HRVATSKO ASFALTERSKO DRUŠTVO

CROATIAN ASPHALT ASSOCIATION

LOW-TEMPERATURE ASPHALT AND RAP MIXES – A WINNING COMBINATION

NISKOTEMPERATURNI ASFALT I RAP MJEŠAVINE – DOBITNA KOMBINACIJA

GABRIELE TEBALDI, UNIVERSITY OF PARMA

MEĐUNARODNI SEMINAR ASFALTNI KOLNICI 2021

INTERNATIONAL SEMINAR ASPHALT PAVEMENTS 2021

OPATIJA, 30.09. – 01.10. 2021.

EU ENVIRONMENTAL CHALLENGES

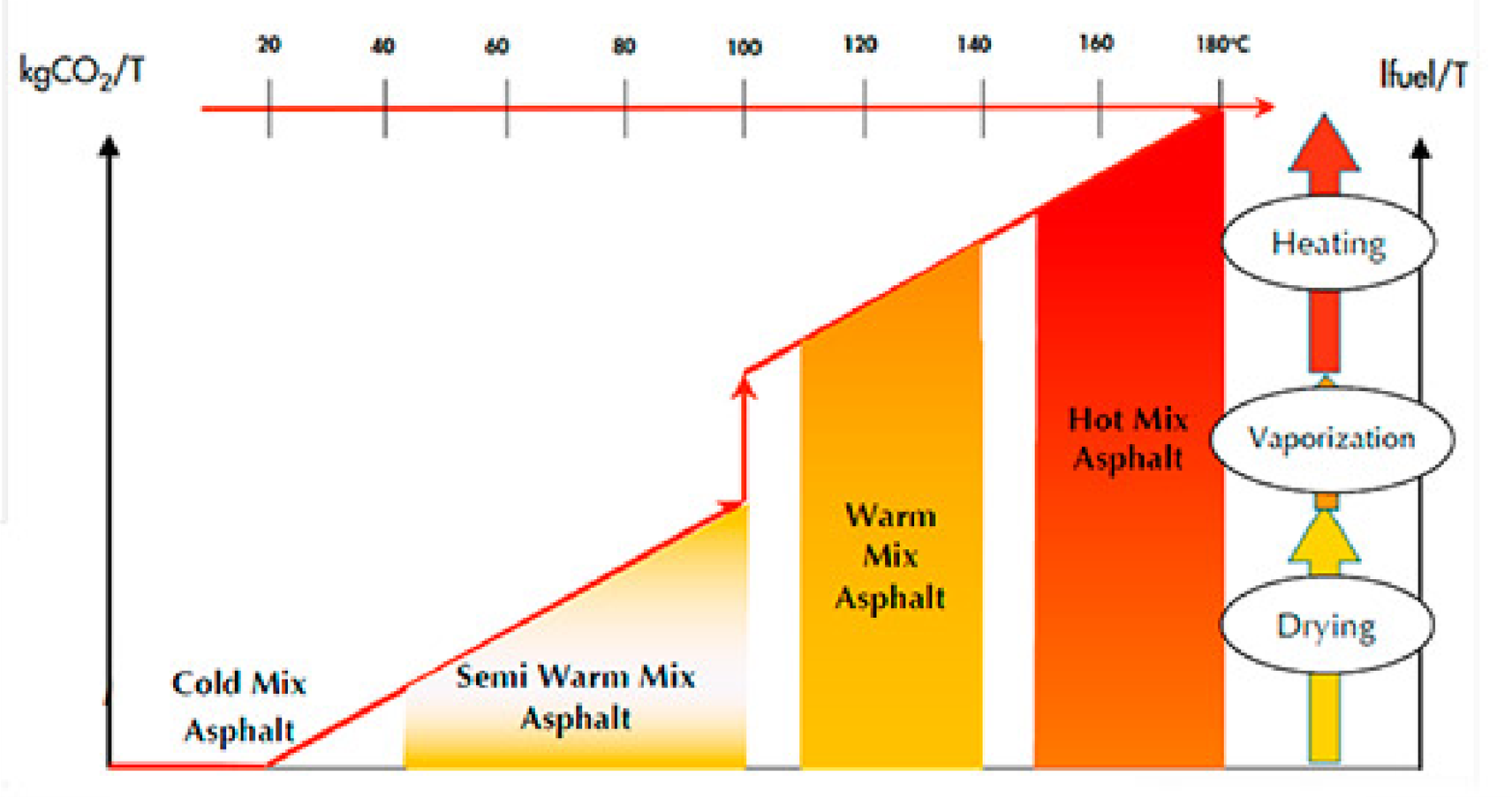
- **It is global and European policy to reduce CO_2 emissions.**
- **The goal of European Commission is a total saving of 55% of CO_2 by 2030.**
- **Ursula von der Leyen wants Europe being the first climate-neutral continent.**

EU ENVIRONMENTAL CHALLENGES

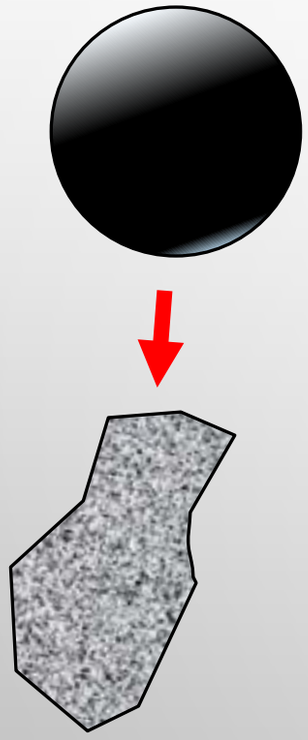
- **Zero-waste economy and society**

The new targets mean a fundamental transition from a linear to a more circular economy where re-use, repair and recycling become the norm, and waste would become a thing of the past. Of course, this requires innovation in markets for recycled materials, new business models, eco-design and industrial symbiosis.

COLD, WARM & HOT MIXTURES

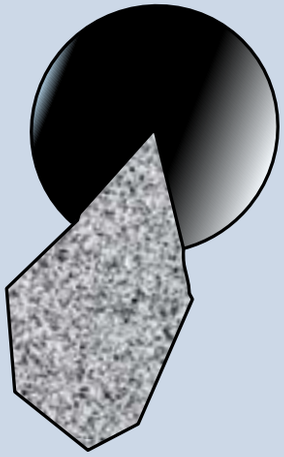


$T_{MIXTURE} \rightarrow T_{AGGREGATES}$



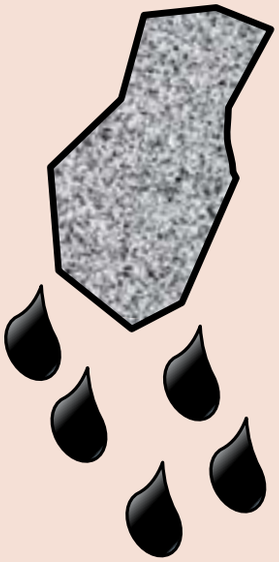
$T_{aggregate} < T_{bitur}$

Bitumen Viscos

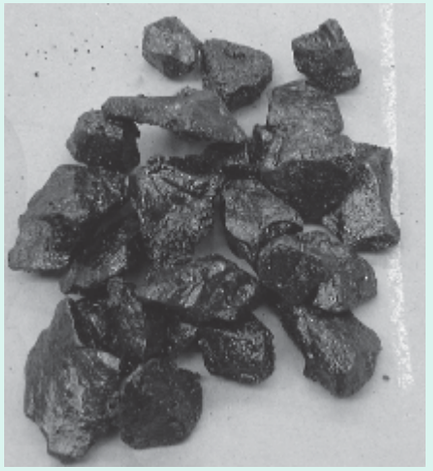


$T_{aggregate} >> T_{b}$

Bitumen Visco



$T_{aggregate} \approx T_{bitumen}$



COLD AND WARM MIXTURES

KEY ACTIONS:

