Europe's Modified Asphalt Binder Experiences

Jean-Pascal Planche, et al

AMAP 12th Annual Meeting
Kansas City, MO

February 17, 2011

Western Research INSTITUTE

Acknowledgements

- **Elf, Elf Asphalt Inc. and Total**
  - **R&D, Projects and Marketing teams, worldwide**
- **Partners: polymer suppliers, customers – road contractors**
- **Road administrations – US and Europe**
  - **LCPC, FHWA and others**
- **University contacts – US and Europe**
  - **Subcontractors from both asphalt and polymer worlds**
- **Competitors‘ challenges**
  - **No improvement when no competition…!**

Outline

- **Transportation Background**
- **European Market of PmB's**
- **Modification Techniques**
- **Application / PmB's usage in Europe**
- **Regulations**
- **Summary**
- **Perspectives**

Transportation Background

The Challenge for Transportation stakeholders:

- **To maintain the flow** of people, goods and services allowing the US to remain economically competitive in a rapidly changing global marketplace
- **A difficult challenge** due to the combined concurrent factors:
  - Increasing (heavy) traffic
  - Shrinking resources – aggregates, asphalts, oil…
  - Unstable economics – crisis…
  - Aging infrastructures – particularly in developed countries
- *Source: summary of NAPA / AI / DOT statements*
- **A worldwide challenge** - by definition

Outline

- Transportation Background
- **European Market of PmB's**
- Modification Techniques
- Application / PmB's usage in Europe
- Regulations
- Summary
- Perspectives

Western Research INSTITUTE

Bitumen worldwide Production ~ 2.5% total refining Prod.

source TECNON		1995	1999	2000	2001	2005	2010
WORLD							
total oil demand (M tons)		**3 288**	**3 509**	**3 581**	**3 651**	**3 931**	**4 273**
	therefrom (M tons)						
	bunker	128,3	137,1	138,2	139,2	142,4	147,8
	fuel oil	476,5	446,5	445,0	441,0	424,0	417,1
world	**pet coke**	35,8	40,3	40,9	41,9	45,3	48,3
	lubes	32,0	33,4	33,6	34,1	36,1	38,3
	bitumen	**86,5**	**91,8**	**93,0**	**94,0**	**98,5**	**104,3**
	therefrom (%)						
	bunker	3,90%	3,91%	3,86%	3,81%	3,62%	3,46%
	fuel oil	14,49%	12,72%	12,43%	12,08%	10,79%	9,76%
world	**pet coke**	1,09%	1,15%	1,14%	1,15%	1,15%	1,13%
	lubes	0,97%	0,95%	0,94%	0,93%	0,92%	0,90%
	bitumen	**2,63%**	**2,62%**	**2,60%**	**2,57%**	**2,51%**	**2,44%**

WesternResearch INSTITUTE

Bitumen worldwide markets
Bitumen demand by region

source TECNON - Projections	1995	1999	2000	2001	2005	2010
BITUMEN DEMAND						
USA	29.3	31.3	31.5	31.6	32	33
canada	2.9	3.3	3.4	3.4	3.7	4
latin america	4.6	5	5.1	5.2	5.7	6.3
western europe	18.2	18.8	18.9	18.8	18.9	19.2
eastern europe	1.8	2.1	2.1	2.1	2.3	2.5
former USSR	6.2	5.4	5.4	5.5	5.6	5.7
africa	1.9	2	2	2.1	2.2	2.4
middle east	4.5	5.2	5.3	5.3	5.6	5.9
japan	5.9	6.1	6.1	6.1	6.2	6.3
east asia	6.5	6.9	7.2	7.5	8.7	9.8
south asia / pacific	4.7	5.9	6.1	6.4	7.7	9.3
total bitumen	86.5	91.8	93.0	94.0	98.5	104.3

Current data (source Eurobitume)

- 2009 European Bitumen consumption = 16.6 Mt - Production = 17.4 Mt
- **Breakdown**
  - Normal paving grades: 13.8 Mt with: Softer 11.0 Mt / Harder 2.8 Mt
  - Paving PmB: 1.5 Mt
  - Industrial grades: 1.2 Mt

WesternResearch INSTITUTE

PmB Market data

Countries / years / info sources	1999 PIARC* (Kt)	2008 Eurobitume (kt)	2009 Eurobit. (kt)	% MS vs. Bitumen
France	251	34** (#300)	33**(300)	8
Germany	250	479	718	29
Czech Republic		40	34	10
Italy	80	153	113	9
Spain		152	153	8
Switzerland		36	24	11
United Kingdom	66	123	78	6 (8 in 09)
Austria, Belgium, Luxembourg, Portugal, Greece, Hungary, Slovakia, Slovenia, **Poland**, Romania, Netherlands		147	308	12.5
Denmark, Estonia, Finland, Norway, Sweden Iceland, Latvia, Lithuania,		28	36	2.5
Europe	**647**	**1192**	**1497**	**10 (7 in 09)**

*** After PIARC Symposium on PmB's, in Rome, Italy - Report N°303, 07/1999**

European Market Summary

- **According to available data sources**
  - ***Warning: careful with exact values – numbers difficult to obtain – high uncertainty, based on voluntary info basis***
  - ***Disclaimer: no official analysis – this is my own!***
- **European market of PmB's still growing**
  - **Despite economic crisis – but UK badly hit in 2009**
  - **Average close to 10% in 2009 – 7% in 2008**
  - **EU Champion is Germany, approaching 30% market share**
    - **PmB = no longer a specialty product in Germany**
  - **Very low usage in Nordic countries – low traffic / perf issues?**
  - **Central & Eastern Europe fast growing**
  - **Mature countries steady - FR, SP, IT, CH… close to 10%**
  - **The French / German market paradox – see next slide**

Focus on German and French Markets

- **France:**
  - **The oldest PmB market in Europe - Most mature**
  - **Techniques validation by LCPC and ad-hoc committees**
  - **Main producers are road contractors – few being oil companies**
    - **Specialty mixes with little PmB usage like high modulus mixes**
  - **No specs until recent EN14023**
  - **Used to use 20% plastomer vs. 80% elastomer**
- **Germany:**
  - **Fast growing PmB market**
  - **Role of ARBIT: study in late1990's to validate PmB performances**
  - **Producers: Mainly oil companies and few road contractors**
  - **Best bids vs. low bids country – long term performances considered**

