Introducing an Activated Mineral as Innovative Binder-Stabilizer for SMA Paving Mixtures

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A Research Financed

by

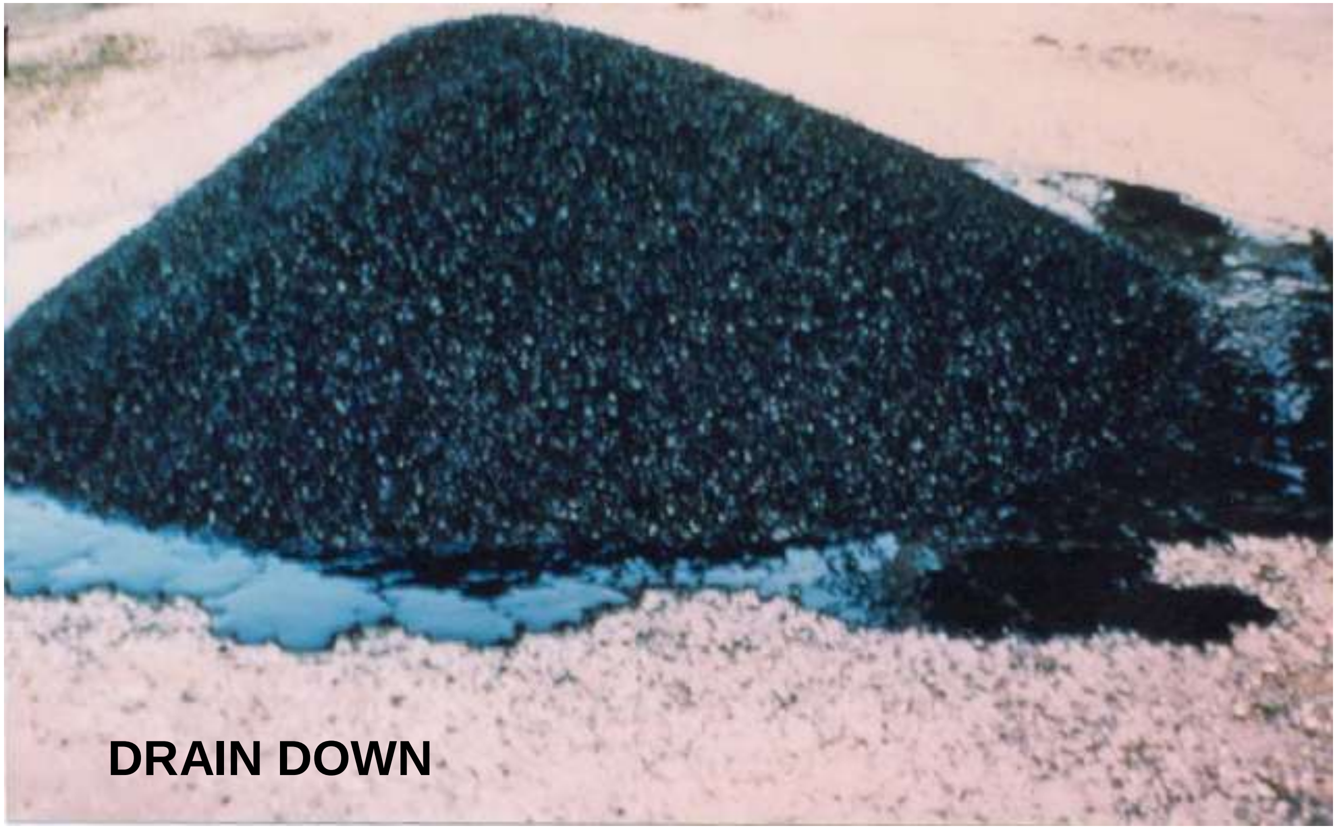
Dimona Silica Industries - DSI, Israel

Member of the Alltech Group Moscow, Russia

SMA – Stone Mastic Asphalt

- Developed in Germany in the 1960's. Now intensively used Worldwide as surface courses.
- Hot asphaltic paving mix (HMA) with high Coarse Aggregate Content coated by Asphalt-Filler mastic, to provide a Stone-Stone skeleton.
- High VMA and high bitumen content. Cellulose Fiber are added to prevent bitumen drainage from the mix during hauling and placement.
- SMA provides a deformation & fatigue resistant, most durable surface layer, suitable for sustainable heavy trafficked Roads and Airports.

Excessive SMA Bitumen Draindown Without a Proper Binder Stabilizer



The Current SMA Problem

- The necessity to add the Cellulose Fibers create serious problems:
  - Prolong the mixing time due to low workability;
  - Elevation of the mixing and compaction temperature;
  - Elevation of the optimum bitumen content;
  - Elevation of the total cost of the mix (up to 60%);
  - Often a non-friendly mix to produce and place;
  - "Fibers serve no real purpose after the mix is compacted in-place" (NCAT pub. AAPTP 04-04, Feb. 2009)
- A better SMA bitumen stabilizer is timely needed

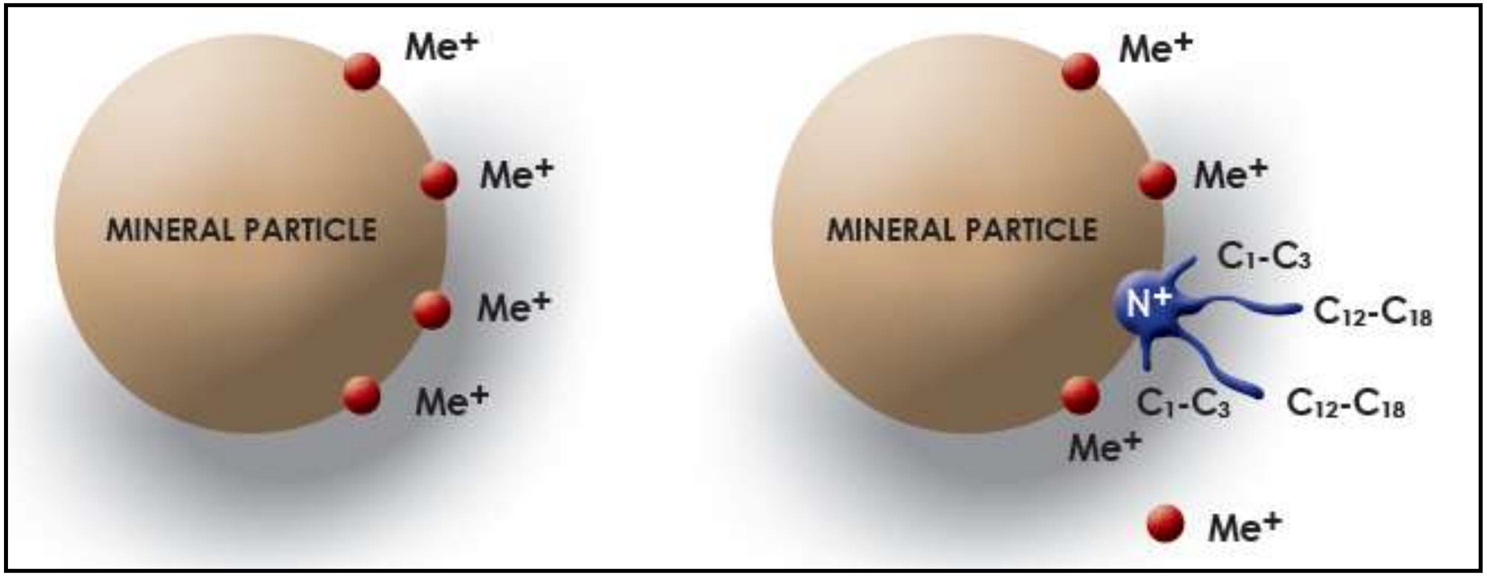
Objectives of Study

- To develop a more efficient and user friendly binder-stabilizer for preventing the bitumen draindown in SMA mixes
- To look for some positive added values of the role of the active bitumen-stabilizer in the compacted SMA also under service condition, together with environmental benefits
- To verify these advantages by unique Physico- chemical modeling and comprehensive laboratory studies

Development of the Activated Mineral Stabilizer

- The main idea is to activate a MICRO ground raw silica mineral by hydro-phobization
- For this purpose the surface properties of the micro mineral particles (-40 mμ) were altered by interaction with surface-active agents
- This was done by metal cation exchange on the mineral particle surface, with NANO long chain organic molecules in the presence of water, that forms a monomolecular organic layer covering the micro silica particles
- The physico-chemical mechanism of this surface activation can be illustrated in the following Figure →

Activation Mechanism



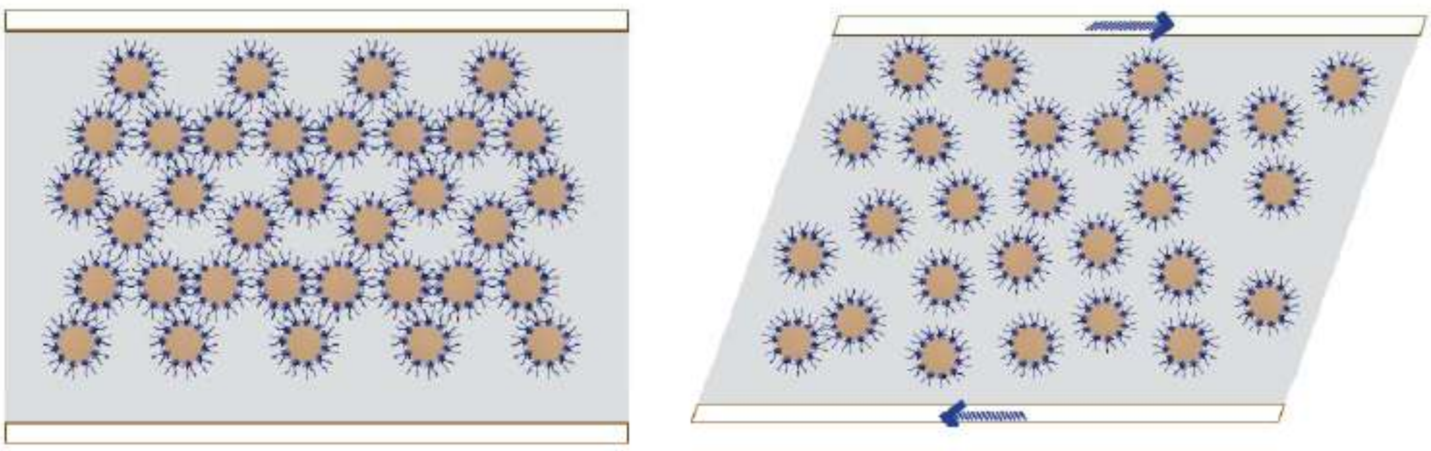
- The Micro **Activated Mineral** (silica) particles will be used as the **Bitumen stabilizer (AMBS)** for SMA or Open-Graded (Porous) asphaltic mixtures