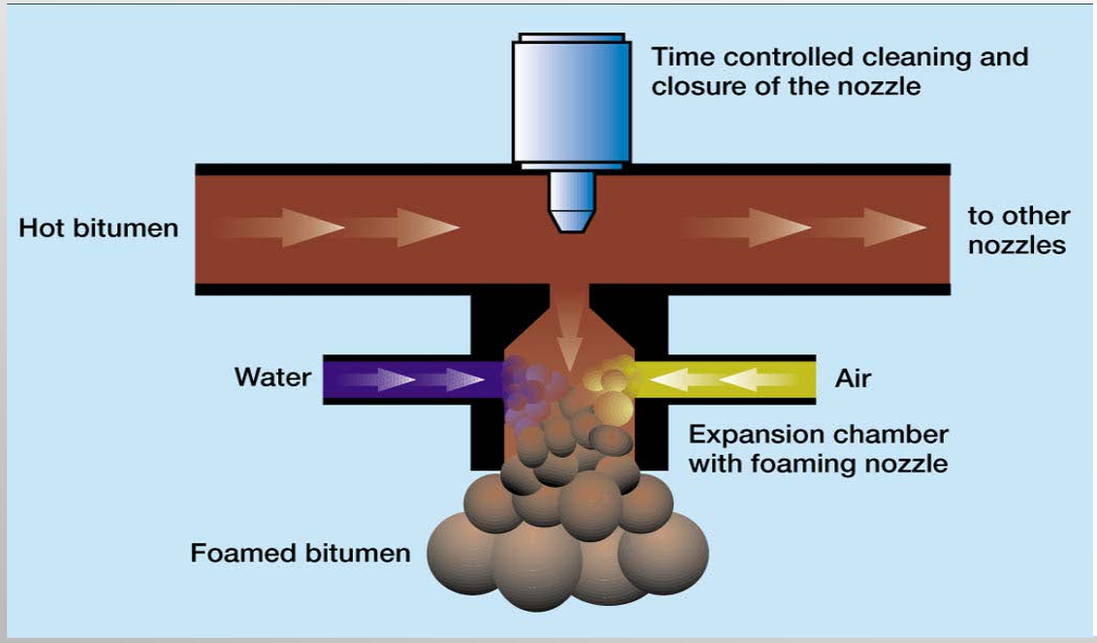
- REACH PROPER VISCOSITY AT LOWER TEMPERATURE
- FOUND A WAY FOR BITUMEN CARRYING INSIDE OF THE MIXTURE WITH A PROPER DISTRIBUTION

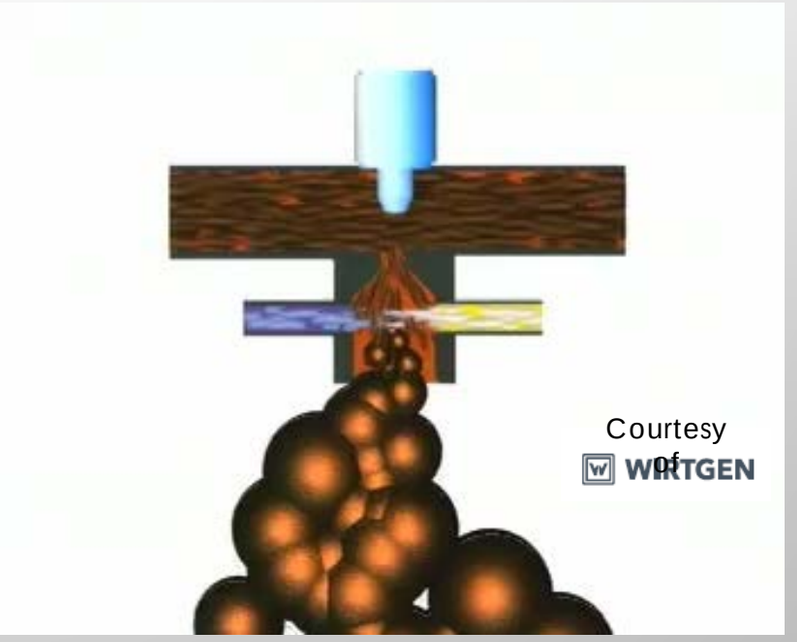
COLD RECYCLING

Foam bitumen

Cold water and air are injected simultaneously into the hot asphalt.

The hot asphalt foams explosively and shoots down into the mixing chamber.



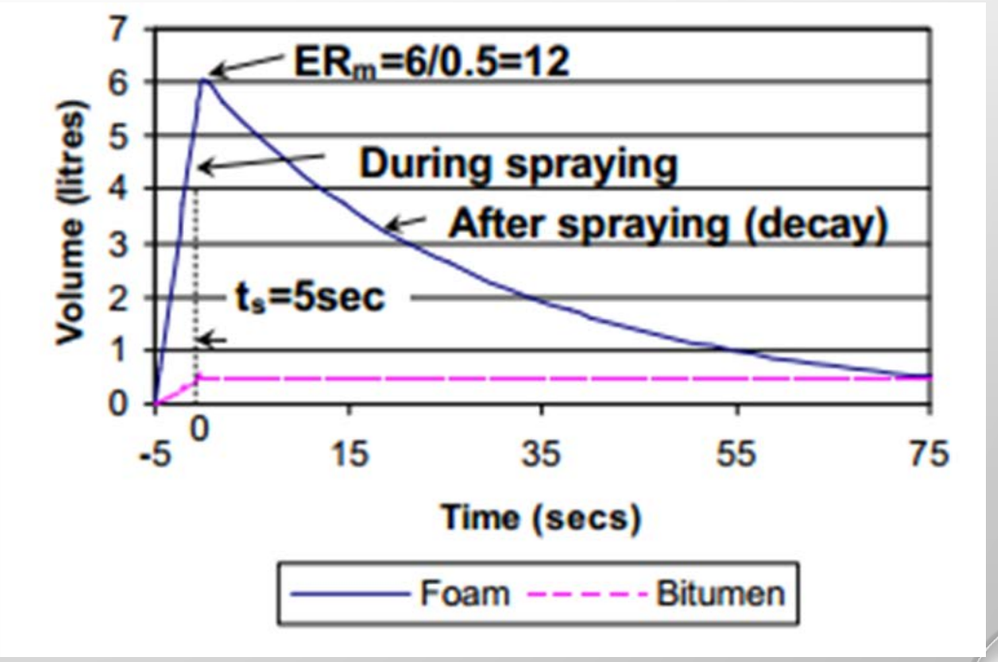


COLD RECYCLING

FOAM BITUMEN

COLD WATER AND AIR ARE INJECTED SIMULTANEOUSLY INTO THE HOT ASPHALT.

THE HOT ASPHALT FOAMS EXPLOSIVELY AND SHOOTS DOWN INTO THE MIXING CHAMBER.



Courtesy of WIRTGEN

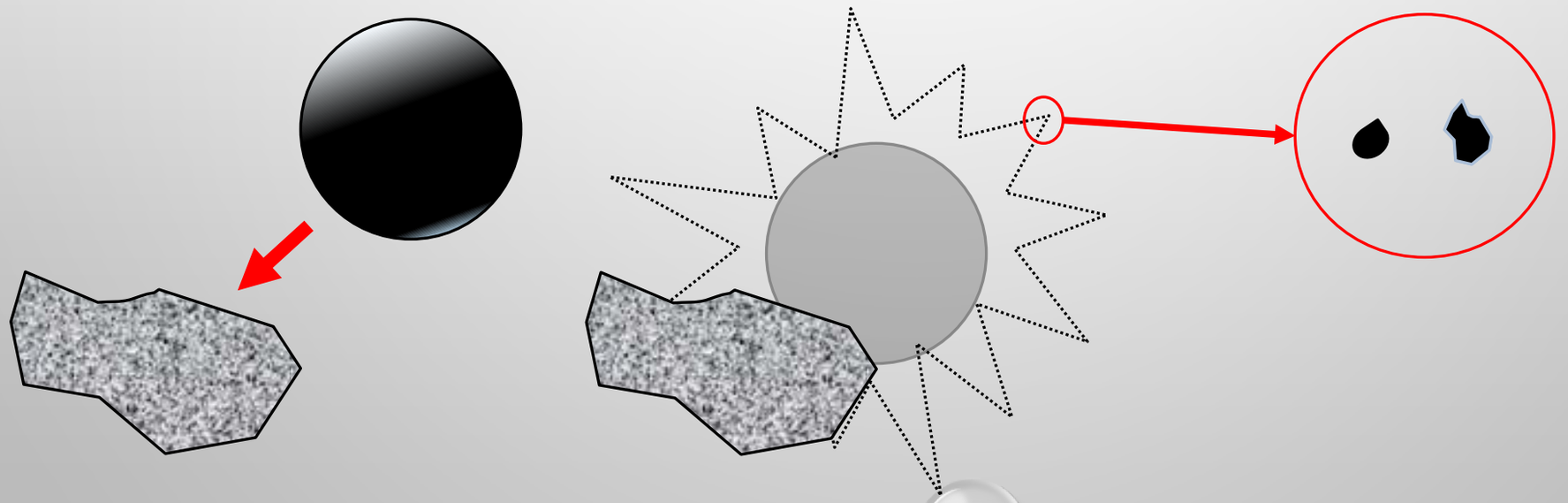
COLD RECYCLING

Foam bitumen

Foamed bitumen is a mass of bubbles. Each bubble is a thin (very thin) film of bitumen surrounding steam (water vapor)