Outline

- Transportation Background
- European Market of PmB's
- **Modification Techniques**
- Application / PmB's usage in Europe
- Regulations
- Summary
- Perspectives

WesternResearch INSTITUTE

Highway Industry Recent Technical Evolutions

- **Binder**
  - **Various asphalt modification techniques to meet new market demands and specifications - Superpave in the US, EN in Europe**
    - **From polymers to additives and combinations**
  - **New specifications more performance based**
    - **From Superpave to Superpave +, and now "Advanced specs" incl. MSCRT**
- **Hot mix**
  - **SMA, Porous asphalt, High modulus mixes and other new special mix designs**
  - **Perpetual pavements**
  - **New specifications, pavement and mix design guides (MEPDG)**
- **Application**
  - **Warm Mix Asphalts: abundance of new techniques – about 30!**
    - **Chemical additives, foaming, waxes…**
  - **Recycled Asphalt Pavements, towards higher recycling rates**
  - **WMA+RAP: the "green-green" combination**
- **Combinations of new binders / mixes / applications**

Why modify binders?

- **More Severe Constraints**
  - **Traffic volume**
  - **Aggressive heavy traffic**
  - **Challenging applications**
- **More Economic constraints**
  - **Oil and aggregate shortage threats**
  - **Durable Investments – longer life pavements**
  - **Thinner and thinner layers**
- **New environmental issues**
  - **Emissions**
  - **Energy consumption**
  - **LCCA = durability is a major driving force, together with recycling**
- **-> Need for modified binders!**

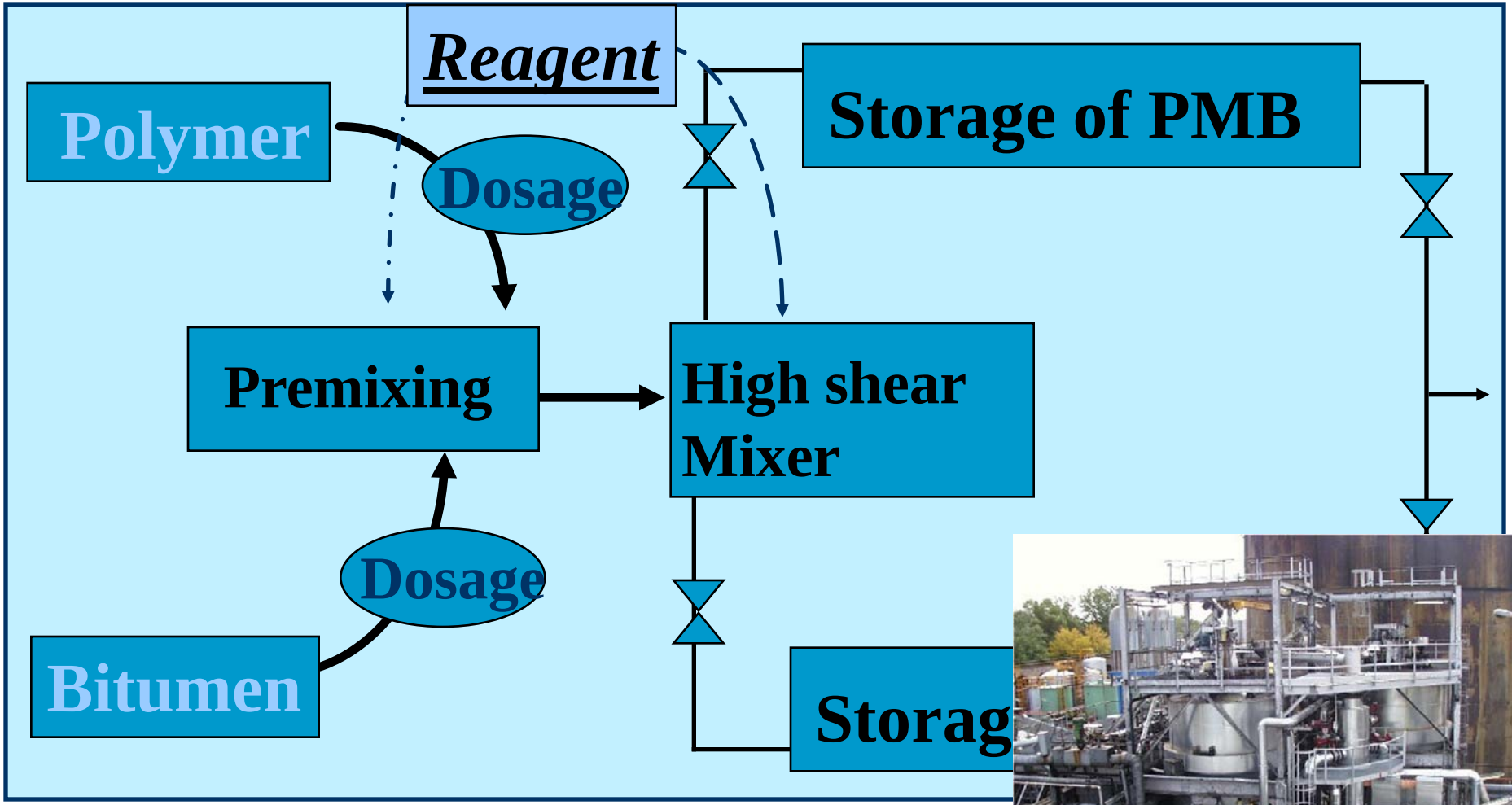
Why use polymer modified binders ?