AMBS - Rheological Behavior

- The activated mineral powder is added to the SMA mixture like the fibers to provide binder stabilization
- Due to its connected organic chains, it builds at rest a temporary bitumen structure ("card house") that increase bitumen viscosity to prevent bitumen draindown
- Under movement, during mixing and laying, this internal structure is disappearing and bitumen viscosity reduces to its original characteristics
- This rheological phenomenon is referred as "**Shear-thinning**" or "**Pseudo Plasticity**" combined with "**Thixotropy**"

AMBS - Rheological Behavior

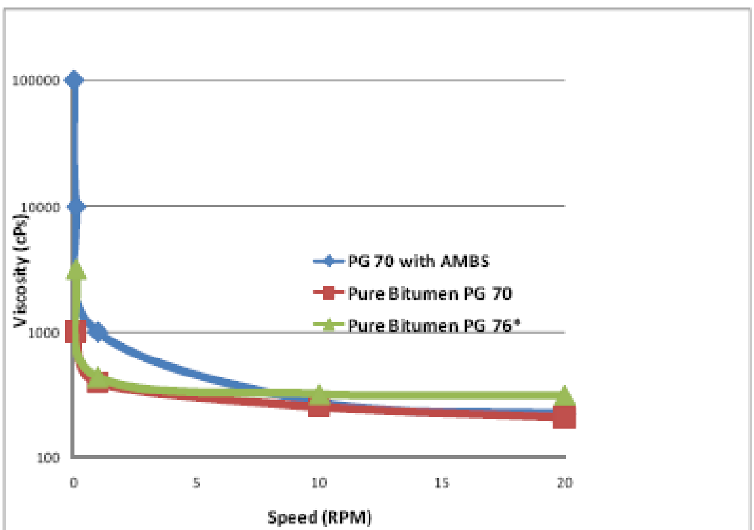
- This rheological mechanism of bitumen stabilization by the **Shear Thinning** effect is schematically described in the following Figure:



Stabilizer Net at Rest ("Card House")   Stabilizer Particles in Movement

AMBS - Rheological Behavior

- This rheological mechanism of bitumen stabilization by the **Shear Thinning** effect is experimentally proven using the Brookfield Device (5% AMBS)



	Speed (RPM)				
	0.01	0.1	1	10	20
	Viscosity (cPs)				
PG70+AMBS	100000	10000	1000	275	225
Plain PG 70		1000	400	256	210
Plain PG 76		3200	440	324	316

Basic Raw material

- Unique waste byproduct of the phosphates industry- natural mineral
- Enough to provide around 100 years-worth
- Unique to Israel
- Exclusive rights for Industrial use granted by State

A unique Clean Tech process

A complete recycling of a waste raw material (natural Mineral):

Raw material:
Waste byproduct of the phosphates industry
Millions of tons reserves
Exclusivity rights on the raw material by the State
Unique to Israel

Ground and activated by Unique Process

AMBS (iBind)

The Plant Site at Dimona

<u>Forecast:</u>

- **<u>Phase A</u>: AMBS (iBind) plant**
- **(Production Fourth qtr. 2011)**

The AMBS Bitumen Stabilizer

- When added to SMA at similar quantities as fibers, **AMBS** provides the following advantages:
  - Mixing time and workability as in regular HMA mixes (dense mixes, Superpave mixes, etc.);
  - Lower mixing and compaction temperature (also diminish hazardous emission);
  - Reduces the optimum bitumen content;
  - Decreases the total cost of the mix;
  - A friendly mix to produce and place;
  - **AMBS** continue to work after the mix is compacted in-place by increasing resistance to water damage, increasing bitumen-agg. adhesion, increasing rutting & fatigue resistance, etc., as verified experimentally →

iBind – Experimental Work

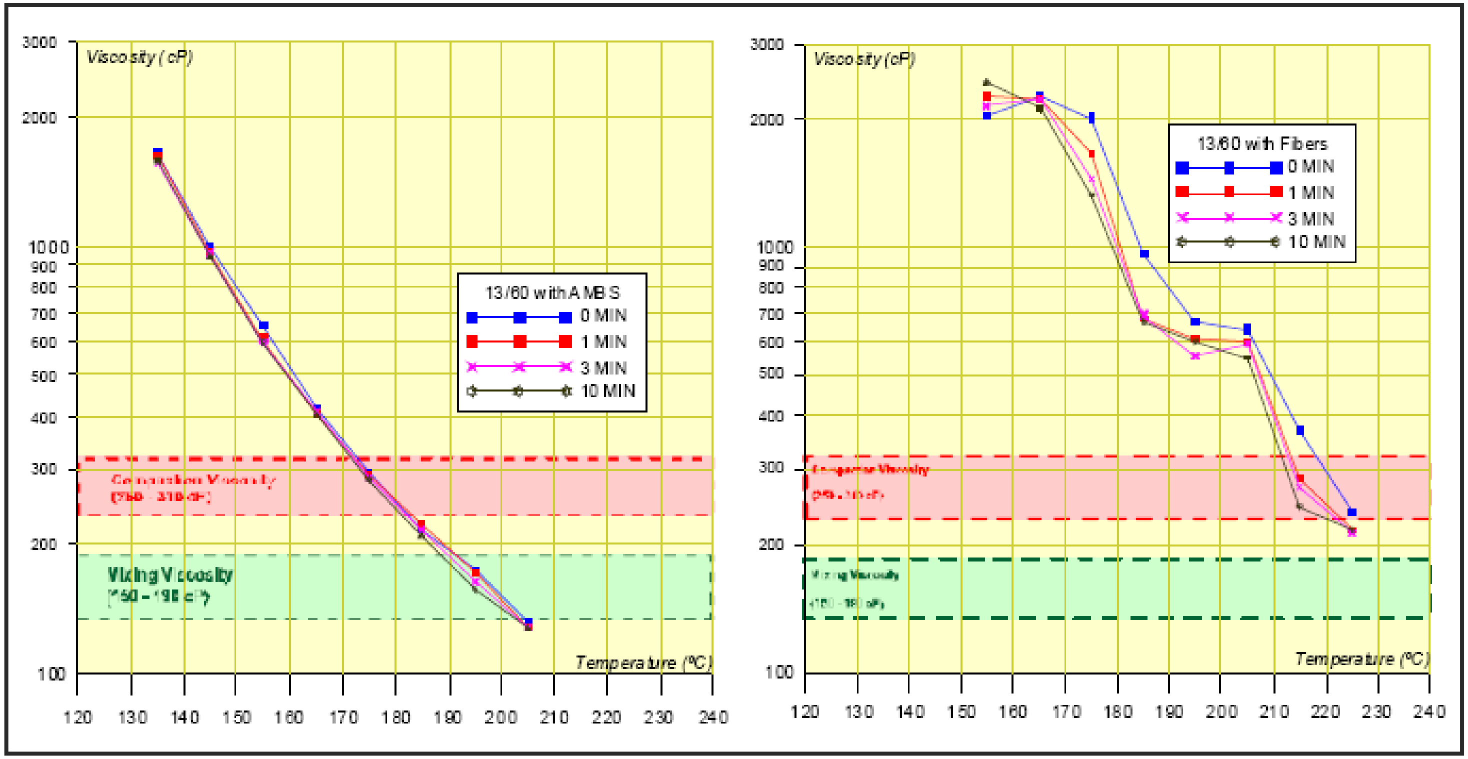
- Development, experimentation and preliminary studies originated in **Israel**. Performed in the Laboratory of the Israeli Standards Institute (ISI)
- Preliminary confirmation of compliance with European Norms was conducted in TPA **Austria**
- Comprehensive investigations of US and EU SMA mixes were conducted in CONSULPAV **Portugal**, AkzoNobel in **Sweden** and in NCAT Alabama **USA**
- A practical application testing were conducted in the Jiangsu Transportation Research Institute (JSTRI), Nanjing **China**. Initial Tests in **Russia**
- Experimental comparative road test sections were constructed in **Israel** and in **China**