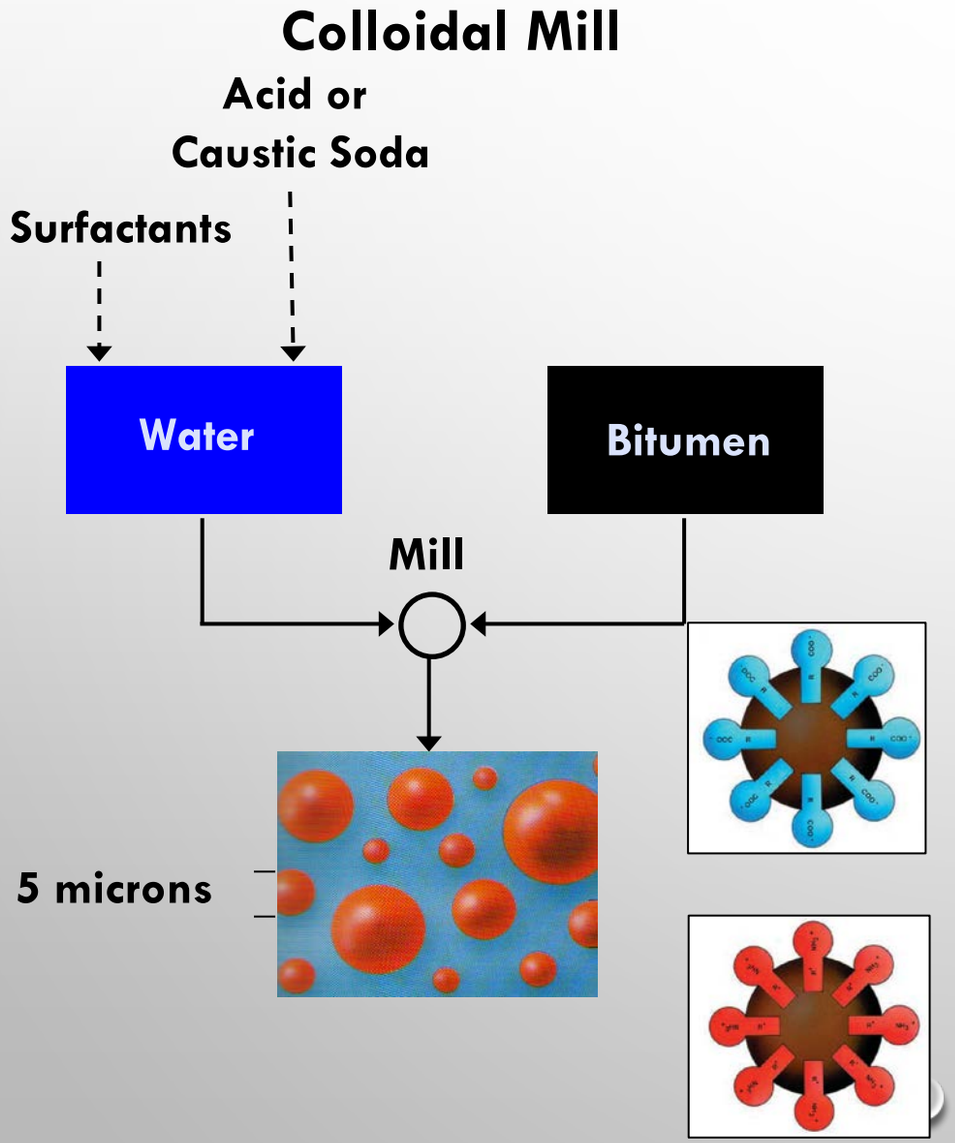
Because the film of bitumen is so thin, if a stone is thrown at one of these bubbles, it will shatter into thousands (maybe millions?) of tiny bitumen splinters Each bitumen splinter has only sufficient heat energy to warm a dust particle (+moisture) and adhere to it (or attach itself onto another bitumen splinter)

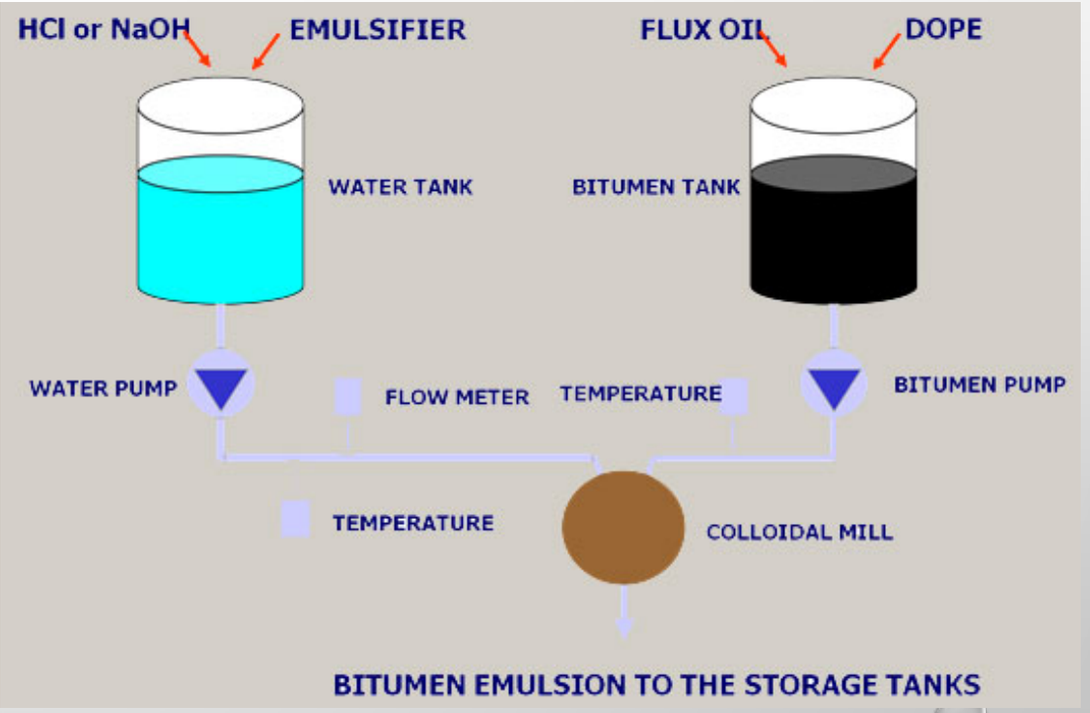
THE BLASTING AND THE DUST PARTICLES ARE THE CARRIERS OF BITUMEN



COLD RECYCLING

Bituminous emulsion



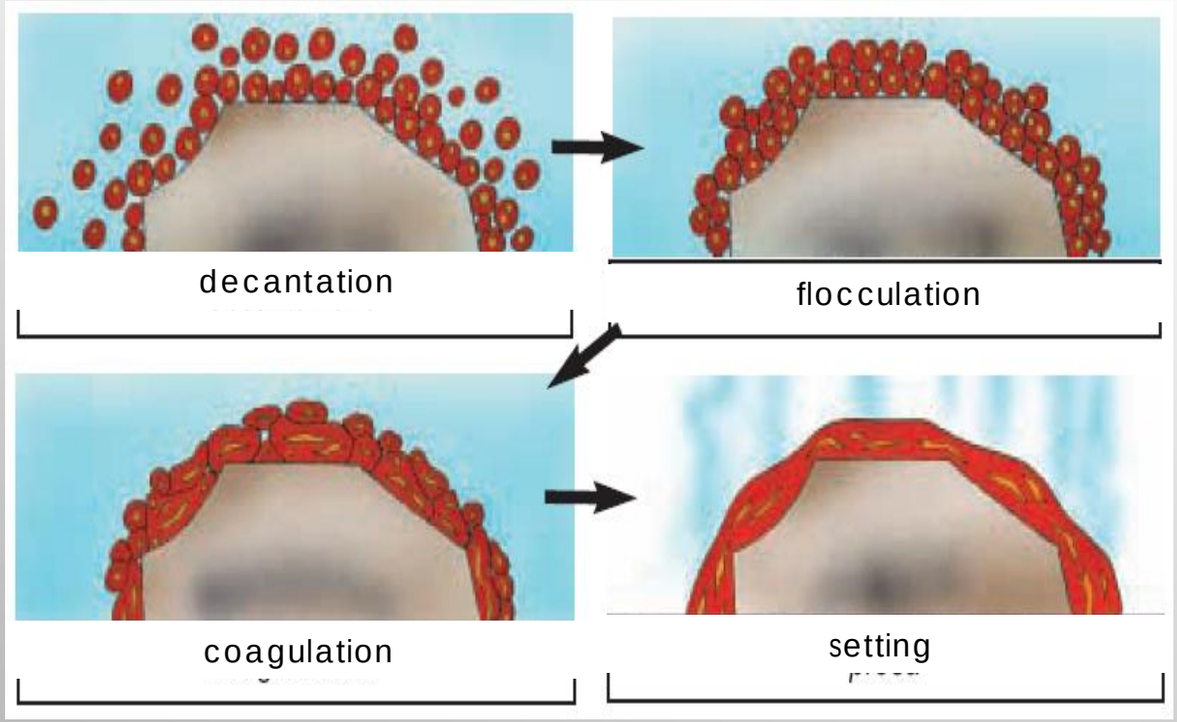


COLD RECYCLING

BITUMINOUS EMULSION

Bitumen emulsion is a form of paint, so it "wet" the surface of all particles of the mixture of aggregates