- **Recognized performance**
  - **Lower sensitivity to temperature**
  - **Improved cohesion**
  - **Improved elongation capability**
  - **Improved mechanical, viscoelastic properties**
    - **within and without the linear range**
  - **Better passive adhesion – water stripping resistance**
- **An essential contributor to the development of innovative products**

Polymer used in Europe

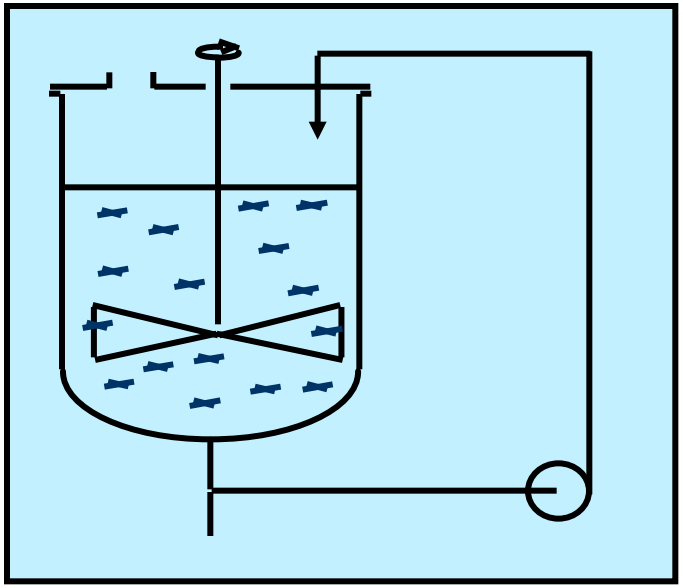
- **Mainly Elastomers**
  - **Mainly SBS types, typically 30% styrene, tribloc linear and/or radial**
  - **Used in Physical asphalt blends**
  - **Used in cross-linked asphalt blends - dynamic vulcanization – Growing use**
  - **Occasionally latex**
  - **PmB+PPA marginally used for the time being yet.**
- **Less and less Plastomers**
  - **Mainly EVA – typically Mass flow index, 5 to 50 and VA content,15 to 35% (by weight)**
  - **Occasionally EBA or PE**
  - **Terpolymers not much used yet in Europe**
- **Back in business: rubber for CRMB**
  - **In Spain mainly but possibly in Germany and elsewhere**

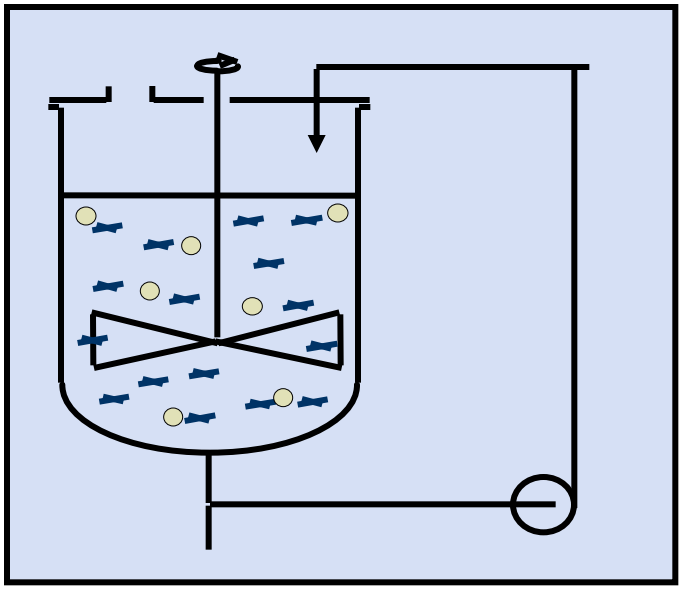
Production of Polymer Modified Binder



Production issues

- **Processes: Physical Blend vs. Cross-linked blend**





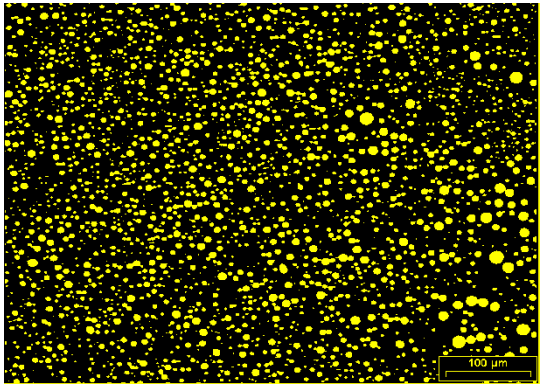
GENERAL CASE =
SBS physical blend

Cross-linked in situ
= SB(S) physical blend + reagent

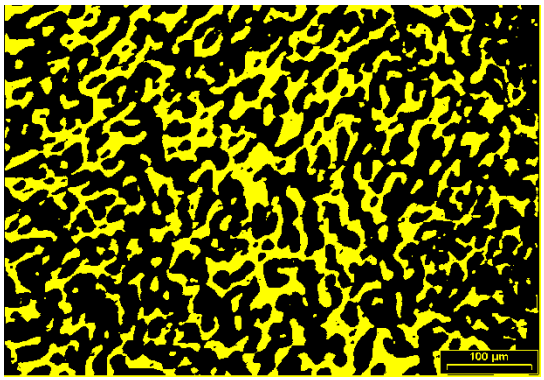
- **Process Parameters: time, temperature, agitation system – speed and shear.**
- **Looking for a finished product ready-to-use, stable during storage and application**

The compatibility issue

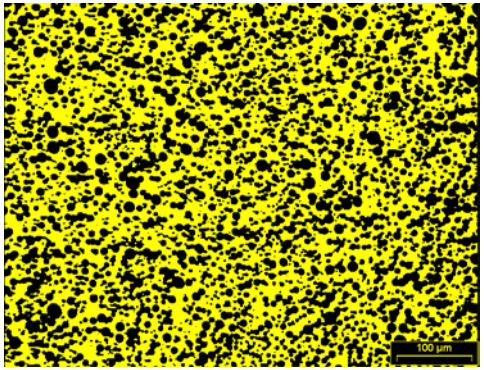
- **How to get an homogenous material?**
  - **Physical blend – as a function of polymer content, and base and SBS origins (constant here)**



