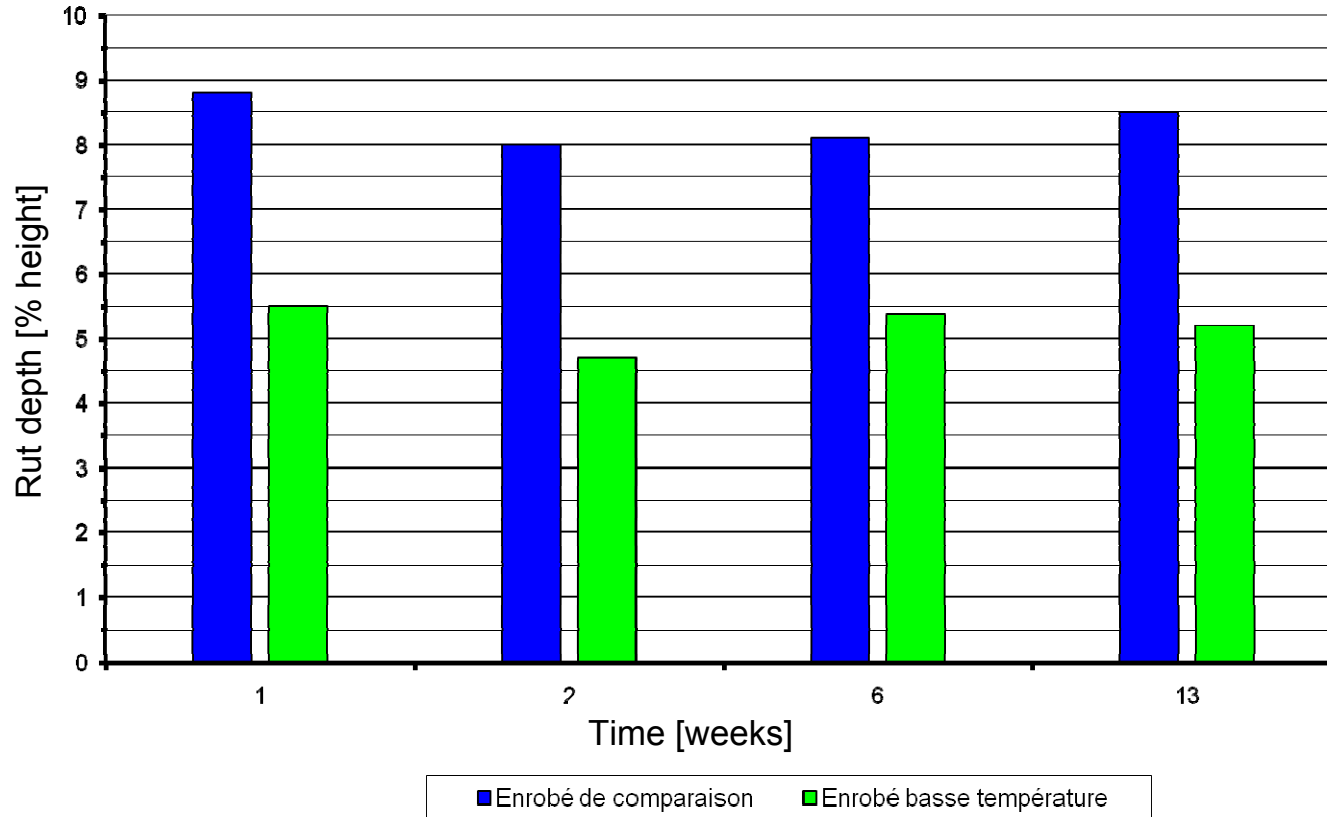
WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA performance: Case study (LAVOC)

Tests results (base course): Rutting resistance ; 30'000 loadings



- Higher void content for WMA.
- WMA: higher resistance to rutting.
- Strong influence of the void content.
- No conclusion regarding curing time.