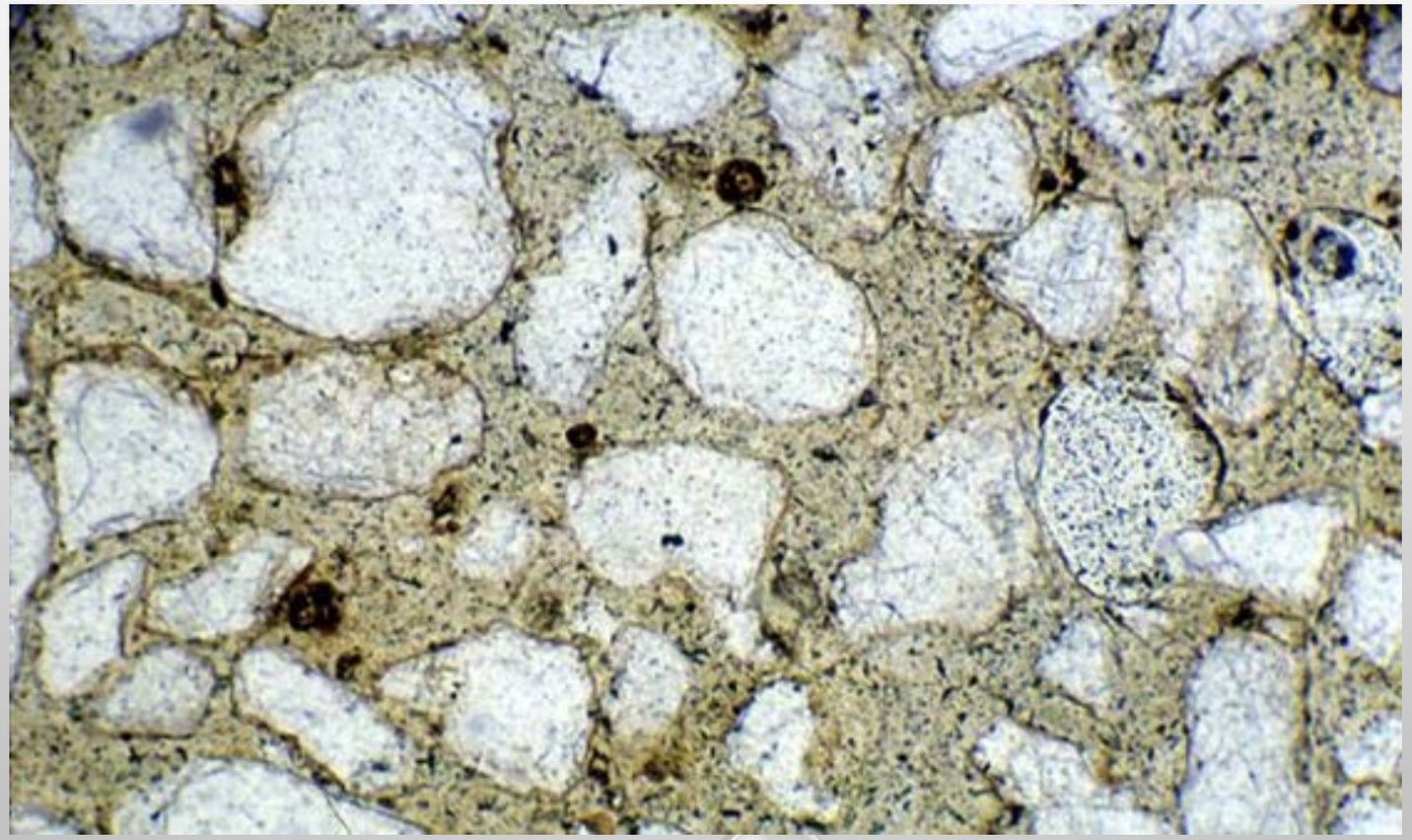
The water is the carrier of bitumen



Courtesy of Kim Jenkins

COLD RECYCLING

BSMs are non-continuously bounded materials [generally max 2% of bitumen]



COLD RECYCLING

ENVIRONMENTAL BENEFITS OF COLD IN PLACE RECYCLING

USE OF CIR INSTEAD OF TRADITIONAL MILL AND HMA OVERLAY TECHNIQUES

- CARBON DIOXIDE **-52%**
- NITRIC OXIDE AND NITROGEN DIOXIDE **-54%**
- SULFUR DIOXIDE **-61%**
- WATER USAGE **-20%**
- ENERGY CONSUMPTION ***-23%***
- USE OF VIRGIN AGGREGATES **-37%**

[Yusuf Mehta et alt.]

COSTS ANALYSIS

- COST FOR COLD IN PLACE RECYCLING

MATERIALS, 46.6% ← **Main cost saving**

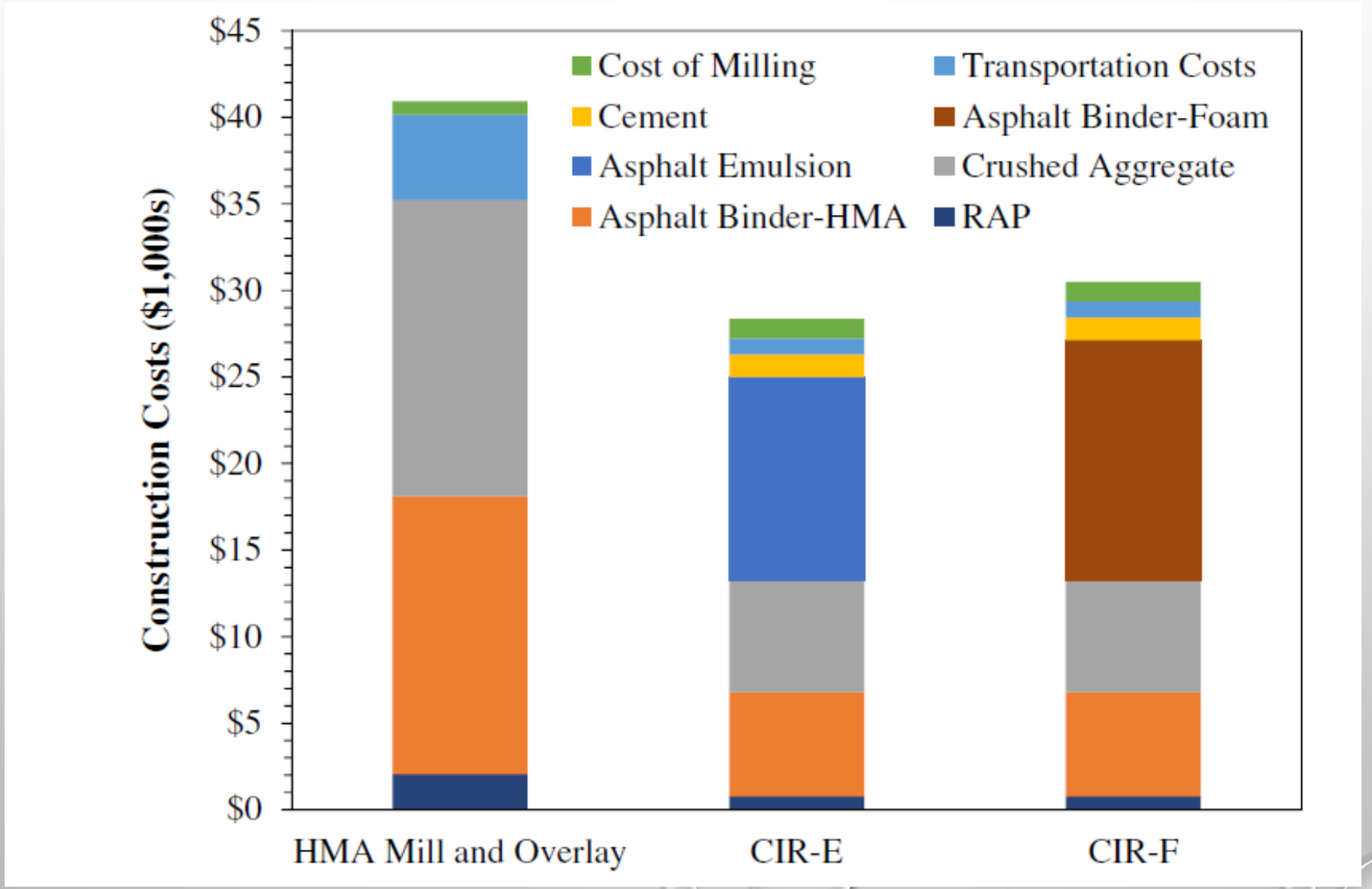
EQUIPMENT, 29.7%

LABOR, 23.7%

A REVIEW OF CURRENT LITERATURE SHOWS

THAT SAVINGS UP TO 67% CAN BE ACHIEVED BY USING COLD IN PLACE RECYCLING (IOWA DEPARTMENT OF TRANSPORTATION).

