Warm mixes: Laboratory studies in Brazil

Leni Leite
Luis Alberto Nascimento
Marcos Chacur
PETROBRAS/CENPES

Overview

- Warm mixes: advantages and concerns
- Technologies of warm mixes
- Academic works about warm mixes in Brazil
- Petrobras research studies
- Conclusions
- Future works

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Advantages

- Less emissions – reduce workers exposure
- Fuel saving
- Less binder aging
- Paving benefits

- Ability to pave in cooler temperatures and still obtain density
- Ability to haul the mix longer distances and still have workability to place and compact
- Ability to compact mixture with less effort (assuming typical conditions, not cold weather or long haul)
- Ability to incorporate higher percentages of RAP
- Ability to place thick lifts and open to traffic in a short time period

French, German, and Italian data were presented that indicated reduced worker exposure when placing WMA. Direct comparisons of measurements of fumes and aerosols are difficult since different testing protocols and sampling periods are used in different countries. It should be noted that all of the exposure data for HMA were below the acceptable exposure limits. Tests for asphalt aerosols/fumes and polycyclic aromatic hydrocarbons (PAHs) indicated significant reductions compared to HMA. Data presented by the Bitumen Forum appear to result in a 30 to 50 percent reduction.[9] Preliminary data from a forthcoming Italian study indicate even larger reductions.

Reduced Fuel and Energy Usage

Reports indicated that burner fuel savings with WMA typically range from 20 to 35 percent. These levels could be higher if burner tuning was completed to allow the burner to run at lower settings. Fuel savings could be higher (possibly 50 percent or more) with processes such as low-energy asphalt concrete (LEAB) and low-energy asphalt (LEA), in which the aggregates (or a portion of the aggregates) are not heated above the boiling point of water. It does not appear that any change in electrical usage to mix and move the material through the plant has been considered in the analysis of potential fuel savings. No specific study was referenced for the suggested fuel savings.

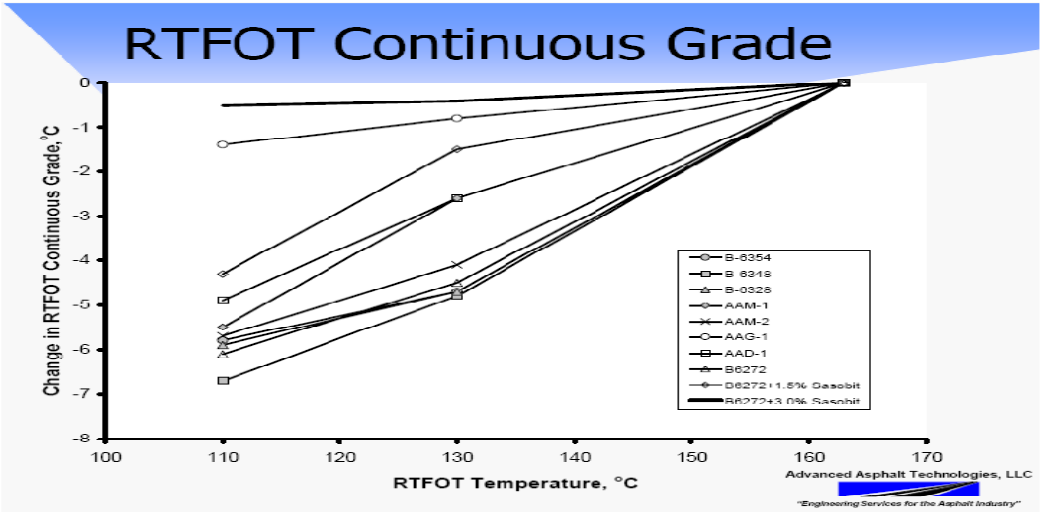

Table 4. Reported reductions in plant emissions (percent) with WMA.[10, 11, 12]

Emission	Norway	Italy	Netherlands	France
CO_2	31.5	30–40	15–30	23
SO_2	NA	35	NA	18
VOC	NA	50	NA	19
CO	28.5	10–30	NA	NA
NO_x	61.5	60–70	NA	18*
Dust	54.0	25–55	NA	NA

*Reported as NO_2
NA—not available

Source: FHWA 2008

Concerns

- Rutting
- Moisture susceptibility
- Workability – how to measure
- Fatigue life if the application causes high voids

Binder Grade Selection

- Lower Production Temperatures
  - Less Binder Aging
  - Potentially Improved Long-Term Performance
  - Greater Potential for Early Rutting

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Workability Summary

- Gyratory Compaction
  - Does not appear to be sensitive
- Torque
  - Promising at low temperatures
- Force
  - In progress

UMass Workability Device

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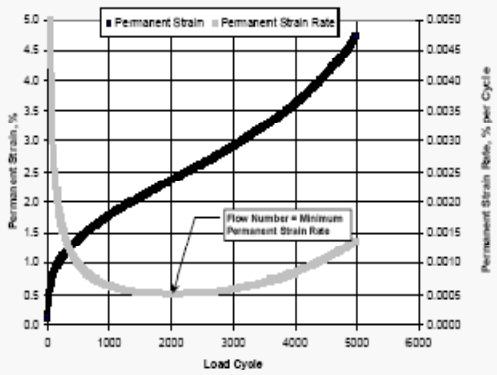
WMA Moisture Susceptibility Concern

- Lower production temperatures benefits
  - Lower emissions
  - Fuel savings
- May cause issues with moisture susceptibility
  - Aggregates may not dry enough

Concerns

Required Performance Testing

- Moisture Sensitivity
  - AASHTO T283
- Rutting Resistance
  - Flow Number



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Key Differences Volumetric Design

Item	HMA AASHTO R35	WMA Proposed
Mixing & Compaction Temperatures	Viscosity	Coating Workability Compactability
Specimen Preparation	Standard	Process specific Short-term aging
Optimum Binder Content	AASHTO M323 Volumetrics	AASHTO M323 Volumetrics
Moisture Sensitivity	AASHTO T283	AASHTO T283
Rutting Resistance	None	Flow Number Test