AMBS – Experimental Research

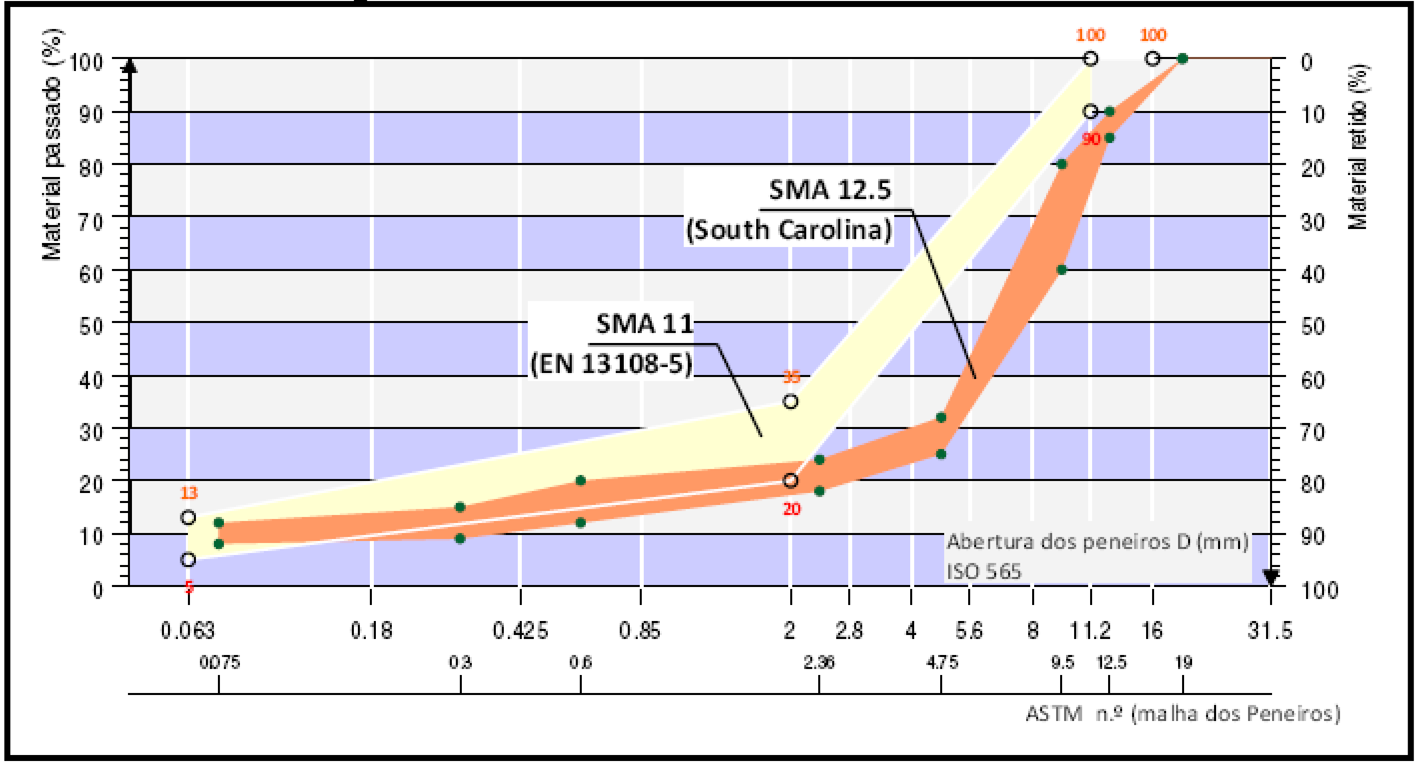
Highlights of Results

AMBS Investigation - PORTUGAL

Viscosity vs. Temperature – AMBS & Fibers

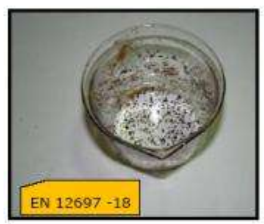


AMBS Investigation – PORTUGAL
General Testing and Mix Design
European and American Mixes



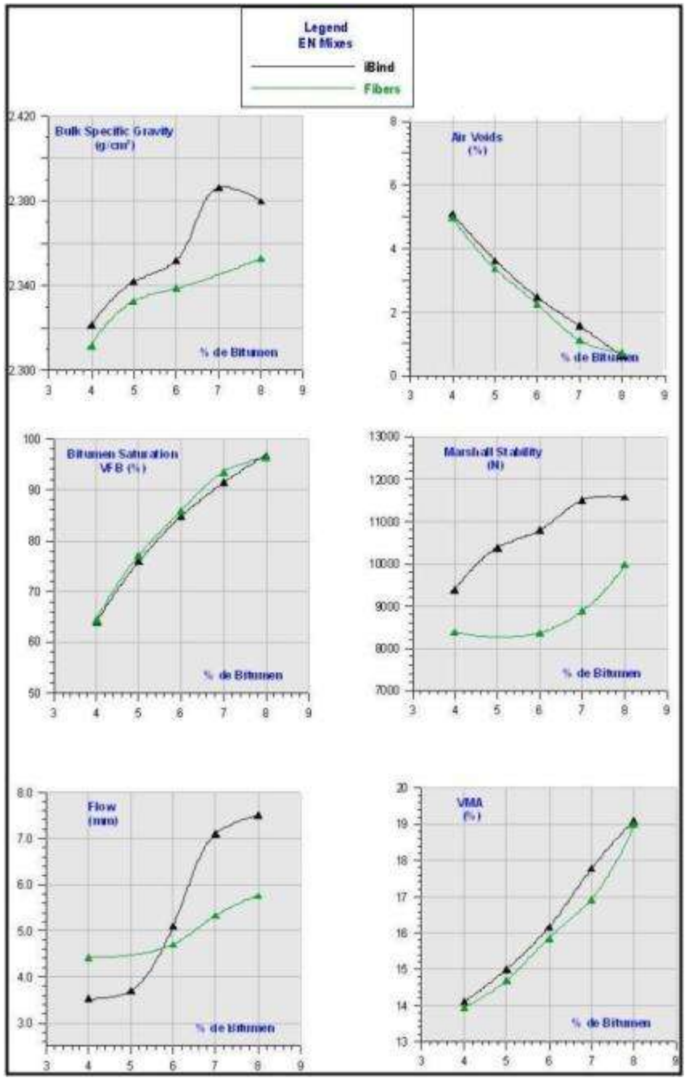
AMBS Investigation – PORTUGAL
Draindown Tests

Gradation	European Norm - EN		South Carolina - SC	
Stabilizer	AMBS OBC=6.0%	Fibers OBC=6.5%	AMBS OBC=5.5%	Fibers OBC=6.0%
EN 12697 – 18 (Beaker	0.1	0.1	-	-
EN 12697 – 18 (Basket)	0.0	0.0	-	-
ASTM D6390-5 (Basket)	-	-	0.3	0.3



AMBS Investigation – PORTUGAL Mix Design Tests

- AMBS and Fiber stabilized SMA mixes were tested, designed and compared according to **European** and **American** standards and specifications
- Volumetric and mechanical properties of the mixes, at a wide range of bitumen contents, were determined by the Marshall mix design procedure
- Mixing Temperature of **160ºC** was chosen for the AMBS mixes, and **170ºC** for the Fiber mixes. A compaction temperature of 150ºC was selected for all mixes



AMBS Investigation – PORTUGAL

Typical Marshall Mix Design Summary on European EN **Gradation using**
STYRELF 13/60
(PG 76-28) Bitumen with AMBS and Fiber Stabilizers

AMBS Investigation – PORTUGAL Mix Design Tests
Determination of OBC

	Property	Mix Design Criterion	Bitumen content for each property AMBS (%)	Bitumen content for each property Fibers (%)	Remarks
EN	**%Air Voids**	2.0-4.5	5.3	5.1	
	% VMA	Min. 17	6.5	7.1	
	%VFB	65-85	5.0	5.0	
	Bulk Sp. Grav.	Max.	7.0	7.0	
	Marshall Stab. (N)	Max.	5.0	7.0	At elevated high value
	Average % OBC		**5.76**	**6.24**	**0.48% difference**
	Recommended % OBC		**6.0**	**6.5**	
SC	**%Air Voids**	3.5±0.5	4.4	5.5	
	% VMA	Min. 17	6.6	6.3	
	%VFB	65-85	4.5	5.1	
	Bulk Sp. Grav.	Max.	5.0	6.0	
	Marshall Stab. (N)	Max.	6.0	6.0	
	Average % OBC		**5.30**	**5.78**	**0.48% difference**
	Recommended % OBC		**5.5**	**6.0**	

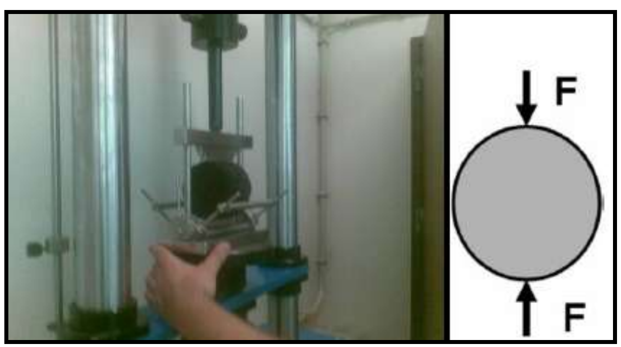
AMBS Investigation – PORTUGAL Mix Design Tests
Summary of Properties at OBC

Gradation	European Norm - EN		South Carolina - SC	
Stabilizer	AMBS OBC=6.0%	Fibers OBC=6.5%	AMBS OBC=5.5%	Fibers OBC=6.0%
Density g/cm3	2352	2342	2407	2418
Air Voids %	2.4	1.6	2.3	2.6
VMA %	16.2	16.9	14.9	16.7
Bitumen Saturation - %	84.0	89.0	85.0	85.0
Marshall Stability - N	10750	8650	8950	10100
Flow mm	5.1	5.0	6.7	5.3

AMBS Investigation – PORTUGAL Mechanical Tests

- Water Damage Resistance by Compressive Strength
- Rutting by Wheel Tracking Test
- Cantabro Wear Test
- Indirect Tensile Strength (ITS) at dry conditions
- Tensile Strength Ratio (TSR)
- Frequency Sweep and Fatigue Resistance using the 4P Bending Beam Test