Polymer < 3 %
Asphalt conitnuous phase



Polymer ~ 5 %
Two co-continuous phases

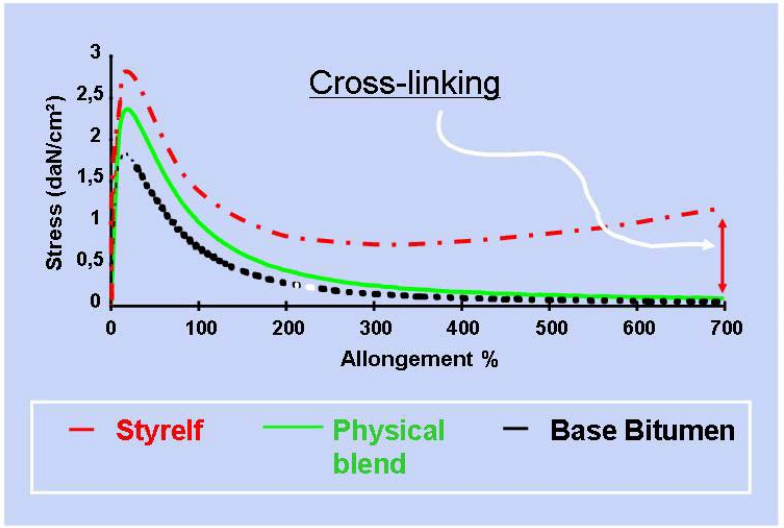


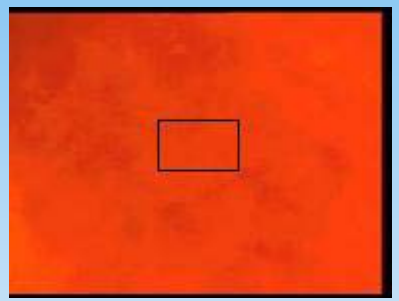
Polymer > 7 %
Polymer phase matrix

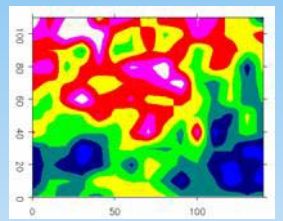
  - **Cross-linked blend**

Why use cross-linked modified binders ? 1/2

- **Intrinsic characteristics of cross-linked elastomer modified binders**
  - **Exceptional elongation characteristics**
  - **Cohesion**
  - **Low and High temperature performance**







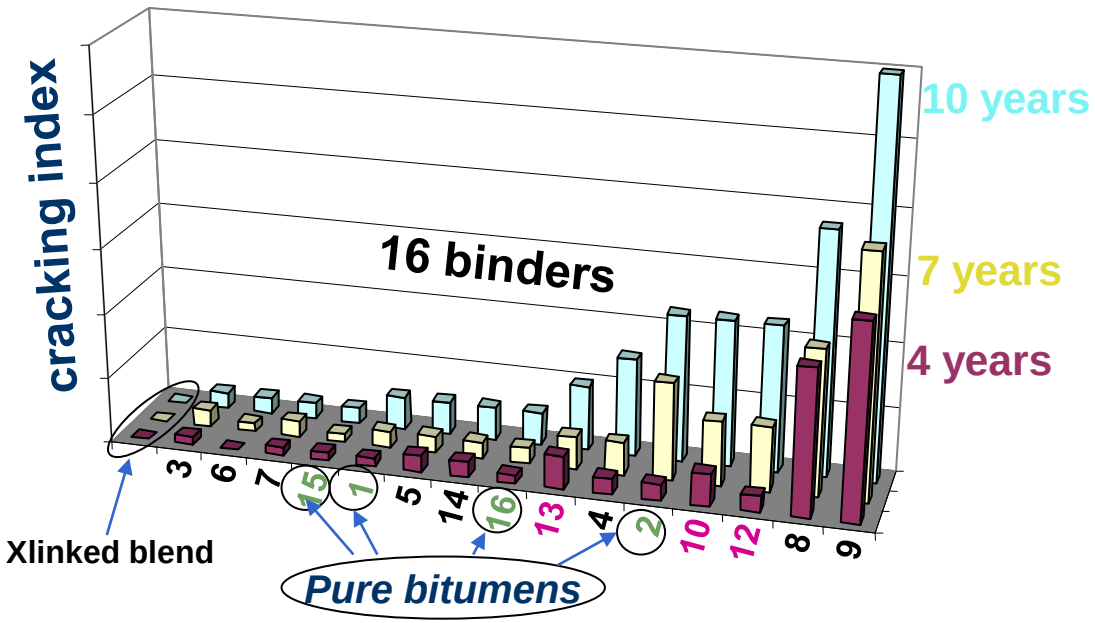
Before / after aging:

Homogeneous polymer content of the in situ crosslinked SBS

Mouillet et al, Orgagec '02

Durability of PmB's after 14 years

Lausanne University (LAVOC) : Cracking index of mixes made with 16 different binders



Cracking

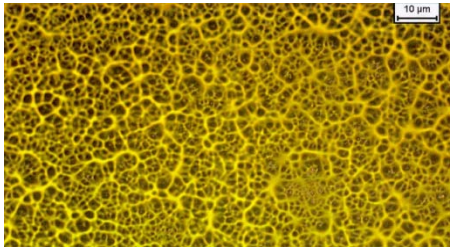
High index = many cracks!!