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Some researchers recommend to use:

- Hard bitumen against rutting
- Hydrated Lime to improve moisture sensitivity problems

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Technologies of warm mixes

- WAM-Foam (U.S. marketing by British Petroleum)
- Low Emission Asphalt
- Aspha-Min
- Advera
- Sasobit
- REVIX
- Evotherm
- Gencor
- Terex
- Double Barrel Green
- Cecabase RT
- Rediset WMX

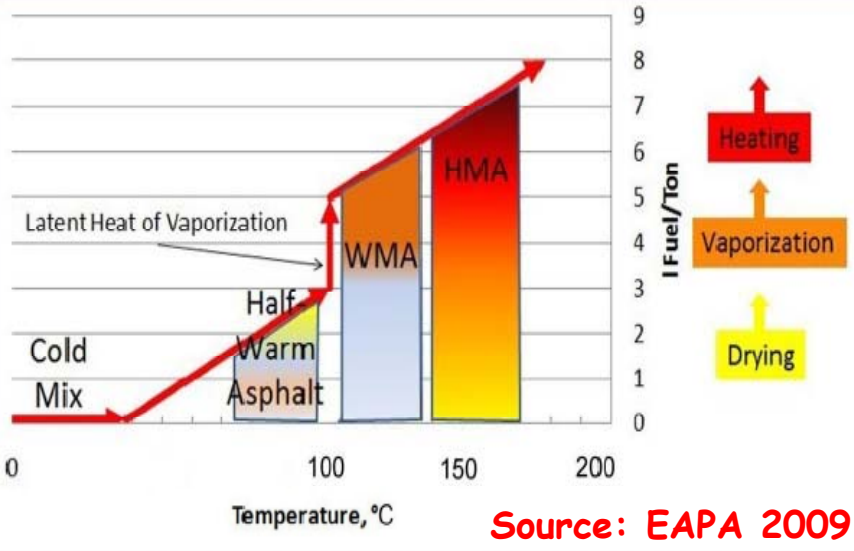
Mathy Tech. & Eng. Services and Paragon Technical Services, Inc

U.S. Department of Transportation Federal Highway Administration

FHWA does not endorse any particular proprietary product or technology.

Warm Mix Asphalt Processes

- **Organic, Wax-like additives**
  - Sasobit® – Sasol International
  - Asphaltan B – Romanta
  - Fatty Acid Amides – Licomont S 100
- **Foaming Processes**
  - Aspha-min zeolite – MHI/Eurovia
  - Low Energy Asphalt – Fairco/Eiffage Travaux Publics
  - WAM Foam –Kolo Veidekke/Shell/BP
  - LEAB® – BAM
- **Emulsion Based**
  - Evotherm™ – Mead Westvaco
- **Surfactant Solution Injection**
  - Mathy Technology and Engineering Services
  - Evotherm™ DAT -Mead WestVaco
- **Vegetable based synthetic binders**
- **Emerging Technologies**
  - REVIX™
  - Aztec Double Barrel Green



Source: EAPA 2009

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Foaming technologies

WMA Process	Company	Additive	Production Temperature (at plant) °C	Use Reported in	Approximate Total Tonnage Produced to Date
FOAMING PROCESSES *(continued)*					
LT Asphalt (foamed asphalt with addition of hygroscopic filler to maintain workability	Nynas	Yes, added 0.5–1.0% of a hygroscopic filler	90 °C (194 °F)	Netherlands and Italy	Unknown
WAM-Foam (soft binder coating followed by foamed hard binder)	Kolo Voidokko, Shell Bitumen (patent rights worldwide, except U.S.), and BP (patent rights U.S.)	Not necessary; a surfactant may be added to aid in the foaming of certain binders and an antistripping agent may be added to the soft binder	110–120 °C (230–248 °F)	France and Norway, also Canada, Italy, Luxembourg, Netherlands, Sweden, Switzerland, and United Kingdom	>60,000 tons
Aspha-min (zeolite)	Eurovia and MHI	Yes, about 0.3% by total weight of mix	Varies, 20–30 C° (36–54 F°) drop from HMA. German guideline recommends 130–170 °C (266–338 °F), depending on binder stiffness	France, Germany, and U.S.	About 300,000 tons
ECOMAC (cold mix warmed before laying)	Screg	Yes (unknown type/ quantity)	Placed at about 45 °C (113 °F)	France	Some trials
LEA, also EBE and EBT (foaming from portion of aggregate fraction)	LEACO, Fairco, and EIFFAGE Travaux Publics	Yes, 0.2–0.5% by weight of binder of a coating and adhesion agent	<100 °C (212 °F)	France, Spain, Italy, and U.S.	>100,000 tons
LEAB® (direct foam with binder additive)	BAM	Yes, added at 0.1% by weight of binder to stabilize foam, aid in coating, and	90 °C (194 °F)	Netherlands	Seven commercial projects

France > 40Mton

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Additives and others

WMA Process	Company	Additive	Production Temperature (at plant) °C	Use Reported in	Approximate Total Tonnage Produced to Date
ORGANIC (WAX) ADDITIVES—ADDED TO BINDER OR MIX					
Sasobit (Fischer-Tropsch wax)	Sasol	Yes, in Germany added on average at 2.5% by weight of binder; lower doses, 1.0–1.5%, used in U.S.	Varies, 20–30 C° (36–54 F°) drop from HMA. German guideline recommends 130–170 °C (266 to 338 °F), depending on binder stiffness	Germany and 20 other countries worldwide	>10 million tons worldwide
Asphaltan-B (Montan wax)	Romonta	Yes, in Germany added on average at 2.5% by weight of binder	Varies, 20–30 C° (36–54 F°) drop from HMA. German guideline recommends 130–170 °C (266–338 °F), depending on binder stiffness	Germany	Unknown
Licomont BS 100 (additive) or Sübit (binder) (fatty acid amides)	Clariant	Yes, about 3% by weight of binder	Varies, 20–30 C° (36–54 F°) drop from HMA. German guideline recommends 130–170 °C (266–38 °F), depending on binder stiffness	Germany	>322,500 square meters since 1994
3E LT or Ecoflex (proprietary)	Colas	Yes	Varies, 30–40 C° (54–72 F°) drop from HMA	France	Unknown
EMERGING U.S. TECHNOLOGIES					
Evotherm™ (hot aggregate coated with emulsion)	Mead-Westvaco	Yes	85–115 °C (185–239 °F)	France, also Canada, China, South Africa and U.S.	>17,000 tons
Double-Barrel Green	Astec	Not necessary; an antistripping agent may be added similar to normal HMA	116–135 °C (240–275 °F)	U.S.	>4,000 tons
Advera (zeolite)	PQ Corporation	Yes, about 0.25% by total weight of mix	Varies, 20–30 C° (36–54 F°) drop from HMA. German guideline recommends 130–170 °C (266–338 °F), depending on binder stiffness	U.S.	>10,000 tons
	Mathy	Dilute surfactant	110 °C (230 °F)	U.S.	Trial sections