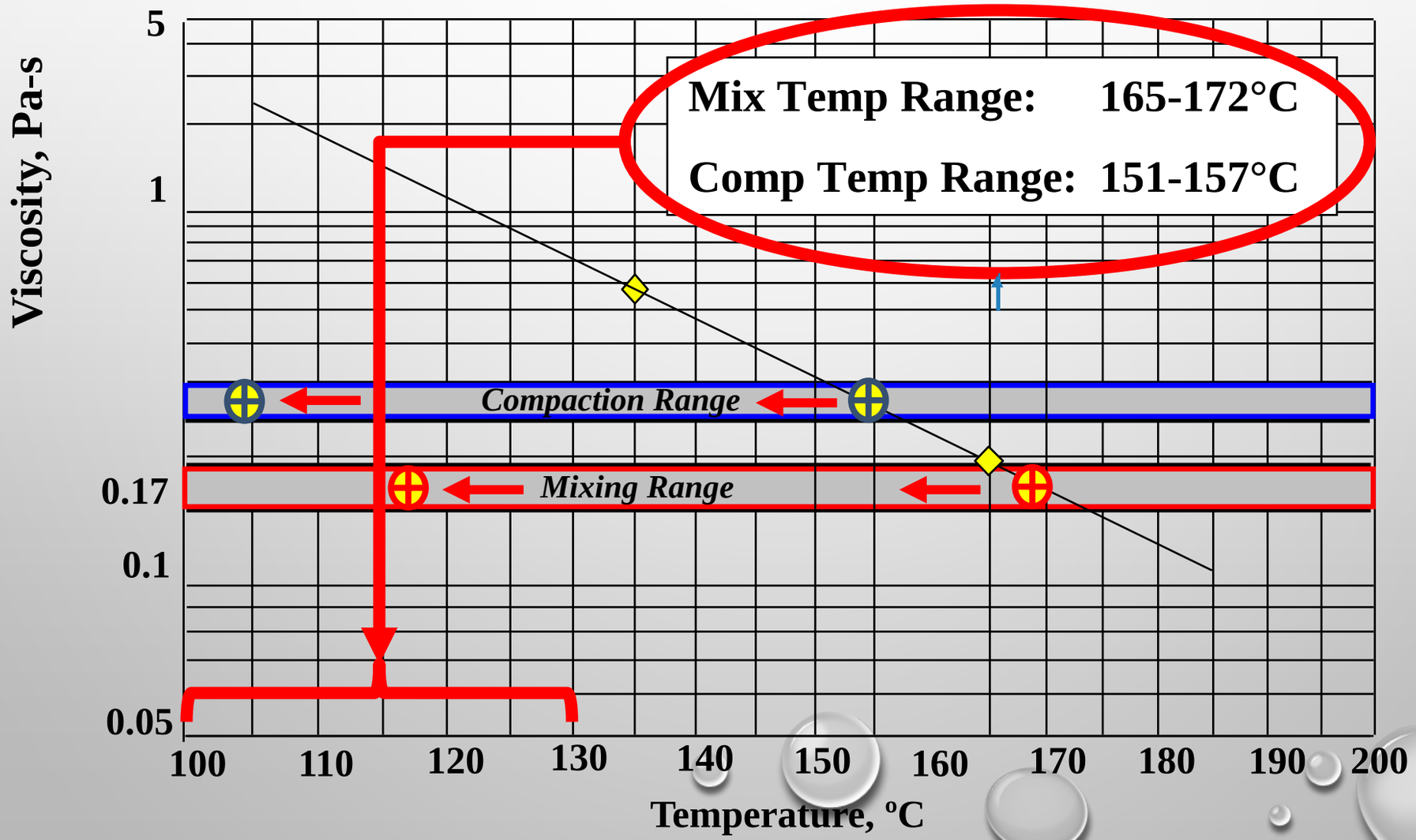
COSTS COMPARISON



[Yusuf Mehta et alt.]

WARM MIXTURES

$T_{mix} \rightarrow \eta = 0.17 \pm 0.02$ Pa·s $T_{comp} \rightarrow \eta = 0.28 \pm 0.03$ Pa·s