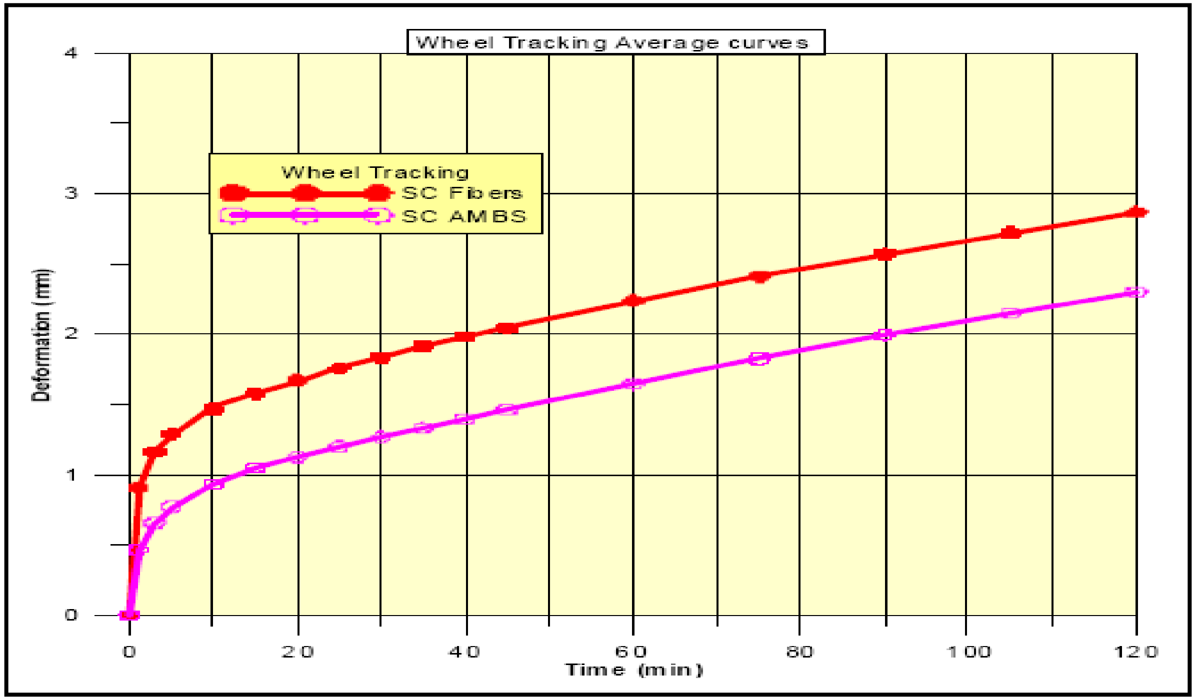
AMBS Investigation – PORTUGAL
Mechanical Tests



AMBS Investigation – PORTUGAL
Mechanical Tests

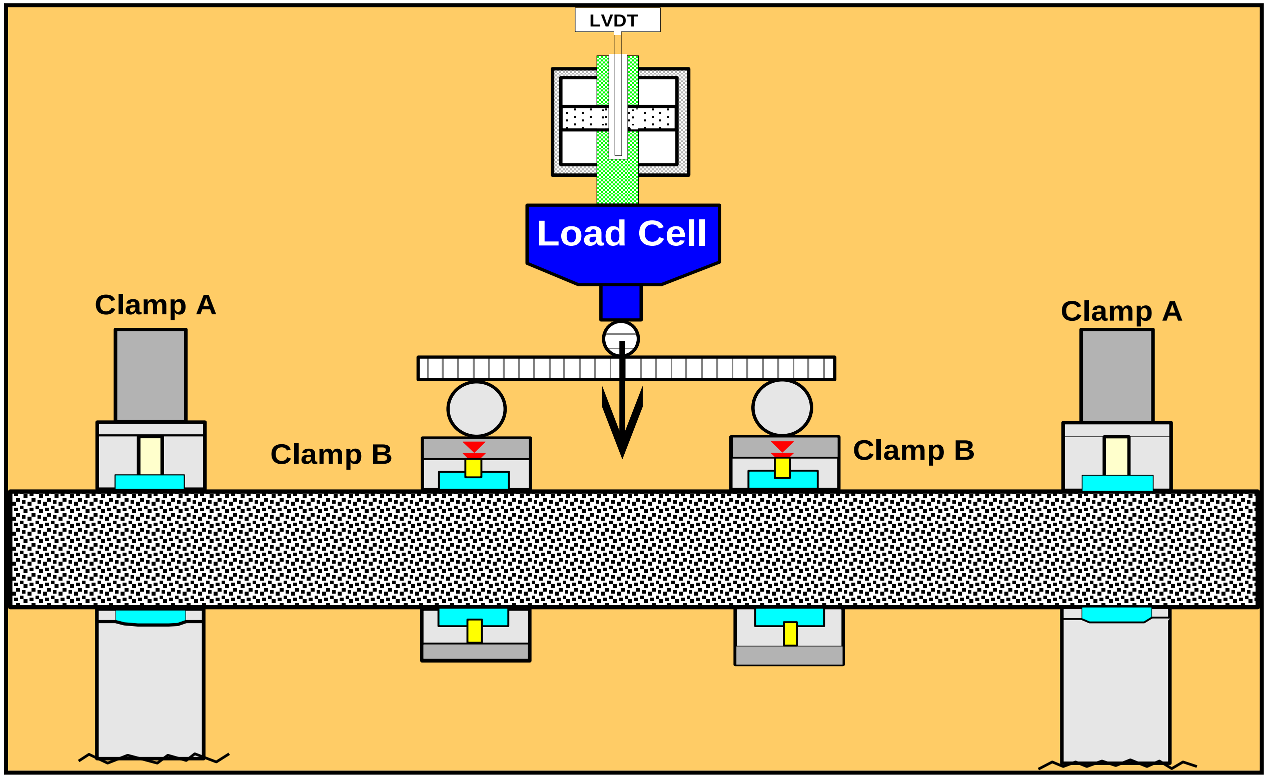
Gradation	European Norm - EN		South Carolina - SC	
Stabilizer	AMBS OBC=6.0%	Fibers OBC=6.5%	AMBS OBC=5.5%	Fibers OBC=6.0%
Water Damage Resistance (% Compression Strength)	115.1	96.2	132.9	115.1
Wheel – Tracking (mm Rutting)	3.54	3.52	2.30	2.87
Cantabro (% Wear)	4.0	1.8	3.8	3.1
Indirect Tensile Strength, Dry (Kpa)	683	655	707	583
Tensile Strength Ratio, TSR (%)	91.7	99.5	80.7	88.3