- **In 2009 : Cross-linked PmB still showing no crack after 19y in service under cold climatic conditions (Swiss Alps)**
- **Correlation with m-value, remaining of elastomer properties**

AG Dumont et al, E&E 2004, Dreessen et Al, TRB 2010, ISAP 2010

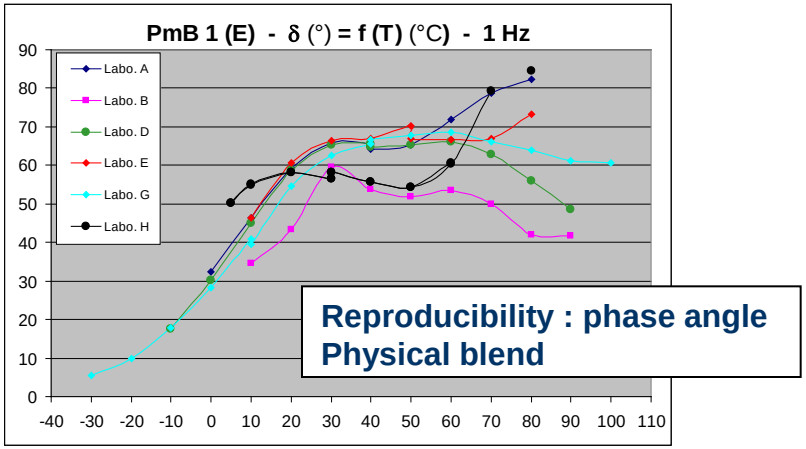
Why use cross-linked modified binders ? 2/2

- ***Words taken from Eurovia, a major European road contractor***
- **Homogeneous product Advantages**
  - **Storage stability: a key asset for any user**
  - **No extra storage costs (no need for stirring)**
  - **No problem when delayed works**

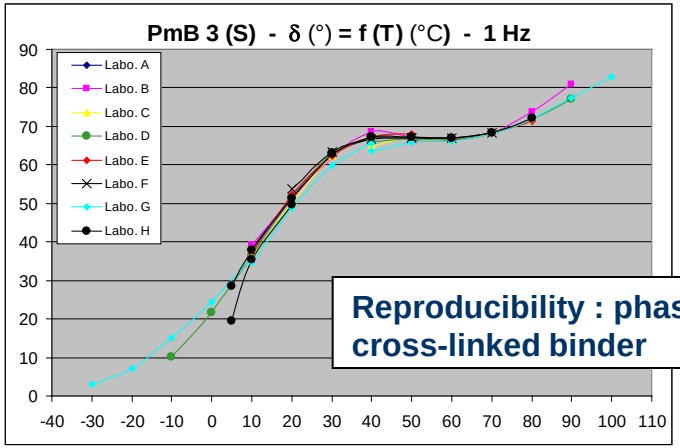


- **"Rheological simple"**
  - **Easy to control**
  - **Quality control on physical blends is often controversial due to poor test reproducibility – particularly when highly modified**

➢ **Homogeneous products create less problems to the user**



Reproducibility : phase angle Physical blend



Reproducibility : phase angle cross-linked binder

Outline

- Transportation Background
- European Market of PmB's
- Modification Techniques
- **Application / PmB's usage in Europe**
- Regulations
- Summary
- Perspectives

Application of polymer modified binders in Europe

- For binder demanding applications
- Hot mix applications
  - **To ensure durability of surface characteristics, resistance to permanent deformation, thermal cracking and raveling**
  - Thin to ultra thin wearing courses
  - Heavy duty paving mixes
  - Porous draining & noiseless asphalt courses
  - Stone mastic asphalt
- Special mixes
  - Anti-cracking sand mixes (reflective cracking resistant)
  - Fuel resistant mixes
  - Waterproofing applications

Applications of polymer modified binders in Europe

- Surface dressing applications
- Heavy duty surface dressings
  - To improve thermal susceptibility, elongation properties and cohesion, adhesion & durability
  - In case of high traffic, winding road to reduce failure risk
  - Fluxed binders PmB (HC or bio flux) and PmB Emulsions
- Micro-surfacing
  - To improve cohesion
  - PmB emulsions
- High performance tack-coats
  - Elongation properties, cohesion and adhesion
  - PmB emulsions

Outline

- Transportation Background
- European Market of PmB's
- Modification Techniques
- Application / PmB's usage in Europe
- **Regulations**
- Summary
- Perspectives

Western Research INSTITUTE

EN14023

Based on:

- Consistency:
  - Pen
  - R&B
- ***Cohesion***
  - FD, DTT, Vialit
- Durability (RTFOT)
- Flash Point
- Brittleness (Fraass)
- Strain recovery (ER)
- Additional
  - Plasticity range
  - Storage stability
  - ER after RTFOT

Example of selected classes for a PMB 45/80-60

CHARACTERISTIC	PROPERTY	TEST METHOD	UNIT	SELECTED CLASS
Consistency at intermediate service temperature	Penetration at 25 °C	EN 1426	0,1 mm	45-80 (Class 4)
Consistency at elevated service temperature	Softening point	EN 1427	°C	≥ 60 (Class 6)
Cohesion	Force ductility (50 mm/min traction) or	EN 13589 followed by EN 13703	J/cm²	≥ 2 (Class 3)
	Tensile test (100 mm/min traction) or	EN 13587 followed by EN 13703	J/cm²	-
	Vialit pendulum (Impact test)	EN 13588	J/cm²	-
Durability (Resistance to hardening, EN 12607-1)	Change of mass	EN 12607-1	%	≤ 0,5 (Class 3)
	Retained penetration	EN 1426	%	≥ 50 (Class 5)
	Increase in softening point	EN 1427	°C	≤ 8 (Class 2)
Brittleness at low service temperature	Fraass breaking point	EN 12593	°C	≤ - 10 (Class 5)
	Elastic recovery at 10 °C	EN 13398	%	NR (Class 0)
Strain recovery	Elastic recovery at 25 °C	EN 13398	%	≥ 50 (Class 5)
	Elastic recovery at 10 °C	EN 13398	%	NR (Class 0)
Additional characteristics	Flash Point	EN ISO 2592	°C	≥ 235 (Class 3)
	Plasticity range	5.1.9	°C	TBR (Class 1)
	Storage stability Difference in softening point	EN 13399 EN 1427	°C	≤ 5 (Class 2)
	Storage stability Difference in penetration	EN 13399 EN 1426	0,1 mm	TBR (Class 1)
	Drop in softening point after EN 12607-1	EN 1427	°C	NR (Class 0)
	Elastic recovery at 25 °C after EN 12607-1	EN 13398	%	≥ 50 (Class 4)
	Elastic recovery at 10 °C after EN 12607-1	EN 13398	%	NR (Class 0)

WesternResearch INSTITUTE

EN 14023 – all grades mandatory properties

- Grade selection upon classes, according to performance levels in Pen, R&B, Cohesion, Resistance to hardening, Flash Point