WARM MIXTURES

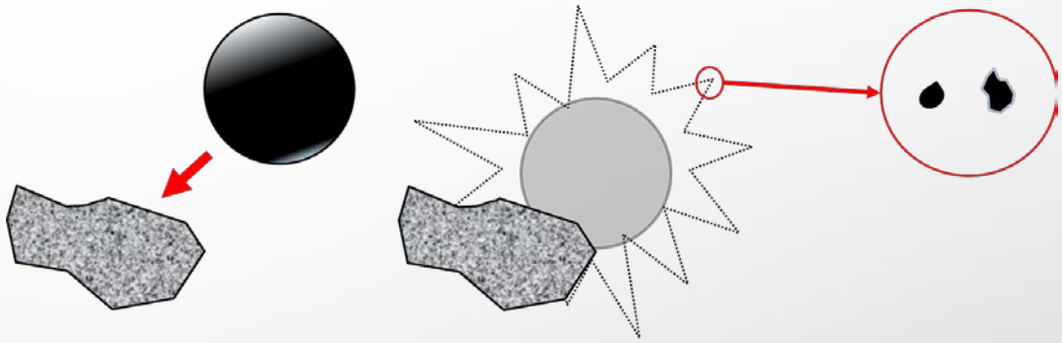
ADVANTAGES OF LOWER TEMPERATURES

- **LOWER FUMES**
- **LOWER PLANT EMISSIONS**
- **LOWER ENERGY CONSUMPTION**
- **LOWER BINDER AGING**

WARM MIXTURES

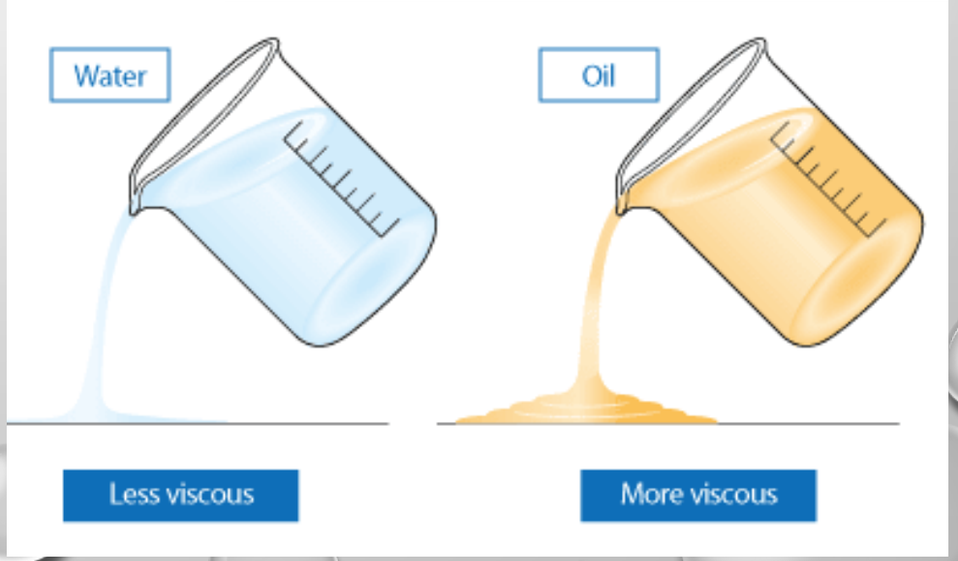
AVAILABLE TECHNOLOGIES

- **MATERIAL PROCESSING**
  - *FOAMED ASPHALT*



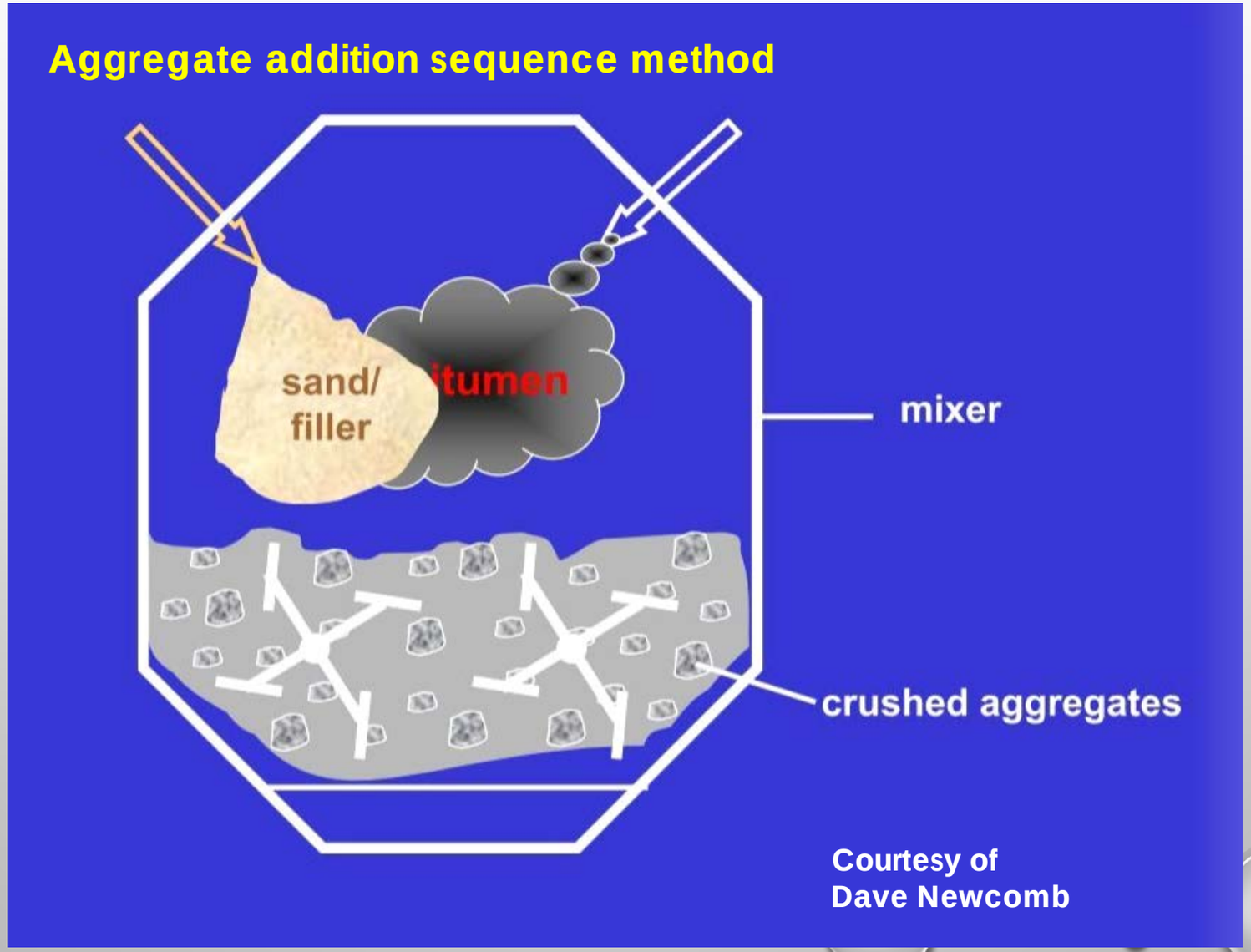
- **ADDITIVES**

  SUBSTANCES THAT MAKE AN "AUTOMATIC" FOAM PROCESS OR INDUCE A REDUCTION IN VISCOSITY
  - *MINERAL*
  - *ORGANIC*



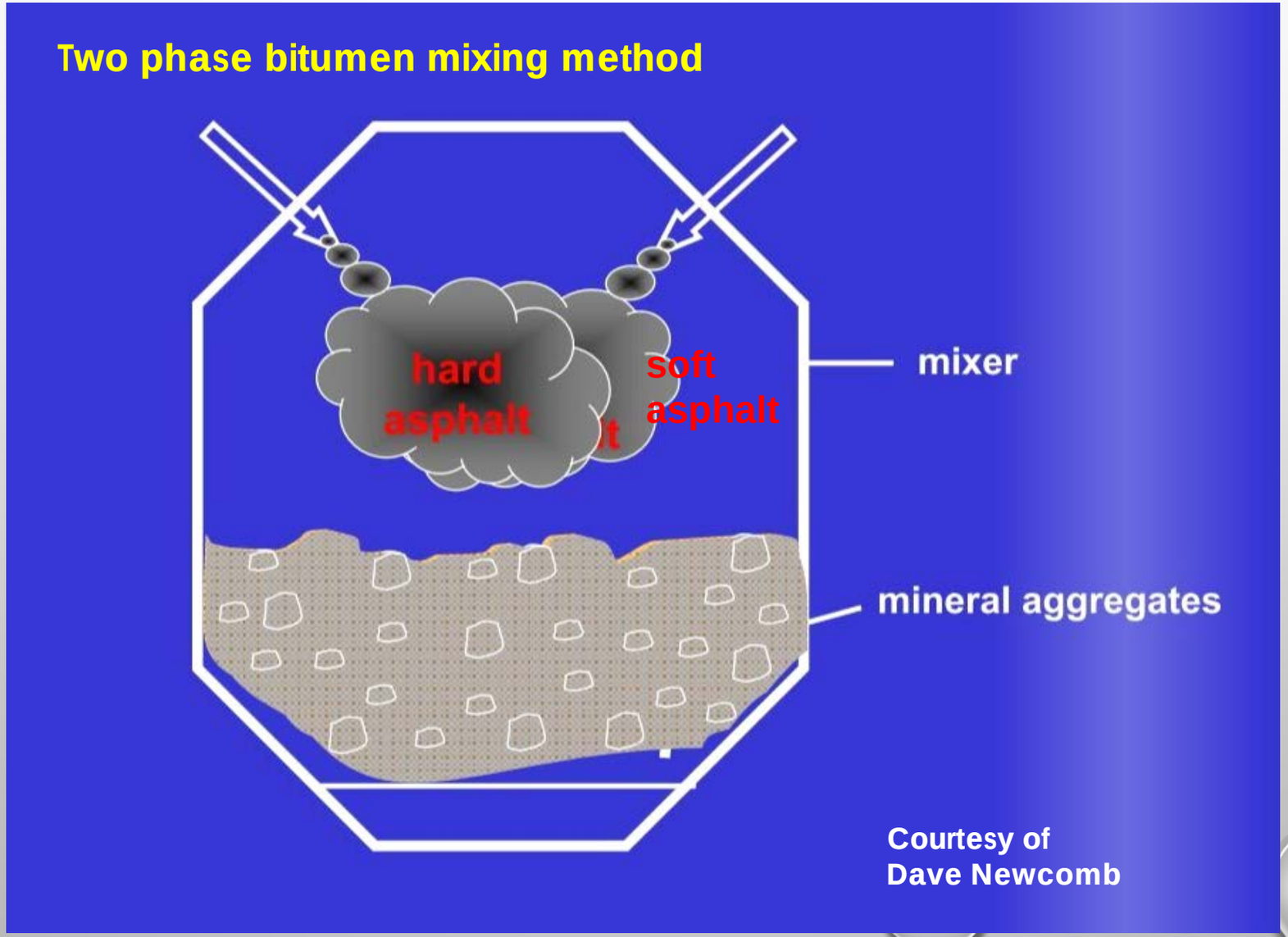
WARM MIXTURES

FOAMED ASPHALT



WARM MIXTURES

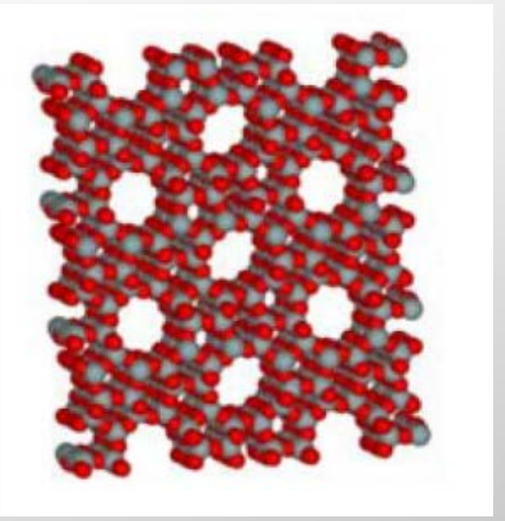
FOAMED ASPHALT



WARM MIXTURES

ZEOLITE (MATERIAL GENERATED FOAMING PROCESS)

Crystalline hydrated aluminum silicate



Zeolite is added (0.3%) to the HMA in the 100 to 200°C; vapor is created by adding zeolite to pre-heated mixture of sand and stone at the same time as asphalt is being to introduced