WAM with regards to energy, emissions and performance

Bueche Nicolas



WMA performance: Case study (LAVOC)

General conclusions on preliminary testing:

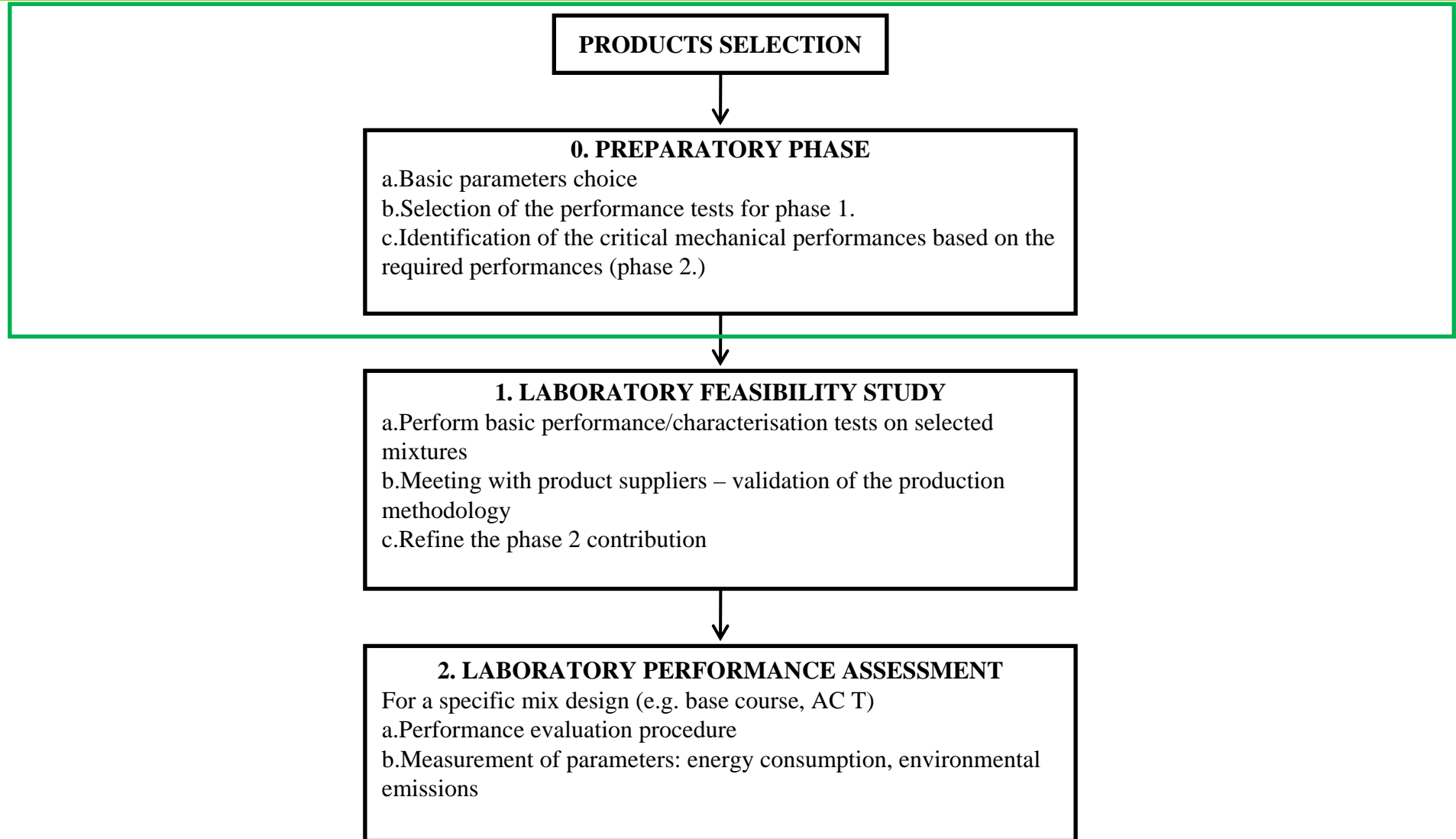
- Production procedure can be performed in laboratory.
- Higher void content than for HMA, with the same compaction energy.
- Potential rutting susceptibility (first mix) with the decreasing of production and laying temperature.
- Resistance to indirect tensile strength might be negatively affected.
- Importance of the mix design.

→ Various influences on the performances that are different than for conventional HMA.

→ How to assess the test results (e.g. PCG)?