Table 1 — Framework specifications for polymer modified bitumens – Properties applying to all polymer modified bitumens

PROPERTY		TEST METHOD	UNIT	Classes for all polymer modified bitumens									
				2	3	4	5	6	7	8	9	10	11
Penetration at 25 °C		EN 1426	0,1 mm	10-40	25-55	45-80	40-100	65-105	75-130	90-150	120-200	200-300	
Softening Point		EN 1427	°C	≥ 80	≥ 75	≥ 70	≥ 65	≥ 60	≥ 55	≥ 50	≥ 45	≥ 40	
Cohesion [a]	Force ductility [a] (50 mm/min traction) or	EN 13589 followed by EN 13703	J/cm²	≥ 3 at 5 °C	≥ 2 at 5 °C	≥ 1 at 5 °C	≥ 2 at 0 °C	≥ 2 at 10 °C	≥ 3 at 10 °C	≥ 0,5 at 15 °C	≥ 2 at 15 °C	≥ 0,5 at 20 °C	≥ 0,5 at 25 °C
	Tensile test [a] (100 mm/min traction) or	EN 13587 followed by EN 13703	J/cm²	≥ 3 at 5°C	≥ 2 at 5 °C	≥ 1 at 5 °C	≥ 3 at 0 °C	≥ 3 at 10 °C					
	Vialit pendulum [a] (Impact test)	EN 13588	J/cm²	≥ 0,7									
Resistance to hardening [b]	Retained Penetration	EN 12607-1	%	≥ 35	≥ 40	≥ 45	≥ 50	≥ 55	≥ 60				
	Increase in Softening point		°C	≤ 8	≤ 10	≤ 12							
	Change of mass [c]		%	≤ 0,3	≤ 0,5	≤ 0,8	≤ 1,0						
Flash Point		EN ISO 2592	°C	≥ 250	≥ 235	≥ 220							

[a] One cohesion method shall be chosen based on end application. Vialit cohesion (EN 13588) shall only be used for surface dressing binders.

[b] The main test is the RTFOT at 163 °C. For some highly viscous polymer modified bitumens where the viscosity is too high to provide a moving film it is not possible to carry out the RTFOT at the reference temperature of 163 °C. In such cases the procedure shall be carried out at 180 °C in accordance with EN 12607-1.

[c] Change of mass can be positive or negative.

The properties in Table 1 shall be specified for all polymer modified bitumens listed in this table. They are associated with regulatory or HSE requirements and shall be included in all specifications.

EN 14023 – all grades optional properties

- Regional requirements on Fraass breaking point and elastic recovery vs. climate, traffic and usage conditions

Table 2 — Framework specifications for polymer modified bitumens – Properties associated with regulatory or other regional requirements

PROPERTY		TEST METHOD	UNIT	Classes for regional requirements										
				0	1	2	3	4	5	6	7	8	9	10
Fraass Breaking Point		EN 12593	°C	NR [a]	TBR [b]	≤ 0	≤ - 5	≤ - 7	≤ - 10	≤ - 12	≤ - 15	≤ - 18	≤ - 20	≤ - 22
Elastic recovery	25 °C or [c]	EN 13398	%	NR [a]	TBR [b]	≥ 80	≥ 70	≥ 60	≥ 50					
	10 °C	EN 13398	%	NR [a]	TBR [b]	≥ 75	≥ 50							

[a] NR. No Requirement may be used when there are no regulations or other regional requirements for the property in the territory of intended use.

[b] TBR. To Be Reported may be used when there are no regulations or other regional requirements for the property in the territory of intended use, but the property has been found useful to describe polymer modified bitumens.

[c] Where required, polymer modified bitumens shall conform to the requirements for elastic recovery at 25 °C or 10 °C.

The properties in Table 2 are required to meet specific regional conditions. They are associated with regulatory or other regional requirements.

Western Research INSTITUTE

EN 14023 – other properties

- Other properties: Plasticity range / R&B drop or ER after RTFOT / Storage stability (R&B, pen differences)

Table 3 — Framework specifications for polymer modified bitumens – Additional properties

PROPERTY	TEST METHOD	UNIT	Classes for the additional properties of polymer modified bitumens							
			0	1	2	3	4	5	6	7
Plasticity range	5.2.8.4	°C	NR[a]	TBR	≥ 85	≥ 80	≥ 75	≥ 70	≥ 65	≥ 60
Drop in softening point after EN 12607-1	EN 1427	°C	NR[a]	TBR	≤ 2	≤ 5				
Elastic recovery at 25 °C after EN 12607-1	EN 13398	%	NR[a]	TBR	≥ 70	≥ 60	≥ 50			
Elastic recovery at 10 °C after EN 12607-1	EN 13398	%	NR[a]	TBR	≥ 50					
Storage stability [b] Difference in softening point	EN 13399 EN 1427	°C	NR[a]	TBR[b]	≤ 5					
Storage stability [b] Difference in penetration	EN 13399 EN 1426	0,1 mm	NR[a]	TBR[b]	≤ 9	≤ 13	≤ 19	≤ 26		