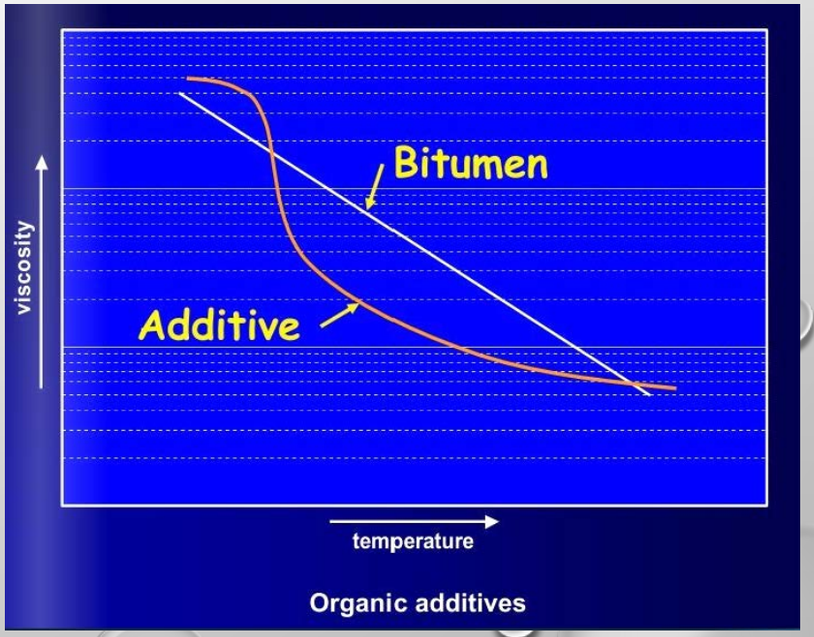
Dave Newcomb

WARM MIXTURES

ORGANIC ADDITIVES

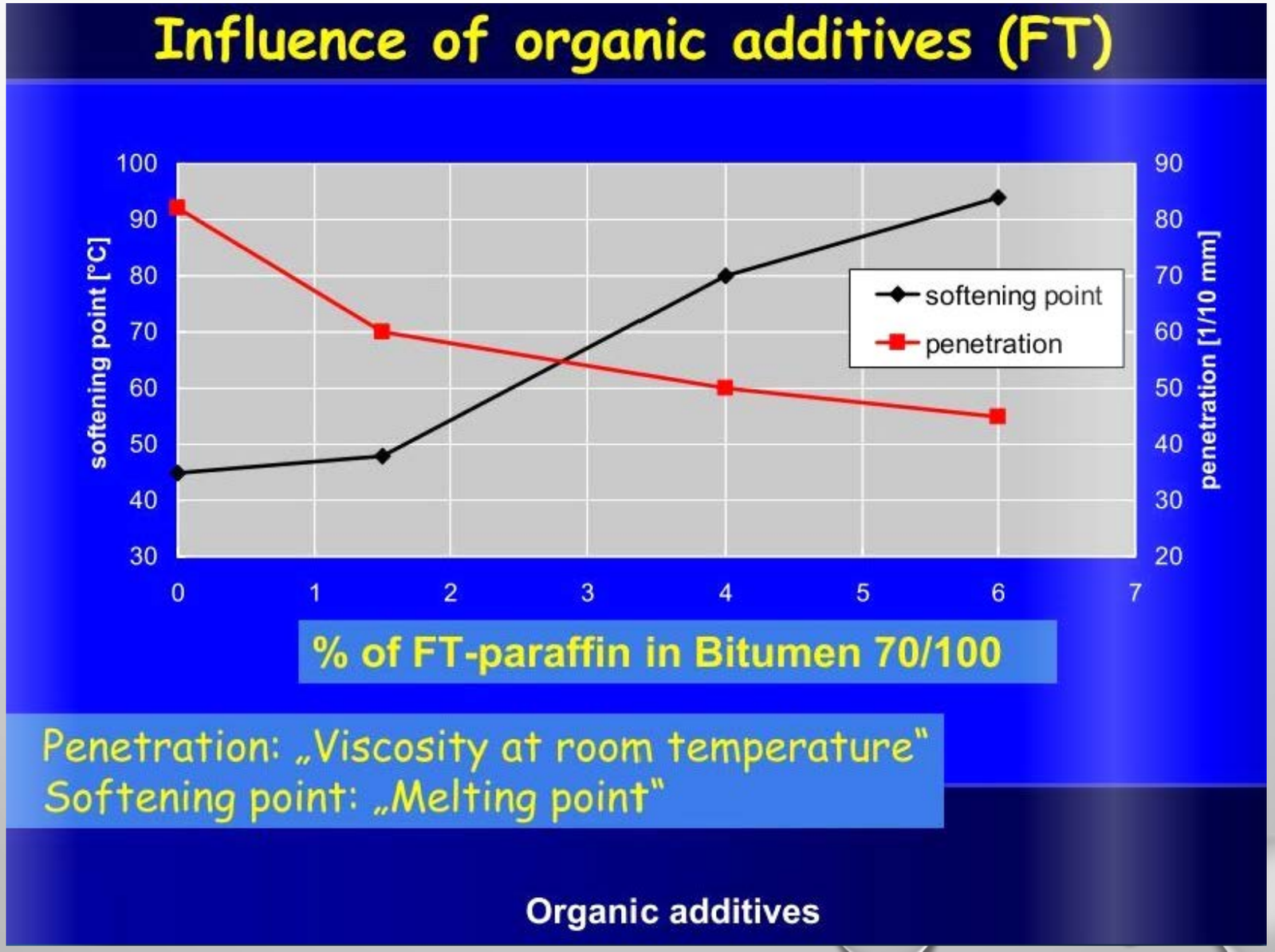
- **SYNTHETIC FISHER-TROPS PARAFFIN WAXES**
  LONG-CHAINED ALIPHATIC HYDROCARBONS FROM COAL GASIFICATION WITH FISHER-TROPS PROCESS
- **LOW MOLECULAR WEIGHT ESTER COMPOUNDS**
- COAL WAX CONSIST MAINLY OF ESTERS FRO FAT ACID AND WAX ALOHOLS PRODUCED BY TOLUENE EXTRACTION OF BROW COAL

	Bitumen wax	*Synthetic wax*
Melting point, ° C	70	100
Penetration at 25 °C, 0,1 mm	120	< 1
Viscosity at 135 °C mm^2/s	8	15
Average molecular weight, g / mol	800	1600
n-paraffins, %	14	73



WARM MIXTURES

ORGANIC ADDITIVES



WARM MIXTURES

WARM ASPHALT RECYCLING

In the HMA the maximum amount of RAP it is strongly related at working temperature: in a lot of cases temperatures are too high with risks for the quality of the added bitumen (early aging) and big increase of costs and emissions

The production of warm bituminous mixtures (warm recycling) offers the possibility of overcoming these problems by lowering the working temperatures (mixing and compaction) without compromising the possibility of using high quantities of RAP.

WARM ASPHALT RECYCLING

Water sensitivity test results – Inter-laboratory test RILEM TC 264 RAP (Prof. Mayca Rubio Gamez)

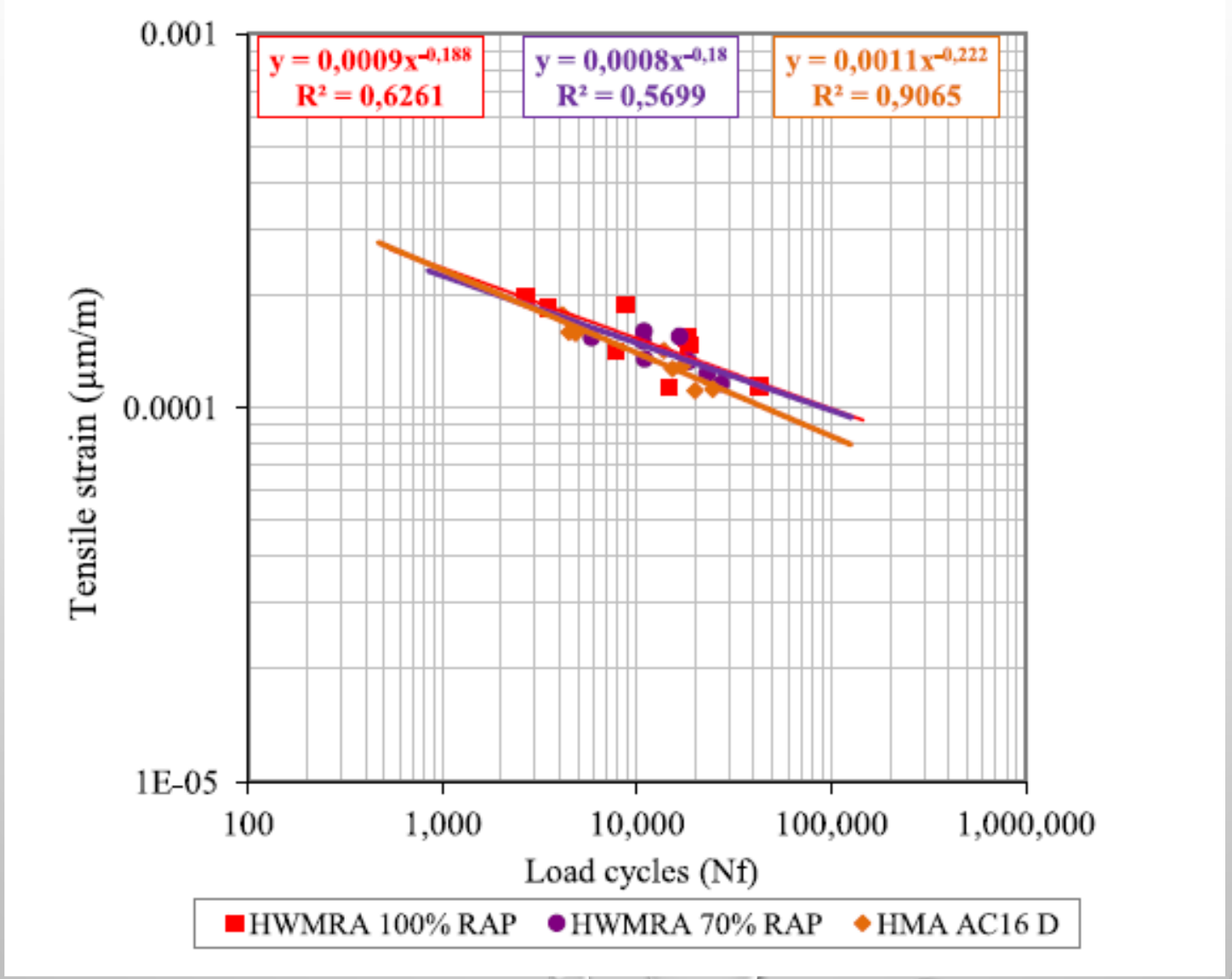
Lab	Test standard	Parameter	HMA	WMA foam (40% RA)		WMA additive (40% RA)	
				Absolute	Relative effect (WMA/HMA)	Absolute	Relative effect (WMA/HMA)
Lab#1	EN12697-12 A	ITSR	88.4%			99.6%	1.13
Lab#2	EN12697-12 A	ITSR	86.6%	86.3%	1.00	91.9%	1.06
Lab#2	EN12697-12 B	i/C	86.7%	95.9%	1.11	98.5%	1.14
Lab#4	EN12697-12 A	ITSR	87.0%	-	-	88.6%	1.02
Lab#4	EN12697-12 B	i/C	89.3%	-	-	88.1%	0.99
Lab#5	EN12697-12 A	ITSR	85.7%	79.4%	0.93	-	-
Lab#6	EN12697-12 A	ITSR	88.2%	-	-	92.6%	1.05