Academic studies in Brazil

Zeolites

- UFC 2007

Mechanical characterization of bituminous mixtures by addition of zeolite

- UFSC 2009

Evaluation of fatigue life and complex modulus of warm mixes using zeolite

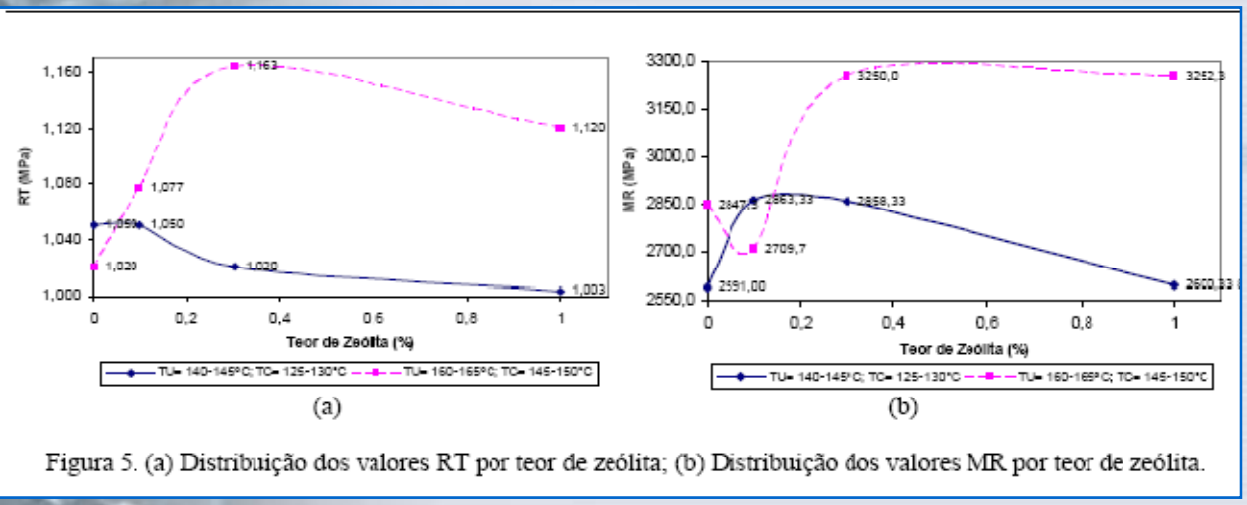
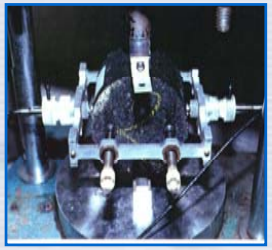


Figura 5. (a) Distribuição dos valores RT por teor de zeólita; (b) Distribuição dos valores MR por teor de zeólita.



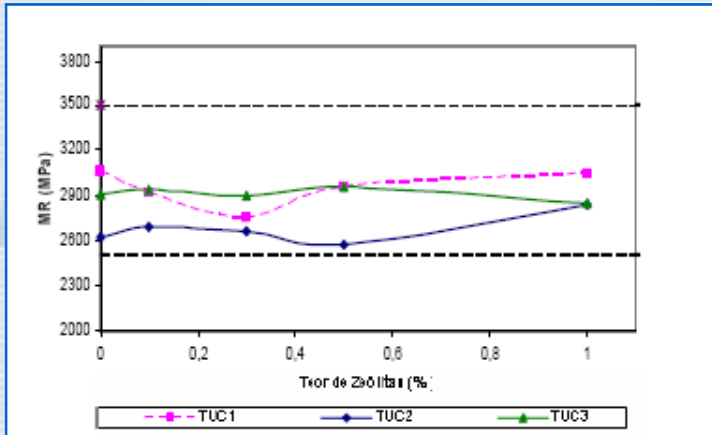
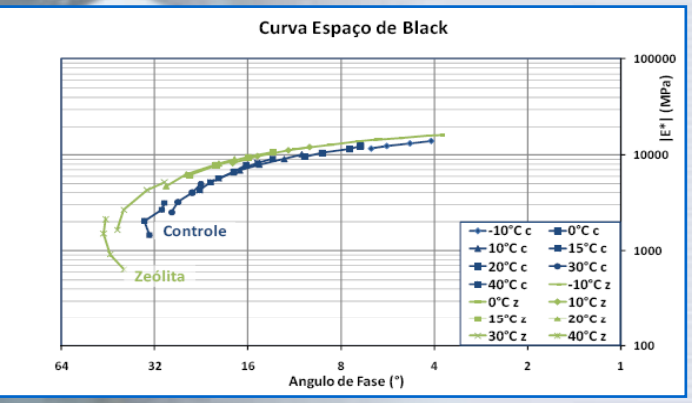
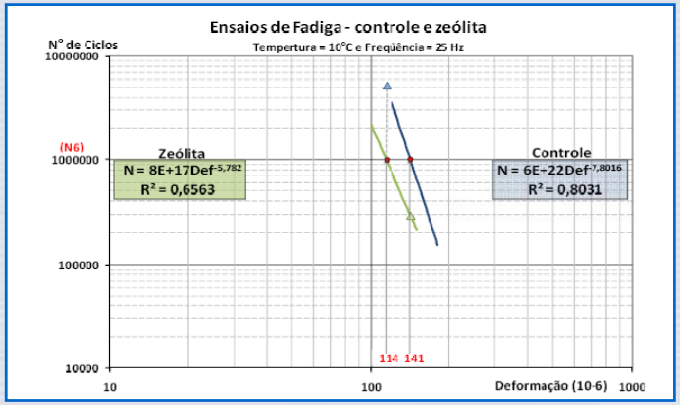