→ Further investigations regarding performances needed.

Assessment of the WMA performance



0. Preparatory phase

- Objective: Preparation of the complete laboratory testing
- Fixe parameters for the complete study:
 - Processes of WMA (products selected);
 - Aggregate, sand and filler type;
 - Base binder;
 - Type of asphalt layer (base course);
 - Mix design method: according to the Belgian volumetric method (BRRC, PradoWin) with respect of the Swiss standards.
- Variable parameter:
 - Various product content (additive, wax,...).
- Literature study: identification of the properties (performance selection) that are potentially critical or not fully validated for further analysis.

1. Laboratory feasibility study

Objectives:

- Control production procedure
- Repeatability
- Characterisation tests
- Better definition of the phase 2 needs



Characterisation tests:

- Binder analysis (raw / modified)
 - Density
 - R&B, Pen, Fraass
 - Viscosity
- Aggregates analysis
 - Density
 - Polishing, fragmentation
 - Porosity
- Asphalt mixture analysis
 - Stability and creep tests
 - Compaction degree
 - Void content

WAM with regards to energy, emissions and performance

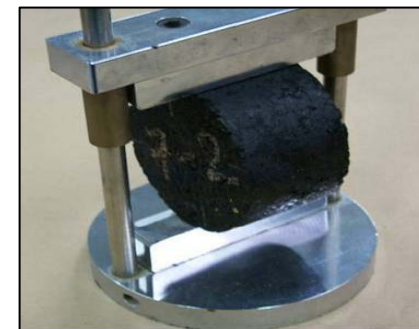
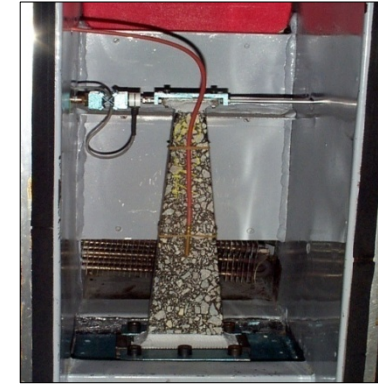
Bueche Nicolas



2. Laboratory performance assessment

Performance tests:

1. Maniability and compactibility
2. Water sensitivity / Stripping
3. Permanent deformation (rutting) – high temperature behaviour
4. Fatigue
5. Low temperature behaviour
6. Aging – Maintain of physico-chemical properties
7. Curing time – Performance increases



2. Laboratory performance assessment

Expected outputs:

- Previsional approach of the performances (phase 2 parameters); analysis of existing models in the literature and proposition of adapted models for WMA.
- Recommendations for the mix design of WMA.
- Proposition of an evaluation procedure for WMA in laboratory.
- Introduction of the results in the global evaluation tool.
- Procedure for the development of a typology of utilisation for different types of WMA.

Preliminary conclusions

- Potential of warm mix asphalt has been demonstrated.
- Environmental and energy savings are obvious, but these aspects do not currently permit to overcome the related costs. By considering the other related potential benefits, the use of WMA could be beneficial.
- However the experience with WMA is currently very limited and some issues need to be addressed.
- Presentation of the methodology for the development of a global assessment tool.
- Preliminary laboratory study highlighted the different behaviour regarding performances
- Focus put on performance evaluation in laboratory and specific characteristics that have not been fully verified.
- Development of a detailed methodology established.

Thank you for your attention !!



nicolas.bueche@epfl.ch

WAM with regards to energy, emissions and performance

Bueche Nicolas



References (1/2)