AMBS Investigation – PORTUGAL
Summary of Mechanical Tests



AMBS Investigation – PORTUGAL

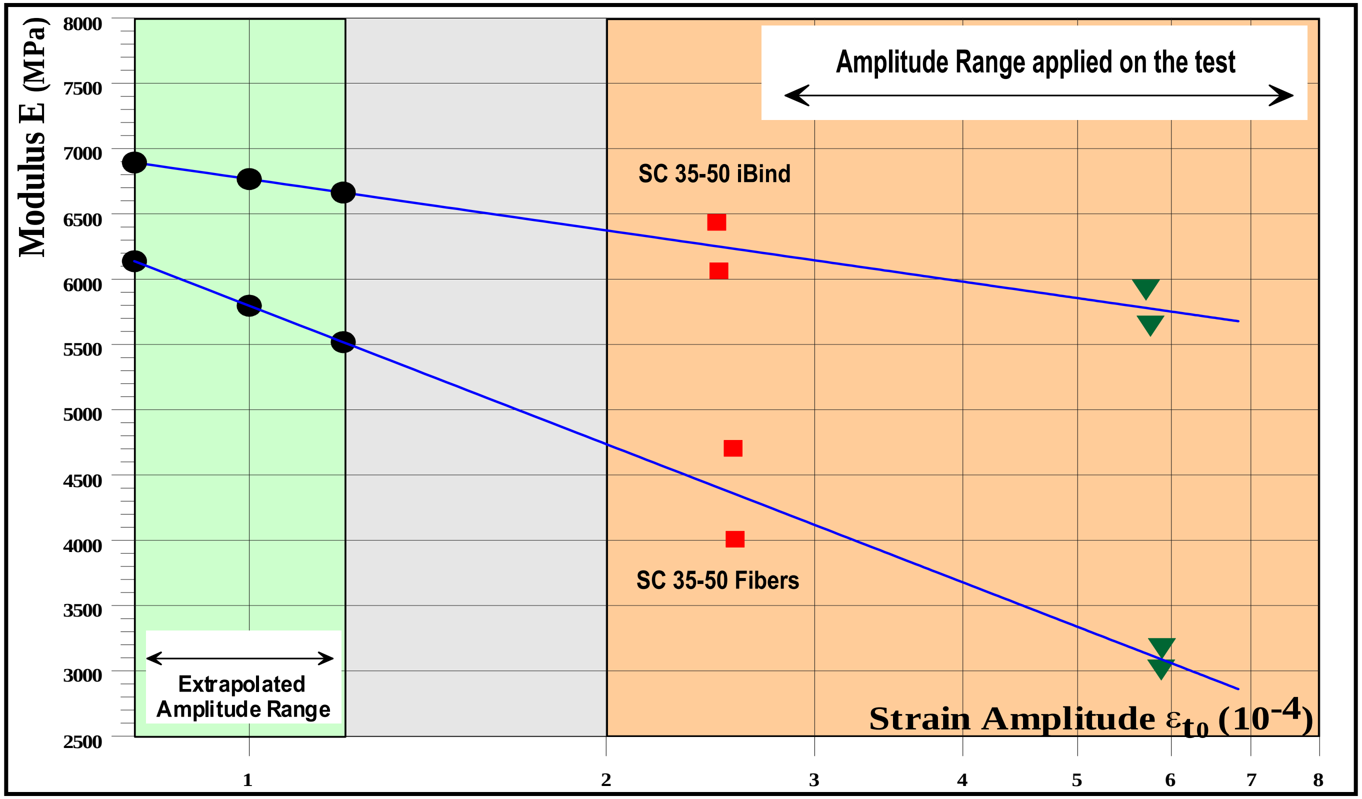
Fatigue Testing – 4 pt. BBT



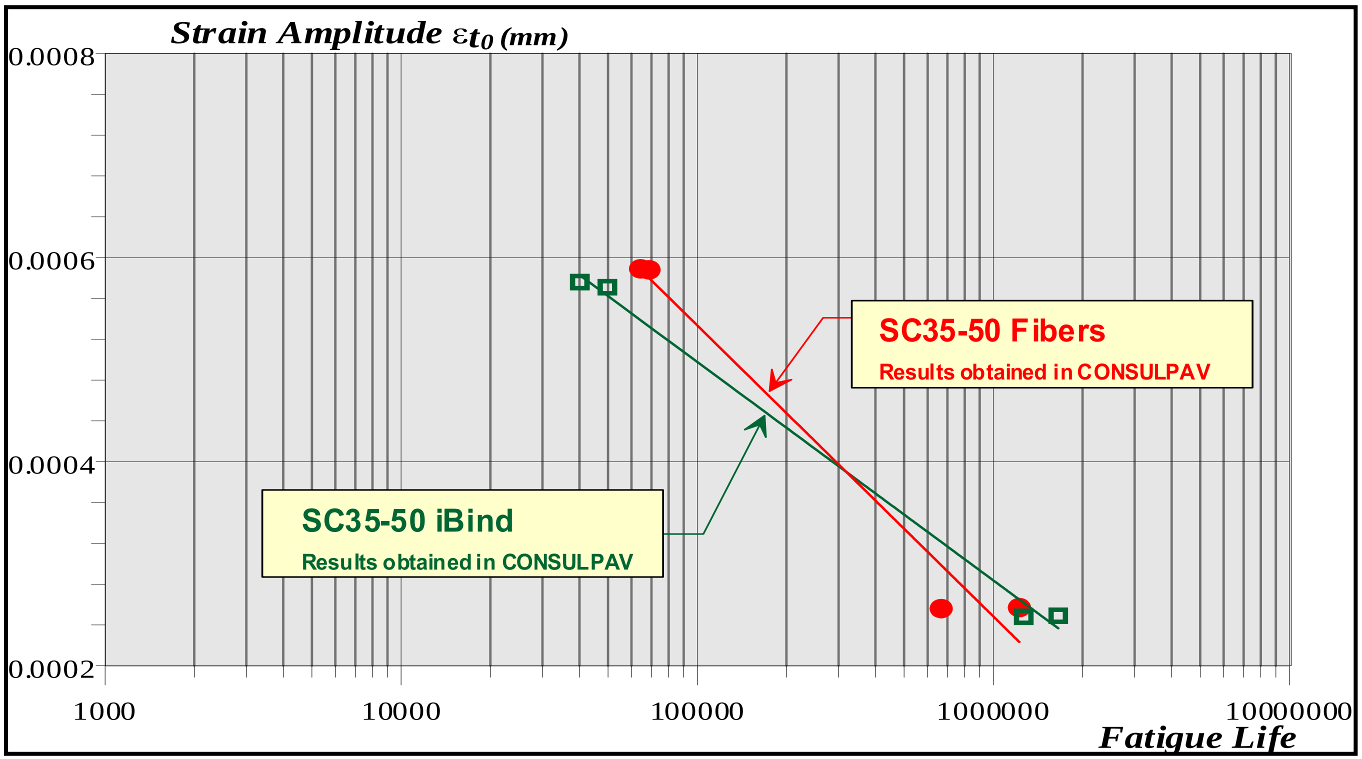
AMBS Investigation – PORTUGAL
Fatigue Testing – 4 pt. BBT

AMBS Investigation – PORTUGAL

Fatigue Results on Plain Asphalt

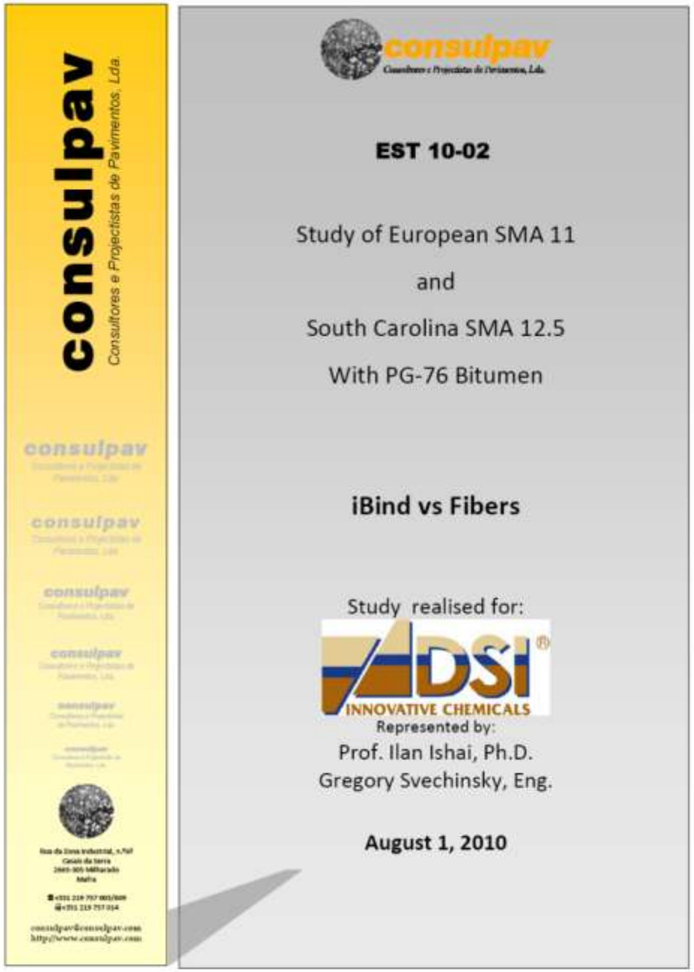


AMBS Investigation – PORTUGAL
Fatigue Results on Plain Asphalt



AMBS Investigation – PORTUGAL
Summary of Mechanical Tests

- AMBS showed significant superiority (compared to Fibers) with respect to the resistance to water damage, as tested by the compressive strength
- Both stabilizers exhibit very high wear resistance in the Cantabro Wear Test
- AMBS SMA mixes showed higher tensile strength, as evaluated by the Indirect Tensile (IDT) Test on dry conditions. TSR values were at acceptable high values
- AMBS SMA mixes showed comparative and better resistance to Rutting and higher Fatigue resistance despite the lower bitumen content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EST 10-02

Study of European SMA 11
and
South Carolina SMA 12.5
With PG-76 Bitumen

iBind vs Fibers

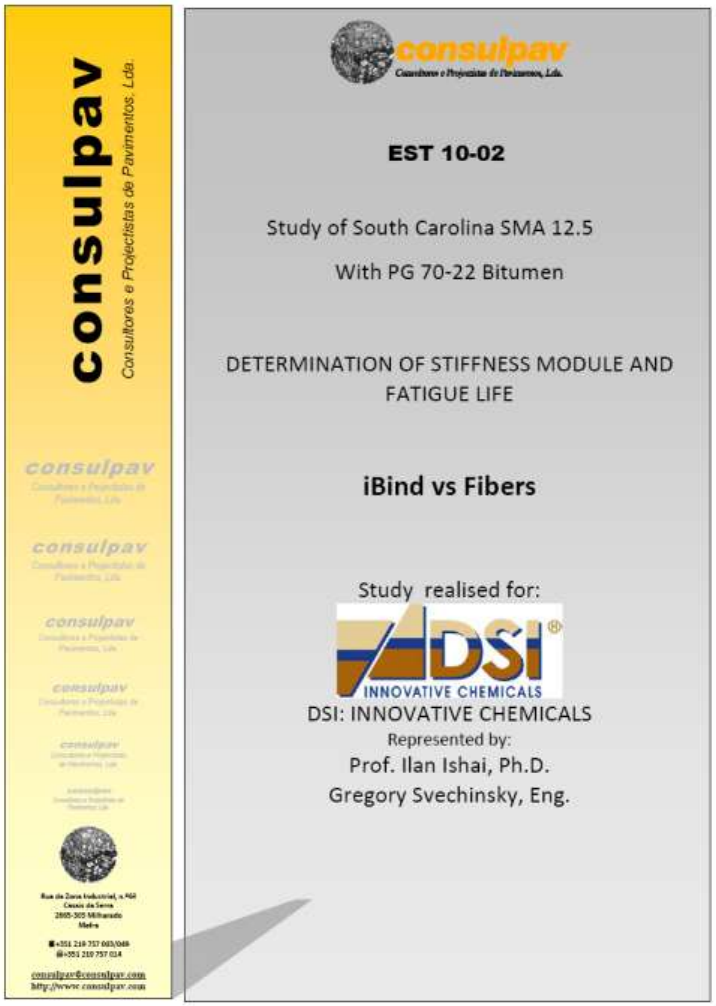
Study realised for:
ADSI® INNOVATIVE CHEMICALS
Represented by:
Prof. Ilan Ishai, Ph.D.
Gregory Svechinsky, Eng.

August 1, 2010

AMBS Investigation –

PORTUGAL

Final Report
Phase 1
August 2010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EST 10-02

Study of South Carolina SMA 12.5

With PG 70-22 Bitumen

DETERMINATION OF STIFFNESS MODULE AND FATIGUE LIFE

iBind vs Fibers

Study realised for:

DSI: INNOVATIVE CHEMICALS

Represented by:

Prof. Ilan Ishai, Ph.D.