Figura 9 (a) Valores de MR por teor de zeólita





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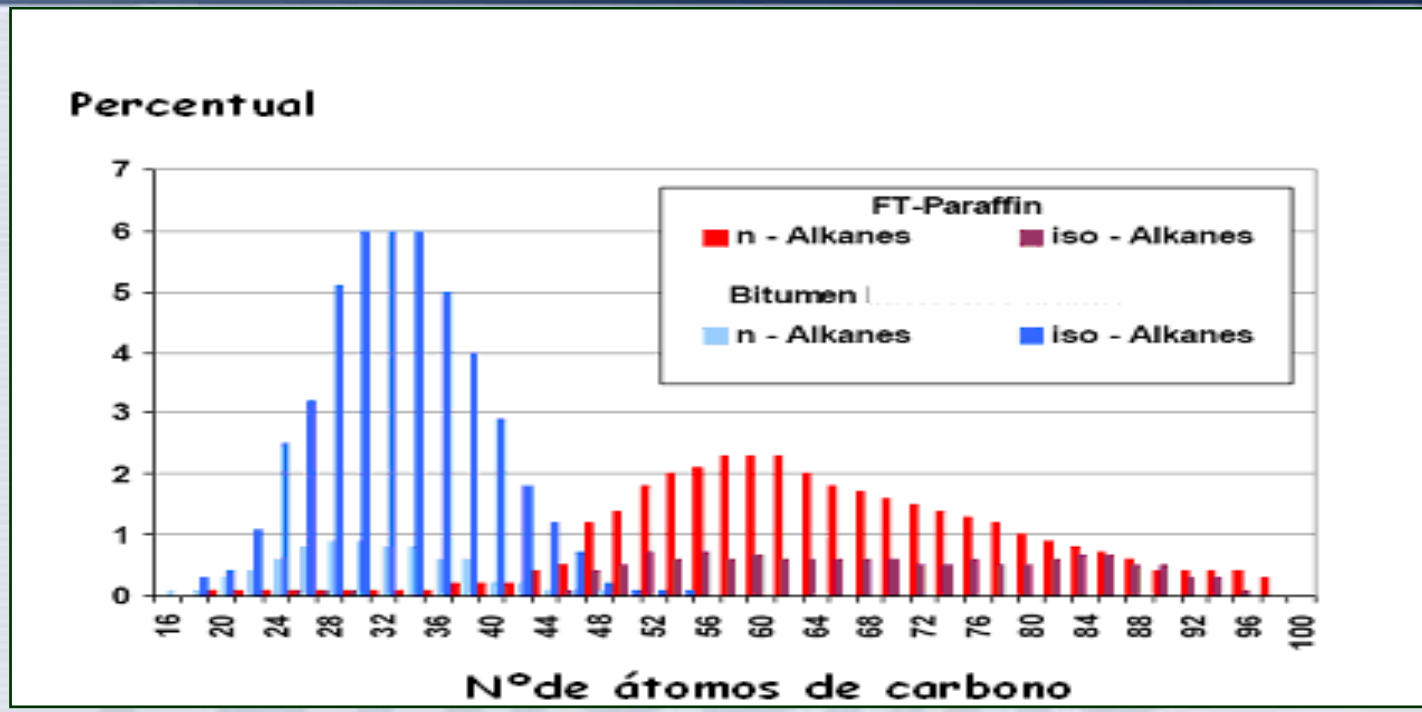
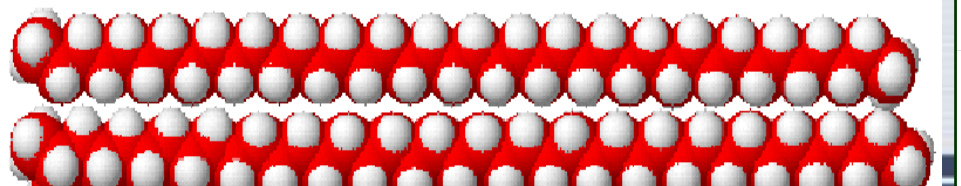
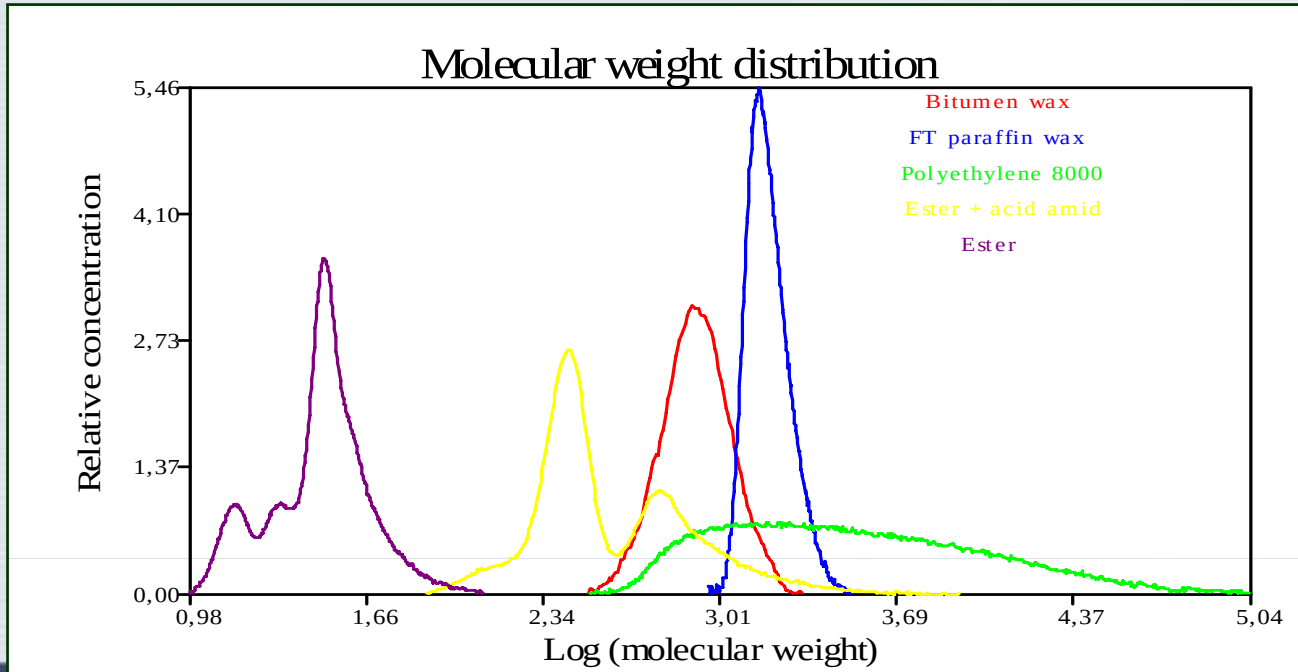
Petrobras studies – Organic additives