- Dumont, A.-G., B. Golaz and M. Pittet (2007). Maîtrise de la viscosité des mélanges bitumineux routiers, EPFL-LAVOC. Lausanne.
- Dumont, A.-G. and N. Bueche (2009 – to be published). Projet initial: Enrobés à faibles impacts énergétiques et écologiques, Federal roads office project VSS 2008/502, EPFL-LAVOC. Lausanne.
- Gonzalez-Leon, J. A., L. Grampre and G. Barreto (2009). Warm mix asphalts with low dosage chemical additives. In: Transportation Research Board 2009. Washington D.C.
- Grampre, L., J. A. Gonzalez-Leon and G. Barreto (2008). Warm asphalt mixtures by chemical additivation: field tests and laboratory studies. In: 4th Eurasphalt and Eurobitume Congress. Copenhagen.
- Harder, G. *et al* (2008). Energy and environmental gains of warm and half-warm asphalt mix: quantitative approach. In: Transportation Research Board 2008. Washington D. C.
- Jullien, A. *et al* (2008). Environmental assessment of a hot mix asphalt process, In: International ISAP Symposium: Asphalt pavement and environment, Zurich
- Kristjánssdóttir, O., L. Michael, S. T. Muench and G. Burke (2007). Assessing the Potential for Warm Mix Asphalt Technology Adoption. In: Transportation Research Board 2007. Washington D. C.
- Mallick, R. B., J. Bergendahl, M. Pakula (2009). A Laboratory Study on CO₂ Emission Reduction Through the Use of Warm Mix Asphalt. In: Transportation Research Board 2009. Washington D. C.
- Olard, F. and C. Le Noan (2007). EBT®: Les Enrobés à Basse Température, 2ème prix de la sélection française du prix AIPCR 2007, Catégorie développement durable. Paris.
- Olard, F. (2008). Enrobés tièdes et semi-tièdes: situation et besoins. In: Workshop EPFL-LAVOC: Enrobés à faibles impacts énergétiques et écologiques. Lausanne.

References (2/2)

- Ould-Henia, M., M. Rodriguez and A.-G. Dumont (2004). Elaboration d'une méthode prédictive de l'orniérage des revêtements bitumineux. Mandat de recherche VSS 1998/074. Lausanne.
- Paranhos, R. S. (2007). Approche multi-échelles des émissions d'un procédé d'élaboration des enrobes à chaud, Thèse de l'Université de Rouen. Rouen
- Prowell, B. D. and G. C. Hurley (2005a). Evaluation of Aspha-min® zeolite for use in Warm Mix Asphalt, National Center for Asphalt Technology, NCAT Report 05-04. Auburn University.
- Prowell, B. D. and G. C. Hurley (2005b). Evaluation of Sasobit® for use in Warm Mix Asphalt, National Center for Asphalt Technology, NCAT Report 05-06. Auburn University.
- Prowell, B. D. and G. C. Hurley (2006). Evaluation of Evotherm® for use in Warm Mix Asphalt, National Center for Asphalt Technology, NCAT Report 06-02. Auburn University.
- Prowell, B. D. and G. C. Hurley (2007). Warm-Mix Asphalt: Best Practices, National Asphalt Pavement Association. Lanham.
- Soenen, H. *et al* (2008). A laboratory study on the use of waxes to reduce paving temperatures, In: 4th Eurasphalt and Eurobitume Congress. Copenhagen.
- Stripple, H. (2001). Life Cycle Assessment of Road: A Pilot Study for Inventory Analysis. Swedish Environmental Research Institute IVL. Gothenburg.



Title of the slide

- Content

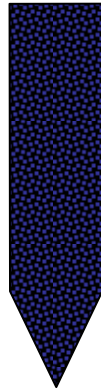
WAM with regards to energy, emissions and performance

Bueche Nicolas

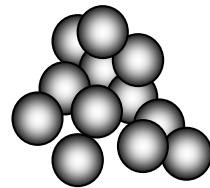


WMA technologies

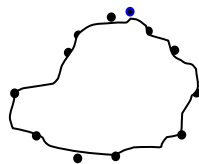
- Foaming process:



Bitumen with approx. 2% water under pressure (imp: injection mode and pressure).



Bitumen volume expansion through vaporisation.
Bitumen volume increases: x 10 – 20



Bitumen adhesion and coating to the aggregates surface.

*Source: Workshop LAVOC
02.07.2008 – Ammann SA*

Energy & emissions assessment of WAM

- Objective is to provide some information for insertion in the global assessment tool.
- Emissions:
 - measurements on an asphalt plant during production and on laboratory samples.
 - Further investigation needed for the measurement device and procedure in laboratory.
 - Utilisation of existing gas emission models (flux calculation based on concentration measurements for selected gases).
- Energy:
 - Measurement on an asphalt plant during production.
 - Calculation using existing models (thermodynamic approach).