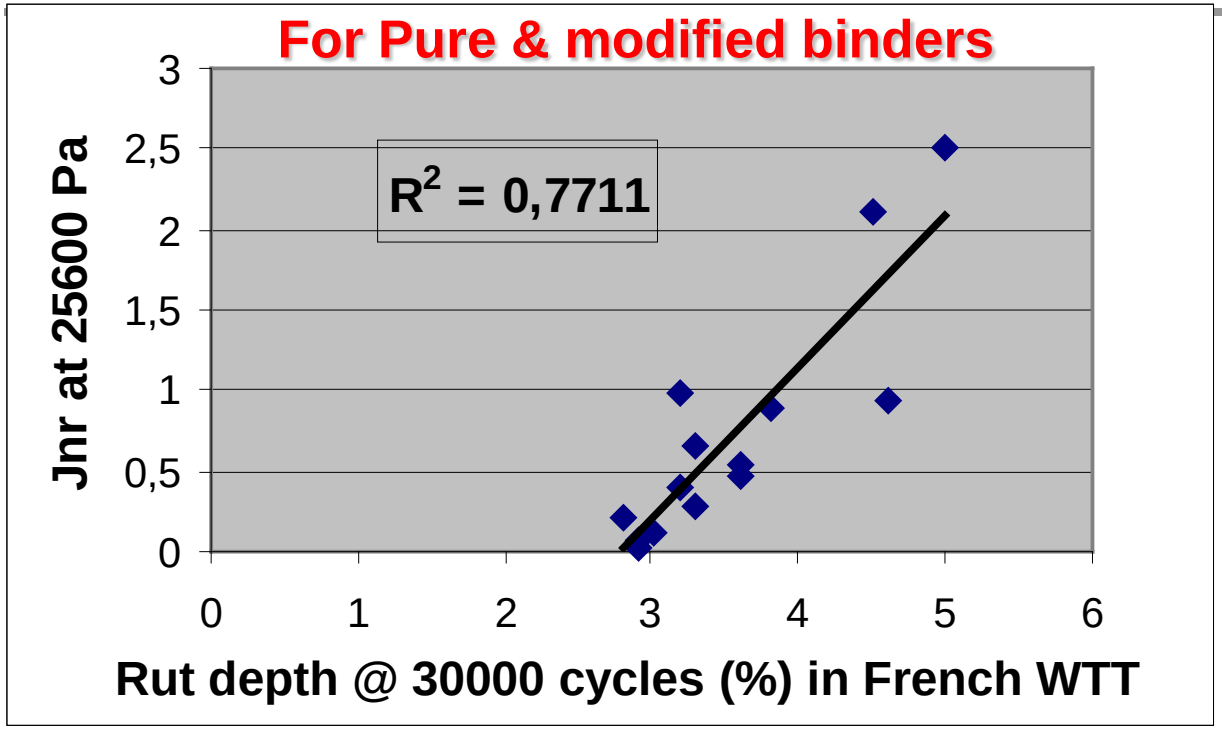
[a] NR. No Requirement may be used when there are no requirements for the property in the territory of intended use.

[b] Storage conditions of the polymer modified binder shall be given by the supplier. Homogeneity is necessary for polymer modified bitumens. The tendency of polymer modified bitumens to separate during storage may be assessed by the storage stability test (see EN 13399). If the product does not fulfil the properties in Table 3 Classes 2 to 5, information shall be given by the supplier regarding storage conditions for the polymer modified bitumen to avoid separation of the components and to ensure the homogeneity of the product.

Binder specifications in Europe – Perspectives

- ***Towards performance based specifications***
- **CEN working groups - WG1/TG5 & ad-hoc groups**
- **FEHRL (Highway research labs): "BitVal project"**
  - **Phase 1 - A review of existing data on bitumen tests used by TC336 WG1 – completed – see http://bitval.fehrl.org/**
  - **Phase 2 – Gap study in the knowledge identified in Phase 1**
  - **Phase 3 – Study of bitumen test methods missing from the original list**
- **Eurobitume – Task Force Performance**
  - **Goal: To develop a bitumen industry viewpoint on Performance Related Standards for bituminous binders for hot applied paving bitumen**
  - **Data collection including 146 binders (58 PmB's, 4 Specials)**
- **-> Lengthy process, constrained by CEN rules…**
  - **But proactive initiatives such as the push from highway**

MSCRT: Asphalt concrete - binder correlation



- Fair correlation Jnr vs. rut depth @ 30000 cycles for a rut resist. mix
- Better correlation at higher stress levels at 60 °C
  - @ 100 Pa ⇒ R^2=0,36 / @ 3.2 kPa ⇒ 0,44 / @ 25.6 kPa ⇒ 0,77
- Validation of links between rutting and non linearity

Presented at IRF 2010

Outline

- Transportation Background
- European Market of PmB's
- Modification Techniques
- Application / PmB's usage in Europe
- Regulations
- **Summary**
- Perspectives

Summary

- ✓ Polymer modified asphalt markets still growing in Europe but at different rates vs. countries # 10%
- ✓ Mainly SBS elastomeric modifiers w or w/o cross-linking - Plastomers (EVA) occasionally used
- ✓ Producers: generally oil companies, but road contractors very important in some countries
- ✓ PmB's used for appropriate applications – "European layer function concept"
- ✓ EN specs soon to be in full force
  - ✓ Still empirical in nature - cohesion used to differentiate with bitumen
  - ✓ Possibly increasing PmB use ?
- ✓ Push towards PR specs – but lengthy process