Bitumen wax

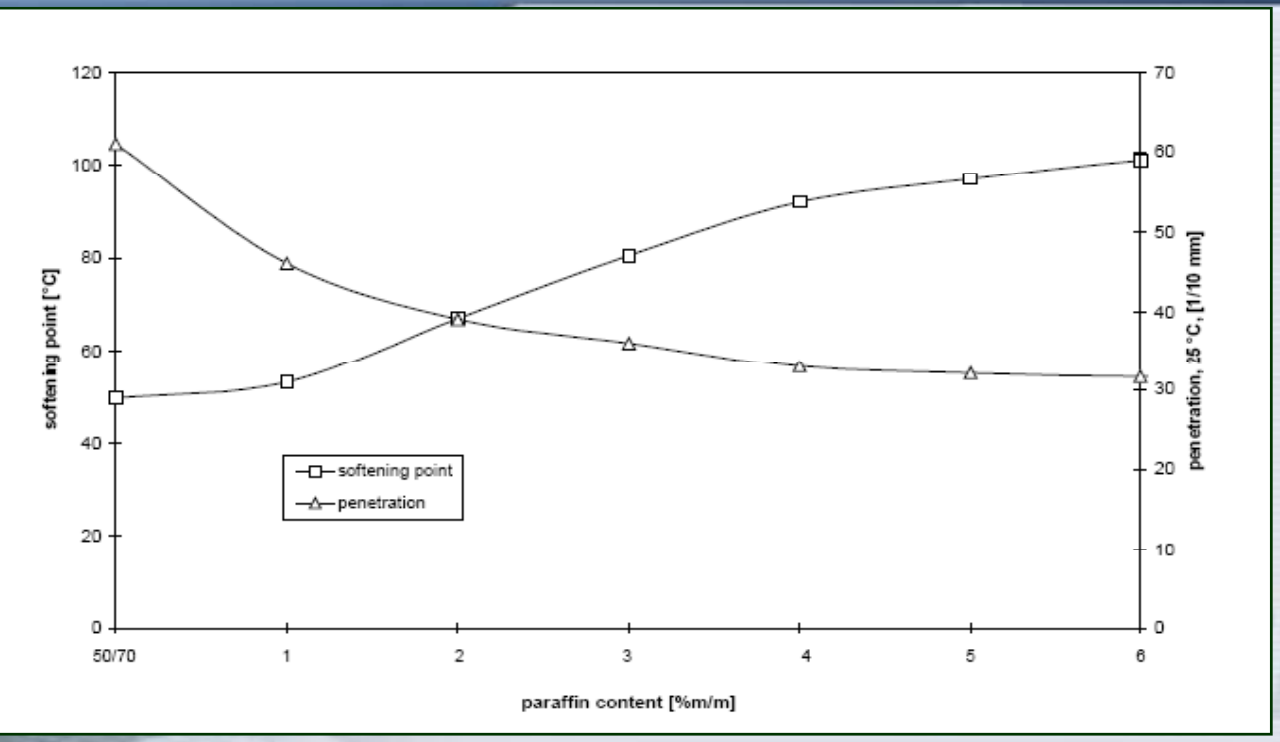


Sasobit





PETROBRAS Sasobit results depend on bitumen crude



Due its high melting point Sasobit increase one PG grade in bitumen

	Bitumen 1	Bitumen 2	Bitumen 3
Sasobit content,%	4	4	4
Mix temperature reduction (°C)	7,1 a 10,3	2,6 a 3,6	16 a 15,1
Compaction temperature reduction (°C)	17,9 a 13,9	6,7 a 5,4	12,3 a 13,6