Gregory Svechinsky, Eng.

iBind

Investigation –

PORTUGAL

Final Report

Phase 2

Fatigue Life

December 2010

AMBS Investigation – PORTUGAL
Interim Conclusions

- Replacing fibers by AMBS in SMA enabled to select lower OBC for both gradation
- Replacing fibers by AMBS in SMA enabled to select lower mixing temperatures by 10-20 ºC
- The performance of AMBS SMA mixes at 0.5-1.0% lower OBC was comparable and sometimes better than Fiber mixes
- It can be clearly stated that, if properly designed, AMBS SMA mixes will satisfy all the standard requirements, as achieved at lower OBC and lower mixing temperatures

1

ACTIVATED MINERALS AS BINDER STABILIZERS IN SMA PAVING MIXTURES

by

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A Paper Submitted to the 90th Annual Meeting of the Transportation Research Board, Washington DC, January 2011

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AMBS Investigation

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ISRAEL and PORTUGAL

A Paper Presented at the 90th Annual Meeting of the TRB **Washigton DC, January 2011**

AMBS Investigation – CHINA General Outlines

- Research performed at the JSTRI – Jiangsu Transportation Research Institute, Nanjing
- Comparison between Regular Chinese SMA mixes with Fibers and AMBS SMA mixes with two bitumen contents
- AMBS and Fibers at 0.3% of mix. Binder - SBS modified bitumen
- Tests performed: Draindown Test, Marshall Design, Wheel Tracking, Cantabro Wear Test, Low Temperature Flexural Beam Test and 4PBB Fatigue Test

AMBS Investigation – CHINA Sample Results
Schellenberg Draindown Test

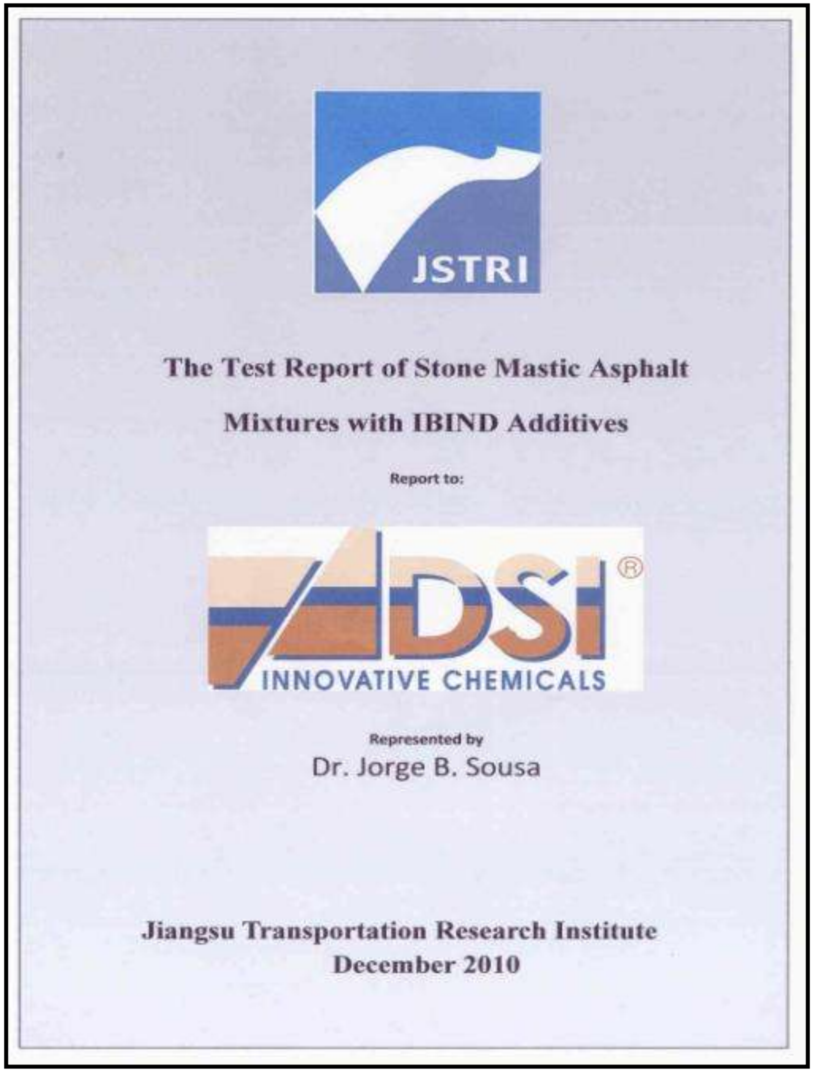
Schellenberg Draindown Test		Loss (%)	Require
Asphalt-aggregate ratio:6.0%, Ibind:0.3% (170℃)	Specimen1	0.07	≤0.1%
	Specimen2	0.08	
	Specimen3	0.07	
Asphalt-aggregate ratio:5.5%, Ibind:0.3% (170℃)	Specimen1	0.04	≤0.1%
	Specimen2	0.04	
	Specimen3	0.05	
Normal SMA, Asphalt 6.1% (185℃)	Specimen1	0.08	≤0.1%
	Specimen2	0.07	
	Specimen3	0.07	

AMBS Investigation – CHINA Sample Results
Wheel Tracking Rutting Test

Rutting test		**Rutting stability (number of cycles to 1mm Rut)**
Asphalt-aggregate ratio:6.0%, Ibind:0.3%	Specimen1	5727
	Specimen2	6000
	Specimen3	6300
	Average	6009
Asphalt-aggregate ratio:5.5%, Ibind:0.3%	Specimen1	5250
	Specimen2	4846
	Specimen3	4846
	Average	5048
Normal SMA,asphalt 6.1%	Specimen1	5727
	Specimen2	5250
	Specimen3	5727
	Average	5568

AMBS Investigation – CHINA Summary of Test Results

Test and Conditions		Fibers BC=6.1%	iBind BC=5.5%	iBind BC=6.0%
Schelleberg Draindown Test At 170/180 ºC (% Drained)		0.07	0.05	0.07
Marshall Stability (kN)		8.58	9.22	11.09
Marshall Retained Stability After 48 hrs Conditioning (%)		87.1	91.4	86.3
Wheel Tracking Test No. of Cycles for 1 mm Rutting		5568	5048	6009
Cantabro Wear Test (% Wear)		7.3	1.9	1.6
Low Temp. Bending and Fatigue Test at 15 C	**Flex. Tensile Strength at -10 C (MPa)**	9.29	13.25	12.15
	Stiffness Modulus at -10 C (MPa)	3000	3848	3637
	Fatigue Life (Reps. To half Es At 600με)	**50,000 (100%)**	**50,000 (100%)**	**450,000 (900%)**


JSTRI

The Test Report of Stone Mastic Asphalt Mixtures with IBIND Additives

Report to:

ADSI®
INNOVATIVE CHEMICALS

Represented by
Dr. Jorge B. Sousa

Jiangsu Transportation Research Institute
December 2010

AMBS Investigation – China

JSTRI
Final Report
Part A
SMA Mixes
December 2010

AMBS Investigation – NCAT USA

iBind (AMBS)	
Max Aggregate Size, mm	19.0
Nominal Max. Agg. Size, mm	12.5
Binder Grade	76-22 M (SBS)
N design gyrations	50 Blow Marshall
Blend Used	Blend 1
Additive	0.40% iBind
Optimum AC, %	5.20
Va, %	4.1
VCA_{DRC}	42.1
VCA_{Mix}	40.2
VMA, %	16.0
VFA, %	75.0
Effective AC, %	5.19
Dust / Asphalt	1.6
Tensile Strength Ratio	0.90
Conditioned Strength, psi	111.5
Unconditioned Strength, psi	123.3

% Passing

Seive Size, in	Seive Size, mm	Design Gradation from Job Mix
3/4"	19.0	100.0
1/2"	12.5	95.3
3/8"	9.5	71.0
#4	4.75	28.8
#8	2.36	18.9
#16	1.18	15.9
#30	0.600	13.5
#50	0.300	11.4
#100	0.150	9.7
#200	0.075	8.3

Combined Gravities of Aggregates

	Proportion	Gsb
Granite 78s	52	2.606
Limestone 78s	30	2.833
Granite M-10s	12	2.695
Boral Flyash	5	2.748
Baghouse Fines	1	2.748
Blend Properties	100	2.690

FIBERS	
Max Aggregate Size, mm	19.0
Nominal Max. Agg. Size, mm	12.5
Binder Grade	76-22 M (SBS)
N design gyrations	50 Blow Marshall
Blend Used	Blend 1
Additive	0.40% Cell. Fiber
Optimum AC, %	6.40
Va, %	4.0
VCA_{DRC}	42.1
VCA_{Mix}	42.0
VMA, %	18.6
VFA, %	78.3
Effective AC, %	6.39
Dust / Asphalt	1.3
Tensile Strength Ratio	1.02
Conditioned Strength, psi	129.1
Unconditioned Strength, psi	126.7

% Passing

Seive Size, in	Seive Size, mm	Design Gradation from Job Mix
3/4"	19.0	100.0
1/2"	12.5	95.3
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Baghouse Fines	1	2.748
Blend Properties	100	2.690

Preliminary Mix Design and ITS Data

AMBS Investigation – NCAT USA

Table 5: Performance Testing Summary

Test	Criteria	iBind	Fiber
Draindown, AASHTO T 305	≤ 0.30%	0%	0%
Tensile Strength Ratio, AASHTO T 283	≥ 0 .80	0.90	1.02
Cantabro Loss Test, EN NLT 352	≤ 20%	9.6%	8.2%
Indirect Tensile Strength, ASTM D 6931	≥ 100 psi	102.2 psi	115.7 psi
Rut Test, AASHTO T 340	≤ 4.5 mm	3.68 mm	4.14 mm
Moisture Susceptibility Test, AASHTO T 324	≥ 5,000 cycles	6,285 cycles	8,750 cycles
Overlay Test, Texas 248 –F	≥ 700 cycles	1,340 cycles	992 cycles

AMBS Investigation – NCAT USA

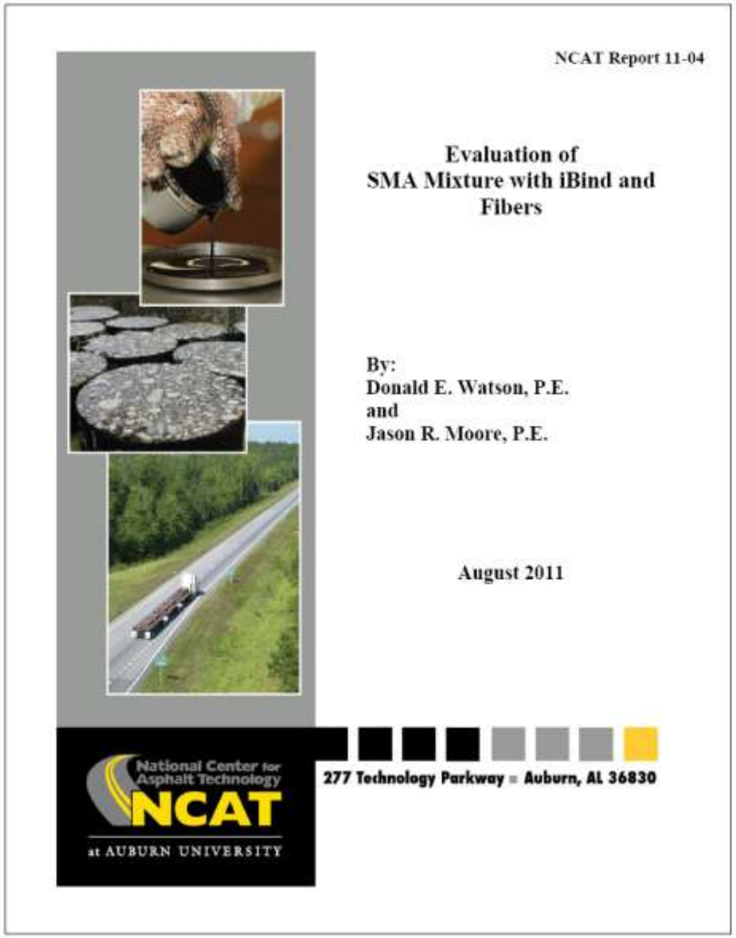
SUMMARY AND CONCLUSIONS

For this study two SMA mixtures were compared, one with fiber and one in which the fiber was replaced with iBind. The mixtures were then verified for volumetric properties. When the optimum volumetric properties were reached, the iBind mixture contained 1.2% less binder than the fiber mixture and also had a production and compaction temperature 15°C less than the fiber mixture. The optimum binder content was selected as the binder value at which 4.0% air voids was reached. Once their volumetric properties were determined the mixtures then underwent performance testing. A summary of the performance testing is given in Table 5 below:

AMBS Investigation – NCAT USA

When viewing the results of the performance testing, it can be seen that the iBind mixture had no problems meeting the tests' criterion even with 1.2% lower asphalt binder content. The iBind mixture performed as well as the fiber mixtures in the performance testing.

AMBS Investigation – NCAT USA


NCAT Report 11-04

Evaluation of
SMA Mixture with iBind and
Fibers

By:
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and
Jason R. Moore, P.E.

August 2011

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

277 Technology Parkway ▪ Auburn, AL 36830

The recent Technical Report

August 2011

AMBS Investigation – ISRAEL First Road Test

- Performed in August-September 2010 on an access road to "Revaya" Quarry, Northern Israel
- Three sections – two with AMBS and one with Fibers. Tack coating before laying
- Implementing 0.35-0.5% AMBS and 0.35% Fibers. Bitumen cont.: 5.0-6.0% for the AMBS and 6.5% for the Fibers
- Bitumen PG 76-10 with Sasobit. Mixing Temperatures – 140-150 ºC for the AMBS and 150-160ºC for the Fibers
- Traffic: several hundred heavy trucks daily

AMBS Investigation – ISRAEL

First Road Test - before

AMBS Investigation – ISRAEL

First Road Test - before

AMBS Investigation – ISRAEL

First Road Test – Mixing Plant

AMBS Investigation – ISRAEL

First Road Test – Applying Tack Coat

AMBS Investigation – ISRAEL

First Road Test – Applying Tack Coat

AMBS Investigation – ISRAEL

First Road Test – Placement

AMBS Investigation – ISRAEL

First Road Test – Compaction

AMBS Investigation – ISRAEL

First Road Test – Sampling

AMBS Investigation – ISRAEL First Road Test – Finished AMBS surface

AMBS Investigation – ISRAEL First Road Test – Finished AMBS surface

AMBS Investigation – ISRAEL First Road Test – a year after

AMBS Investigation – ISRAEL First Road Test – a year after

iBind Investigation – ISRAEL
Road Test – Preliminary Conclusions

- **iBind** SMA mixes were successfully produced and layed with 0.5-1.0% lower bitumen content and 15ºC lower mixing Temperature than the **Fibers**
- The construction workers at the paver were very pleased with the lower temperature and the no-smell and much less fumes
- All QC test results complied with the Israeli Specs.
- After one year of service, all sections perform very well under very heavy quarry traffic

iBind Investigation – ISRAEL
Overlay Rager Street – Beer Sheva

- Paved in April 2011 on the main entrance street of the City of **Beer Sheva.** A night job
- Applying 5 cm SMA 12.5 mm with iBind
- Two Carriageways – One with PMB PG 76-22, with Sasobit, and one with Plain bitumen PG 70-22
- Implementing iBind at 0.35-0.4%. Optimum bitumen content - 5.4%
- Mixing Temperatures – 140-150 ºC for PMB and 150-160ºC for Plain bitumen
- Traffic: Main arterial city street

Overlaying Rager Street, Beer-Sheva

Sieve		1/2"	3/8"	5/16"	#4	#10	#200
Sieve size, (mm)		12.5	9.5	8.0	4.75	2.0	0.075
Percent Passing	Average QC	100	92	84	30	19	9.7
	Specifications	100	90-95	80-90	20-30	15-25	7-11

Property	Mixing / Compaction Temp. (ºC)	Bitumen Content (%)	Bulk Density (Kg./m^3)	VMA (%)	Marshall Stability (lb)	Retained Stability* (%)	Drain-down (%)
Average QC**	145/120	5.4	2292	19	2508	94	0.07
Specifications/ Mix Design	--	5.2± 0.3	--	19 min.	1500 Min.	80 Min.	0.1 Max.

Overlaying Rager Street, Beer-Sheva

Overlaying Rager Street, Beer-Sheva

Overlaying Rager Street, Beer-Sheva

Overlaying Rager Street, Beer-Sheva

Overlaying Rager Street, Beer-Sheva

6 months later

AMBS Road Tests – China

October-November 2011

AMBS Road Tests – China

October-November 2011

AMBS Road Tests – China

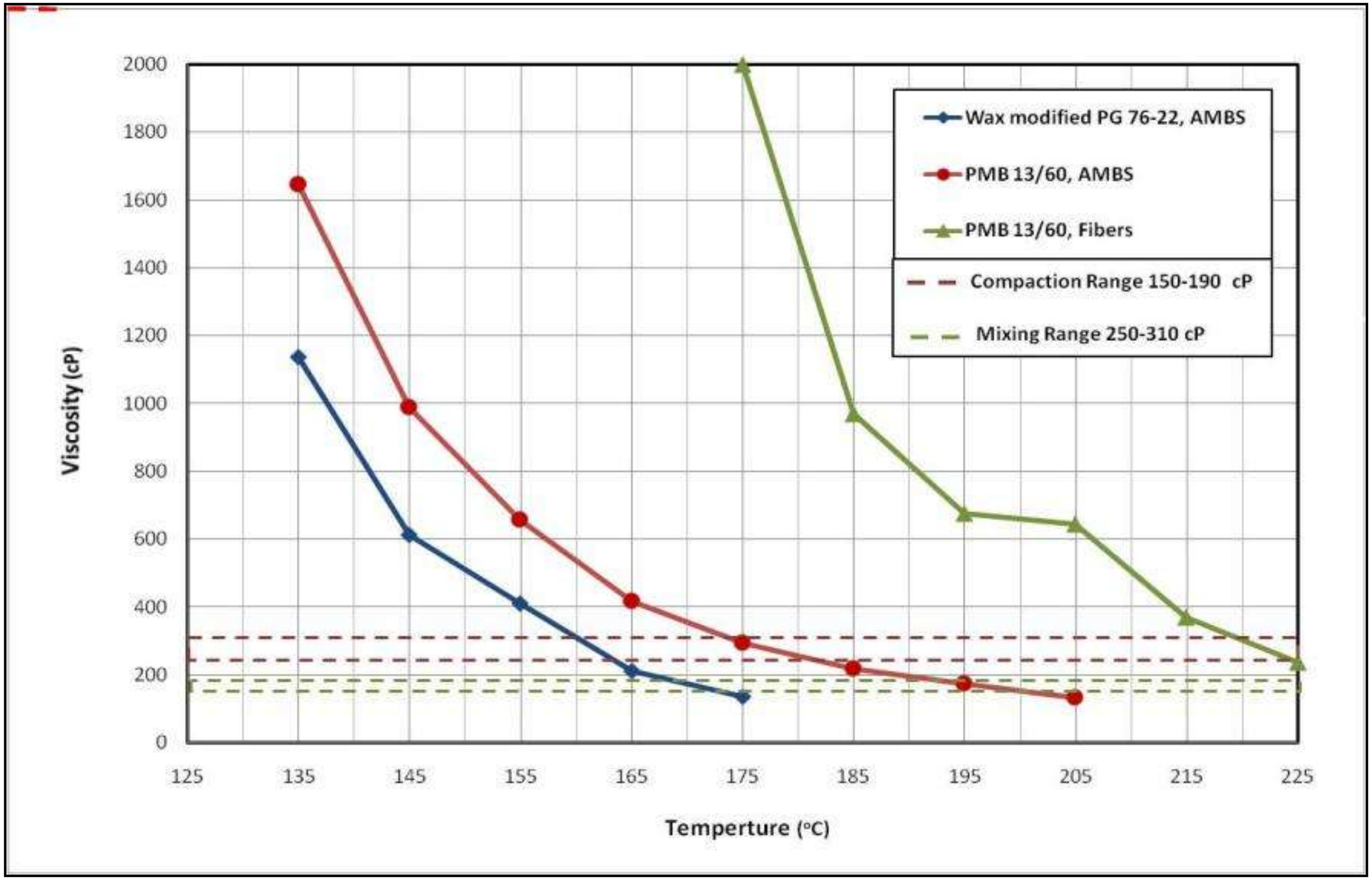
October-November 2011

AMBS Road Tests – China
October-November 2011

Turning SMA to WSMA

- SMA mixes are usually produced at 170-190ºC. They are considered as very hot HMA
- By replacing the Fibers with iBind it was possible to decrease mixing temperature by 10-25ºC while still obtaining good workability
- In order to classify SMA mixes as WMA a further temperature decrease is needed
- This was practically done by further modified the bitumen with a “Wax Flow-improver”, like Sasobit.
- This enable a total reduction of mixing temperature by 30-40ºC (54-72ºF). Thus, iBind and Sasobit turns the very hot SMA mix into a warm SMA $\rightarrow$ WSMA

Turning SMA to WSMA



Environmental Benefits

- The incorporation of the AMBS possesses also pronounced environmental benefits. A comparison and analysis of several environmental indicators were specially conducted