Outline

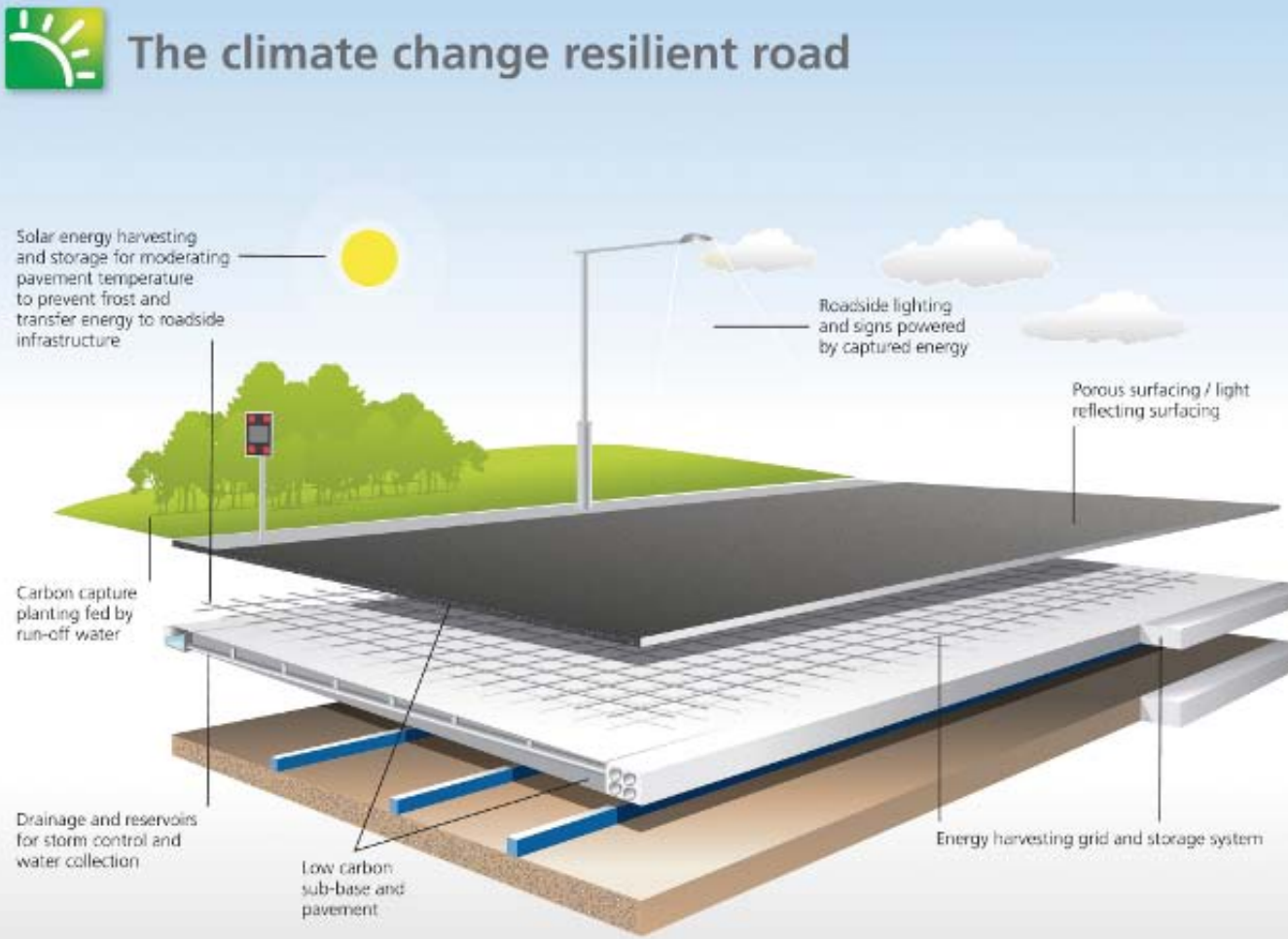
- Transportation Background
- European Market of PmB's
- Modification Techniques
- Application / PmB's usage in Europe
- Regulations
- Summary
- **Perspectives**

Short - Mid term perspectives

- **Recycling**
  - **of PmB's RAP**
  - **RAP with PmB's**
- **WMA with PmB's**
- **Performance based**
  - **Test methods – promising: BBR, FT, DSR, MSCRT**
  - **Specs**
- **Tailored made polymers / additives – alloys / cocktails**
  - **More efficient**
  - **More cost effective**
  - **Easier to handle**

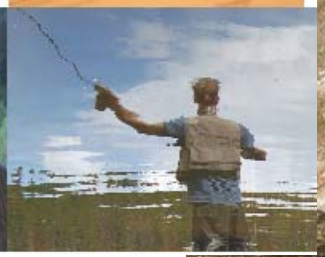
WesternResearch

Forever open roads



http://www.fehrl.org/?m=251

Thank you!

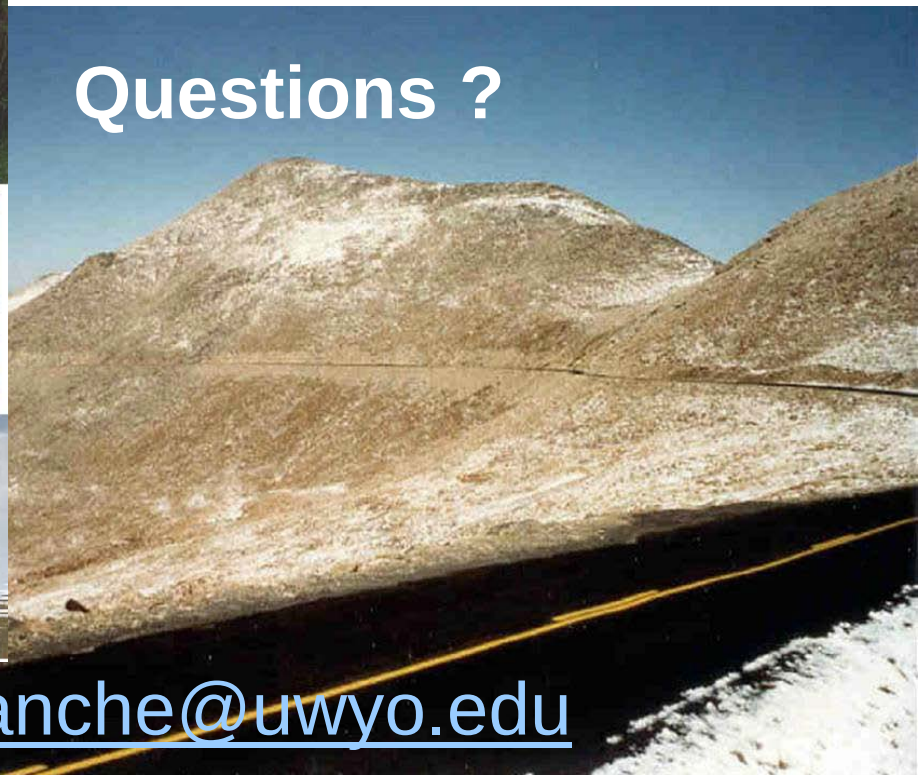


Rendezvous in Laramie this July!

The 2011 Petersen Asphalt Research Conference
July 11 - July 13 Laramie, Wyoming
THE forum for current research
Abstracts due May 10

Pavement Performance Prediction Symposium
July 14, Laramie, Wyoming
Topic: The Effects of Asphalt Binder, Mix Design, and Construction on Pavement Durability

www.petersenasphaltconference.org



jplanche@uwyo.edu