Petrobras studies

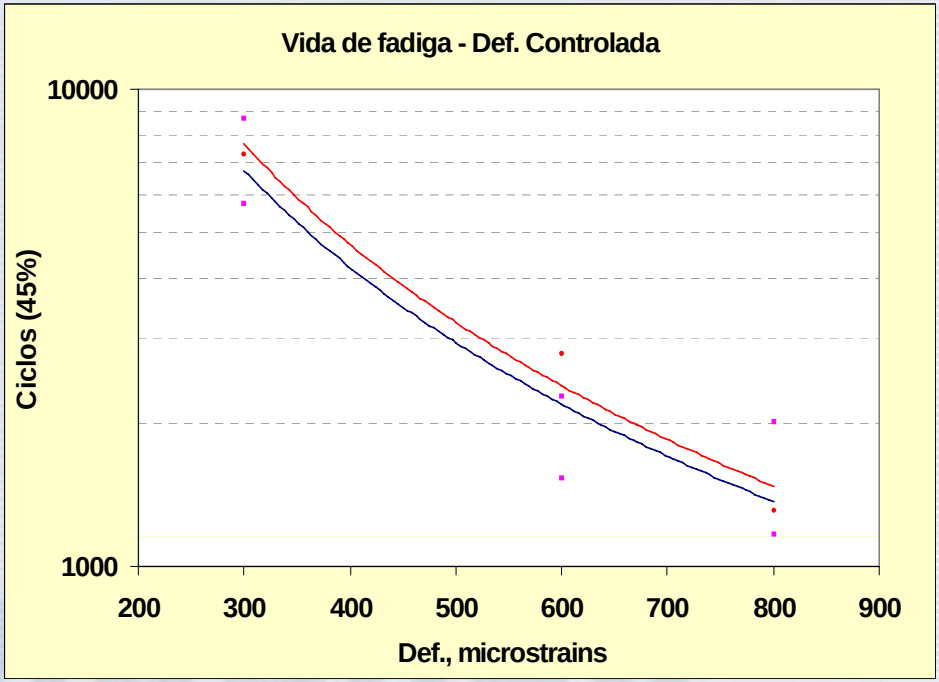
Mix Temperature reduction effects on conventional mixes:

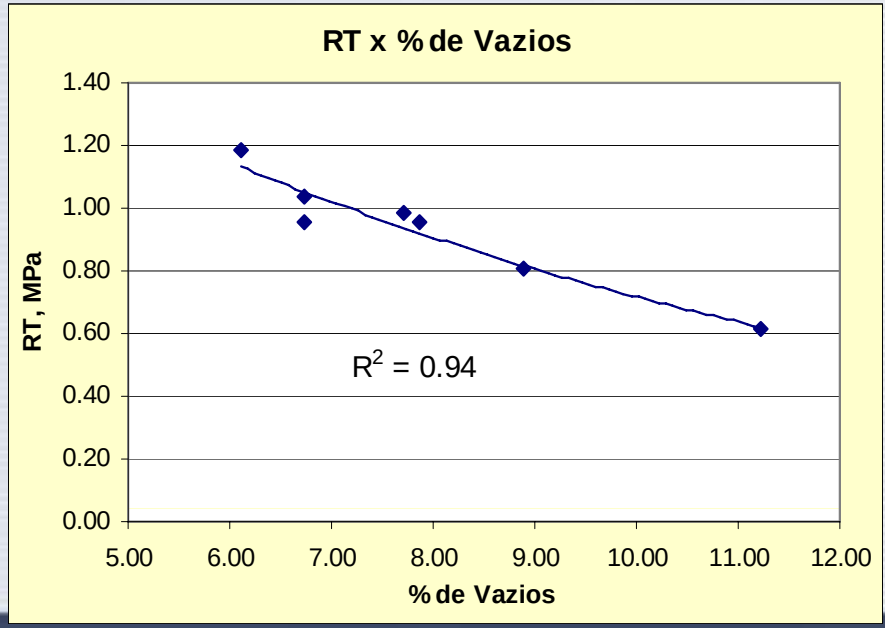
- Workability loss
- Compaction
- Voids content increase
- Pavement permeability increase

→ aging increase

Mechanical properties:

- Indirect tension reduction
- Fatigue life reduction

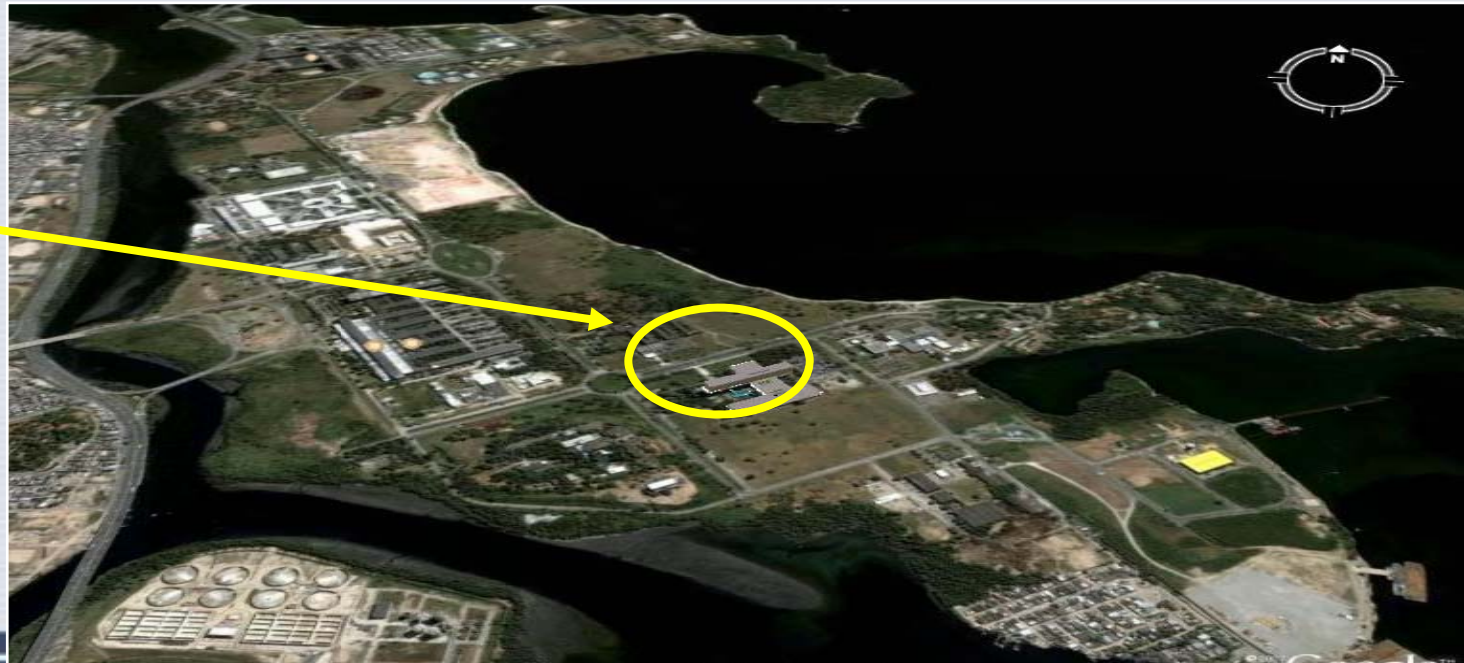




Petrobras experimental track

Aggregates: Max Nominal Size: 12,5mm – granite;
Gyratory compactor mix design; Asphalt binder: Pen 50/70 (PG 64-22);
ASAT additive – Petrobras technology
Compaction:
145°C - conventional x 110°C warm (ASAT additive in the mix)
x 110°C without additive
x 110°C with zeolite