WARM ASPHALT RECYCLING

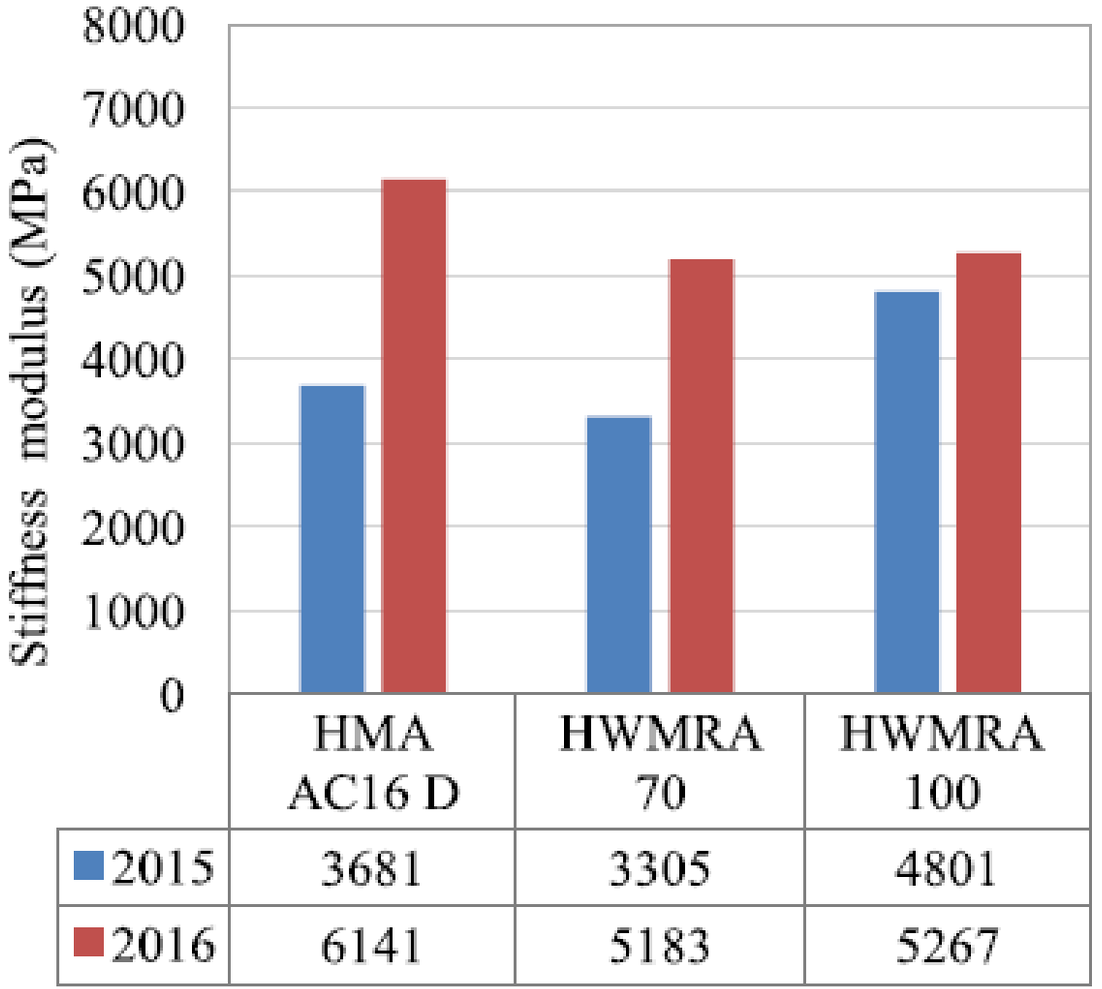
Rutting test results – Inter-laboratory test RILEM TC 264 RAP (Prof. Mayca Rubio Gamez)

Lab	Test standard	Parameter	HMA	WMA foam (40% RA)		WMA additive (40% RA)	
				Absolute	Relative effect (HMA/WMA)	Absolute	Relative effect (HMA/WMA)
Lab#1	EN12697-25 B	$\varepsilon_{1000,calc}$	1.64%	-	-	1.27%	1.29
Lab#2	EN12697-22	d @ 30,000 cycles	4.6%	4.6%	1.00	4.8%	0.96
Lab#3	EN12697-22	d @ 10,000 cycles	5.9%	-	-	1.8%	3.28
Lab#5	EN12697-22	d @ 10,000 cycles	6.0%	7.7%	0.78		
Lab#5	EN12697-22	d @ 30,000 cycles	7.4%	10.7%	0.69	-	-

WARM ASPHALT RECYCLING



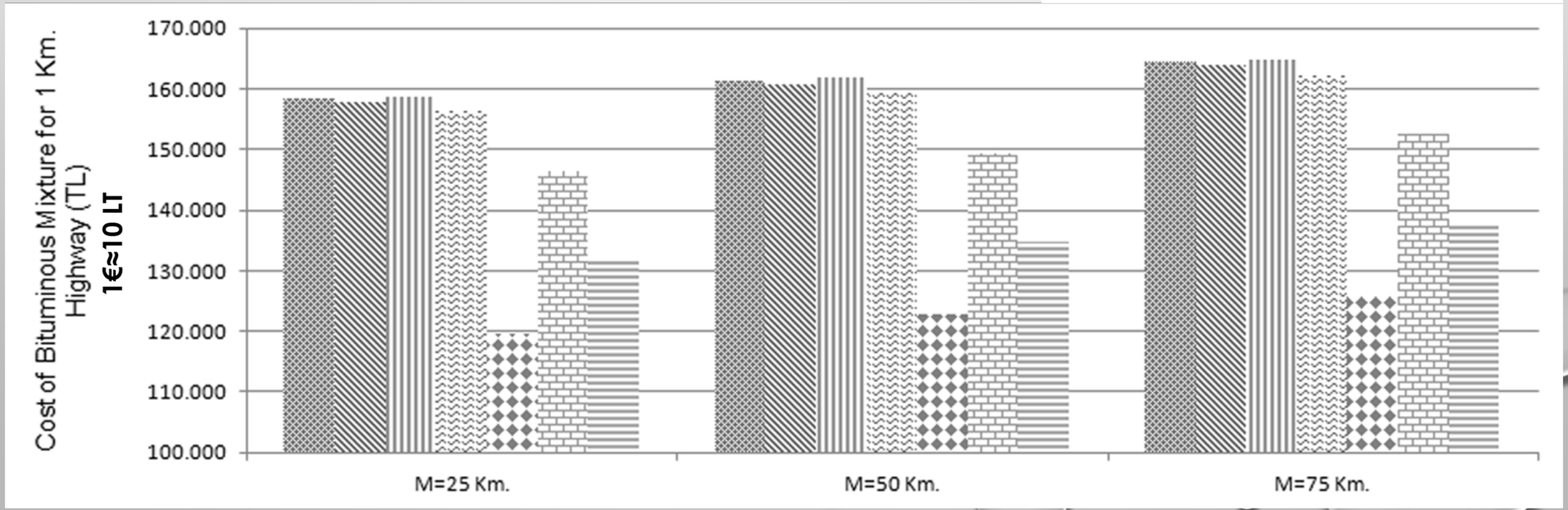
WARM ASPHALT RECYCLING



	HMA AC16 D	HWMRA 70	HWMRA 100
2015	3681	3305	4801
2016	6141	5183	5267

WARM ASPHALT RECYCLING

Cost-benefit analysis was performed to inspect the advantages and disadvantages of RAP in terms of economy. For this purpose a highway section (1 km. in length, 10 m. in width and 5 cm. in thickness) is chose



CONCLUSIONS

COLD/LOW TEMPERATURE RECYCLING CAN BE:

- **ENVIRONMENTALLY FRIENDLY**

- **ECONOMICALLY CONVENIENT**

- **TECHNICALLY VERY EFFICIENT**

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