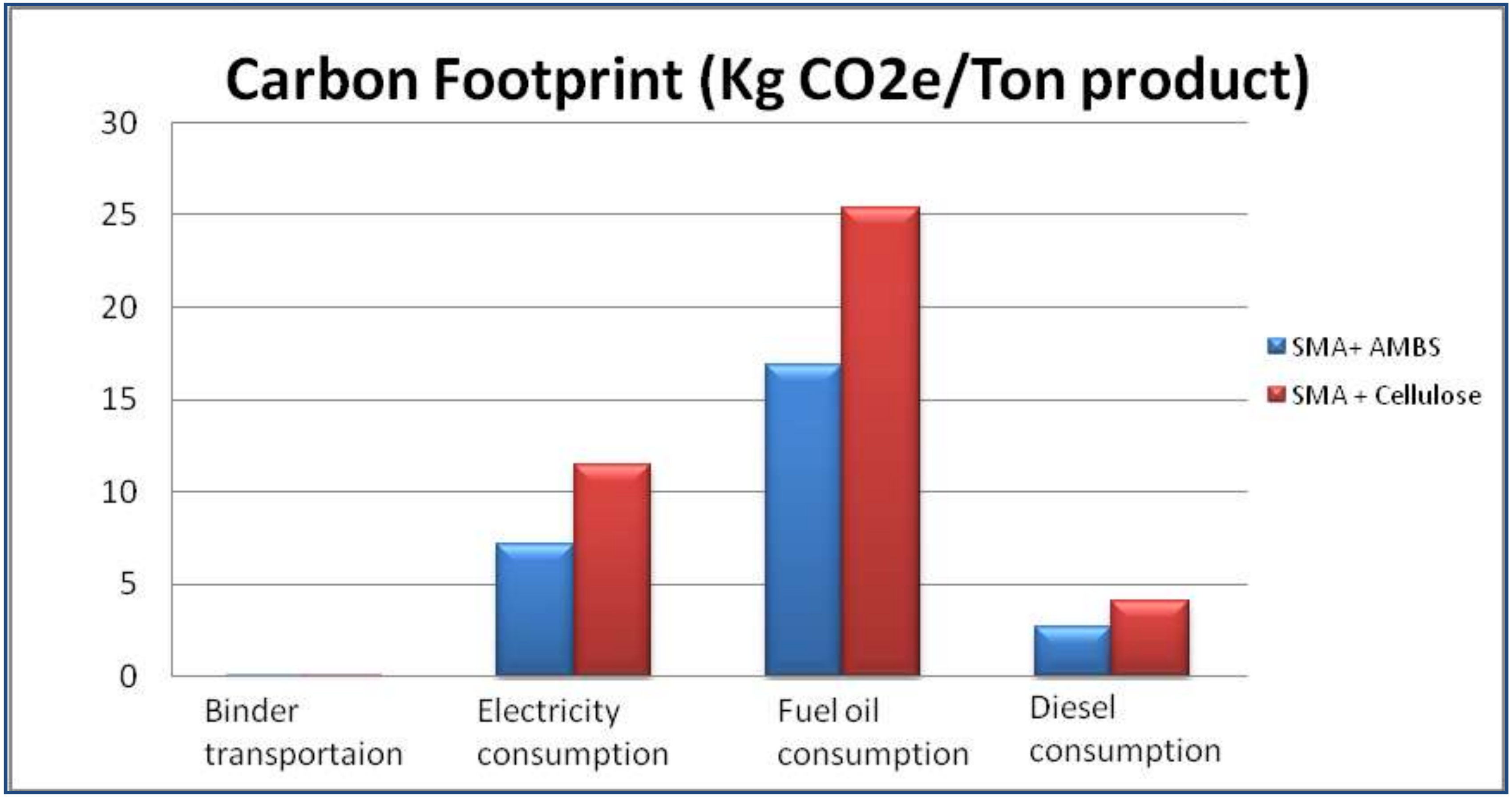
- The analysis focused on the most important air pollutants associated with fuel use and the emission of greenhouse gases

- The indicators chosen were: Carbon Dioxide (CO_2), Nitrogen Oxides (NOx), Sulphur Oxides (SOx), Particulate Matter (PM) and Carbon Monoxide (CO)

- The indicators were converted to reflect their value in terms of external cost, based on academic research on the issue, as well as on European Union guidelines.

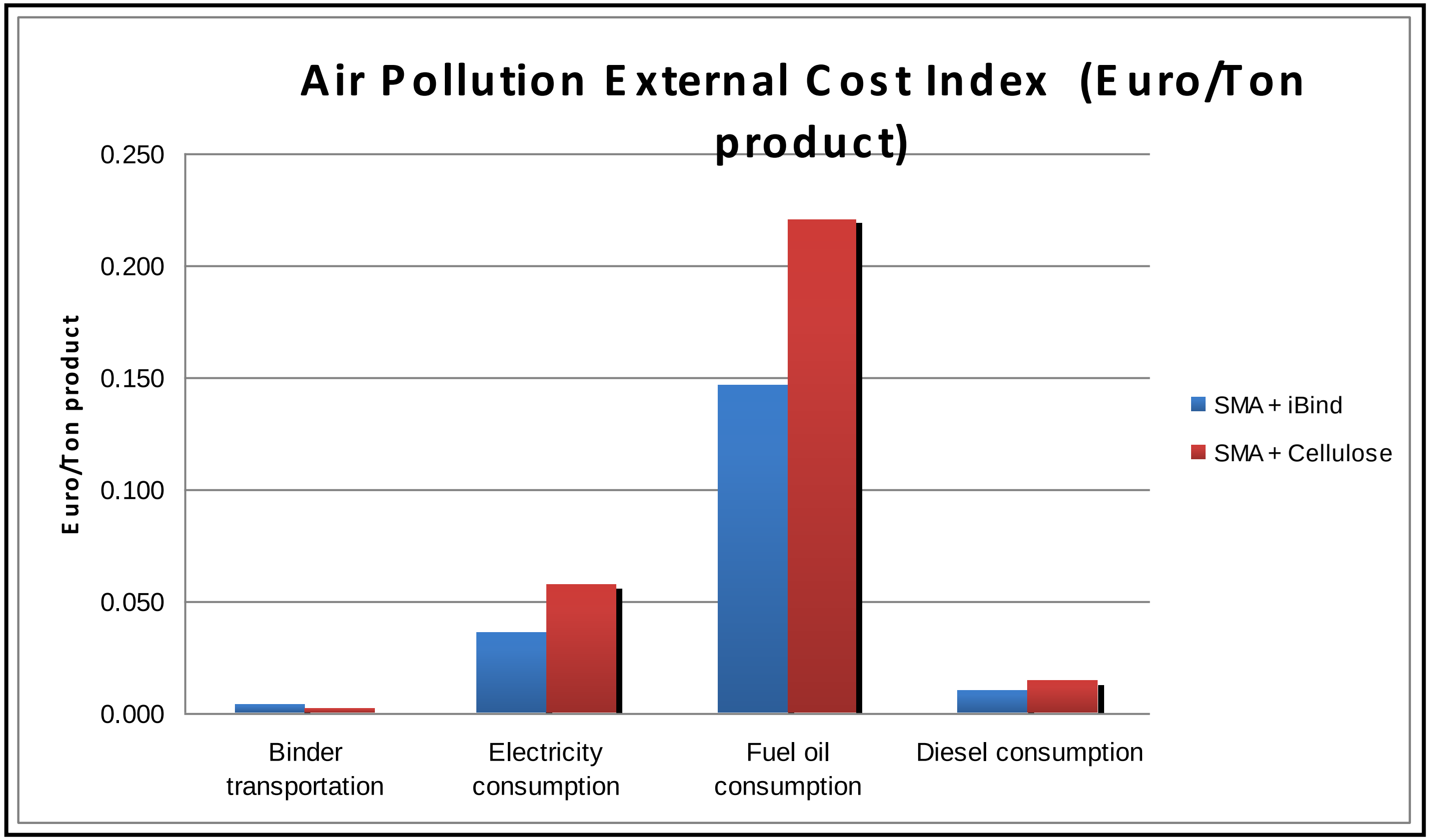
Environmental Benefits

Comparison with respect to Carbon Footprint



Environmental Benefits

Comparison with respect to A.P. External Cost



Environmental Conclusions

- The analysis of the environmental indicators clearly demonstrates a 33% decline in the negative environmental economic cost per ton of product when using the AMBS binder as compared to the Fibers, 34% decline in greenhouse gas emissions for every ton product of SMA with AMBS, and 33% decline in energy consumption for every ton product of SMA with AMBS
- Overall, using AMBS could generate about **30 Eurocents** of environmental benefit for every ton of SMA by lowering the external costs associated with asphalt production.

AMBS - General Conclusions

- Using unique physico-chemical processes, Micro-grinded raw silica mineral, activated by Nano long-chain molecules can serve as an efficient binder stabilizer to prevent bitumen draindown in SMA paving mixes.
- When replacing the cellulose fibers by the AMBS, SMA mixes can be mixed and compacted at the same conditions as conventional HMA with respect to the lower mixing duration, and lower mixing & compaction temperatures. Also, mixes can be designed at much lower binder content
- At optimum designs, European and American SMA mixes with AMBS also show comparable and better mechanical properties. These results were obtained with 0.5-1.2% less binder content and 10-20^{o}C less mixing temperature, as compared to the fibers

AMBS - General Conclusions

- The incorporation of the AMBS possesses also pronounced environmental benefits. Generally, the comparison of the environmental indicators analyzed clearly demonstrates an average of 33% decline in the negative environmental economic cost and also in energy consumption for every ton product of SMA
- By replacing conventional PMB in the AMBS SMA mix with wax modified bitumens, additional reduction in mixing temperature, between 30-40^{o}C (54-72ºF), was obtained. This is a true Warm SMA mix -- **WSMA**

"AMBS" – generic

"iBind" - descriptive

since it Interlock the Binder within the mix

Thank You for Your Attention