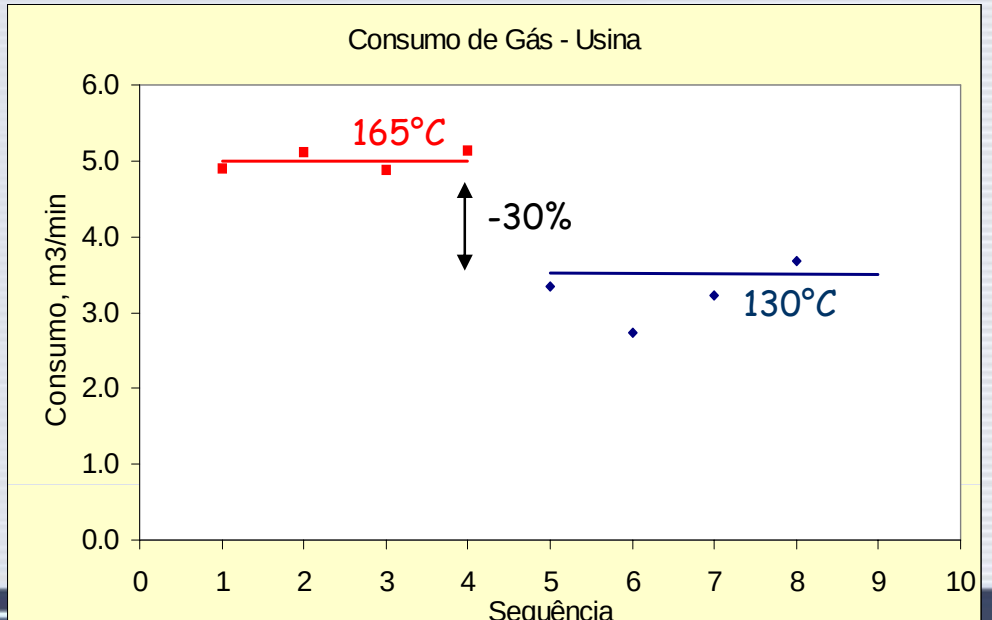
University City
- Rio de Janeiro



Petrobras technology – warm mixes

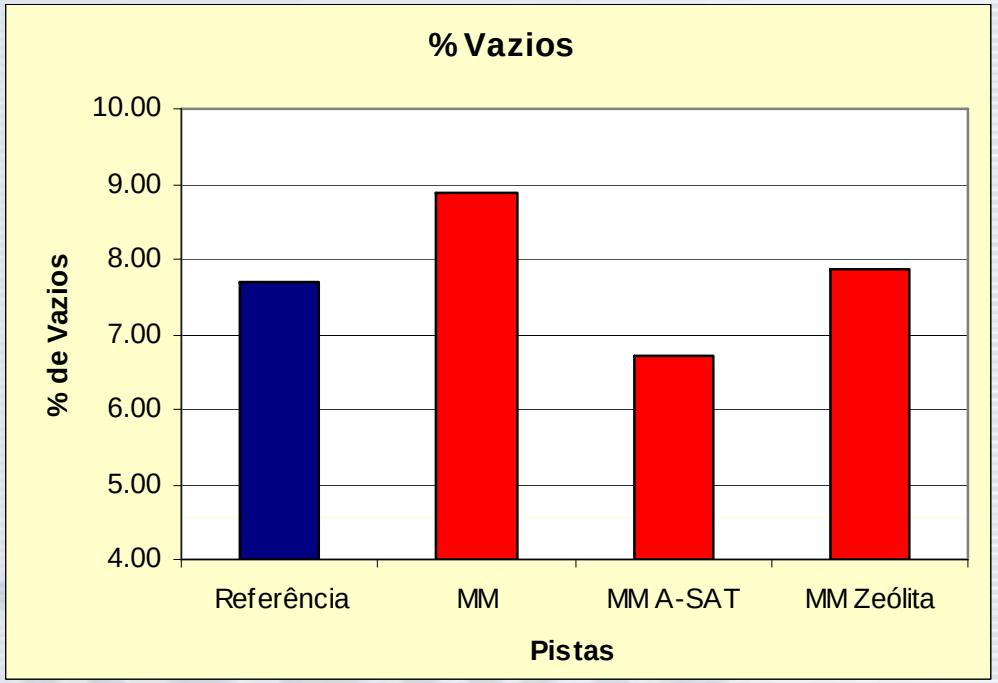
-35°C

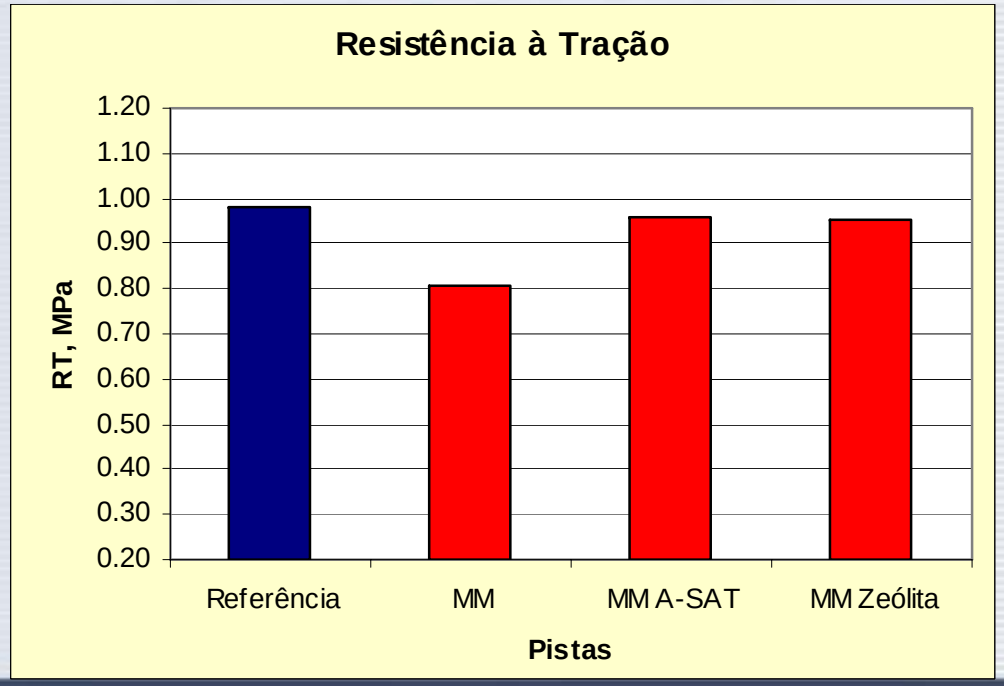
Fuel consumption:
30% less



Some results

- ASAT additive did not decrease indirect tension
- ASAT additive cause voids reduction
- Warm mix without additive presented high voids content and increase indirect tension
- ASAT and zeolite showed similar behavior





Petrobras technology - warm mixes

- Accelerated loading with Brazilian traffic simulator

- One month equivalent to ten years traffic loading;
- Evaluation of damages: rutting, fatigue cracking, etc ….

Results:

No cracks, no rutting, performance similar to conventional asphalt

Conclusions

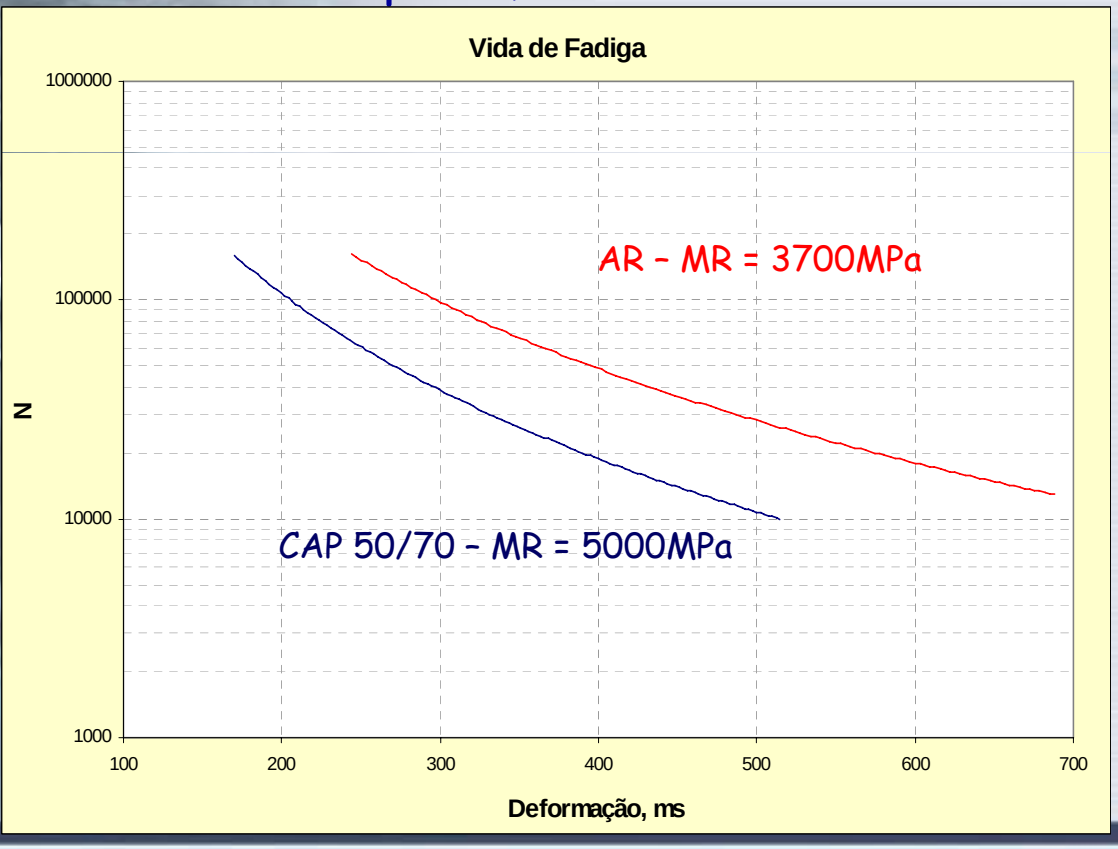
- Implementation of warm mixes requires laboratory - rutting, fatigue, water susceptibility and workability tests and field studies;
- Durability and efficiency should be equal or superior to conventional mixes;
- Sustainable pavements should be well done
- Costs comparison:
  - Zeolite increase about 8% per ton mix;
  - The price of Sasobit and organic additives are similar or superior than polymers;
  - WAM Foam requires mix plant changes;
- No Brasil: licitação exigindo tecnologia específica de Mistura Morna com aditivo químico.

Future works

Modified binders have better performance

- More fatigue life and better rutting resistance
- adhesion improved

Warm mixes with modified asphalt binders that have mix temperature higher than conventional binders will result less fuel consumption, less emissions and more durability



Experimental test will be done next December with crumb rubber terminal blend asphalt

- **VOC and particulates will be measured in the workers**

Thank you