Bitumen Stabilized Materials
Characteristics, use and performances

Gabriele Tebaldi, Ph.D., P.E., Rilem Fellow

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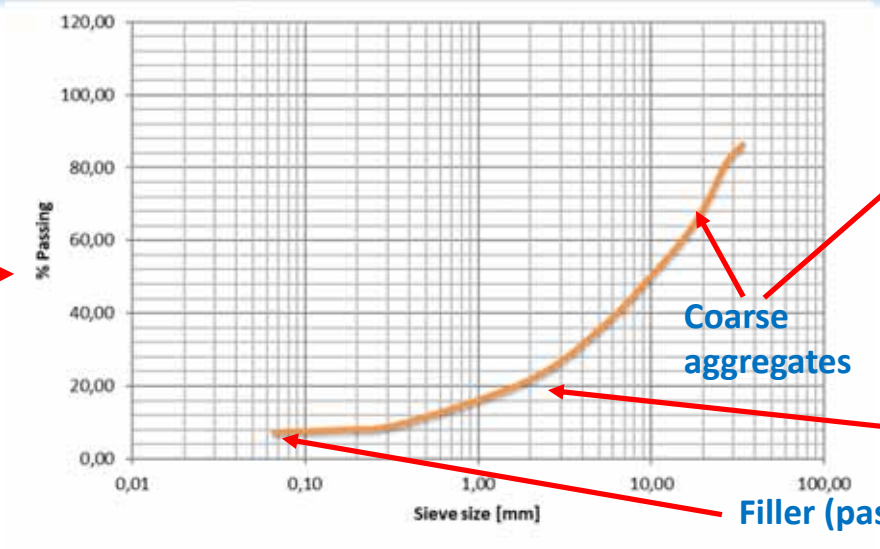
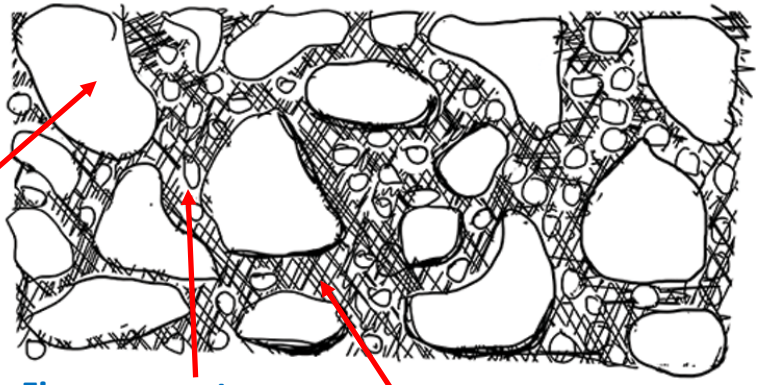
Opatija 11. – 12. 05. 2023.

Asphalt mixtures

University of Parma



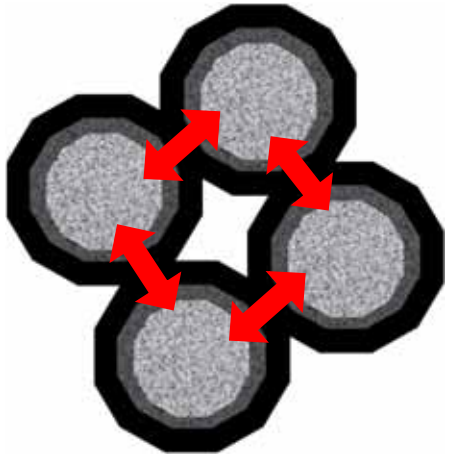


Coarse aggregates

Fine aggregates

Mastic: bitumen + filler

Filler (passing at 0,062/0,075 mm)

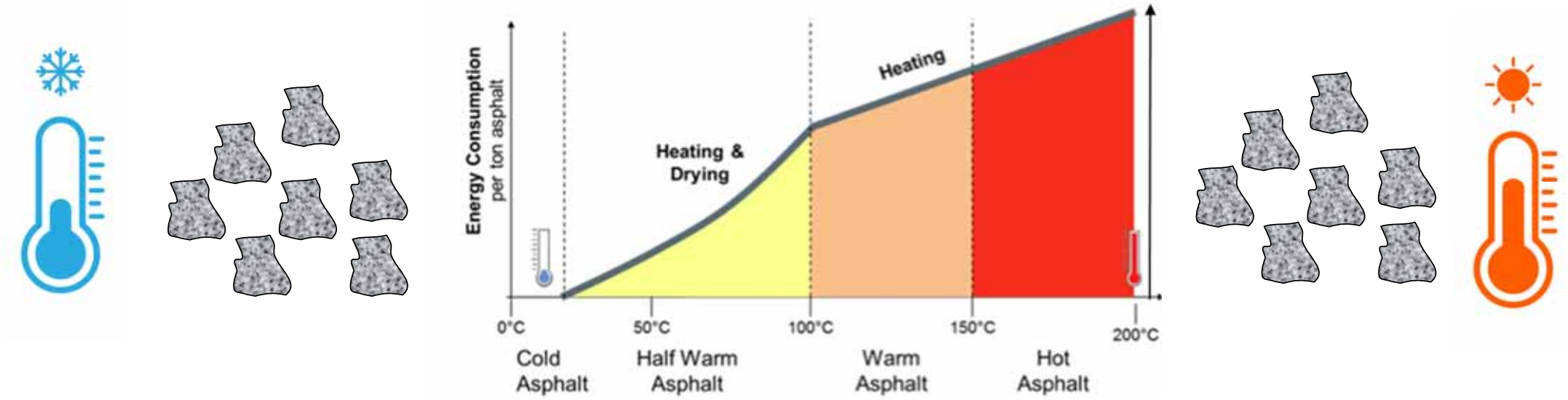


Adhesion between aggregates' surfaces and bitumen provides the strength of the mixture

Asphalt mixtures: hot & cold

University of Parma

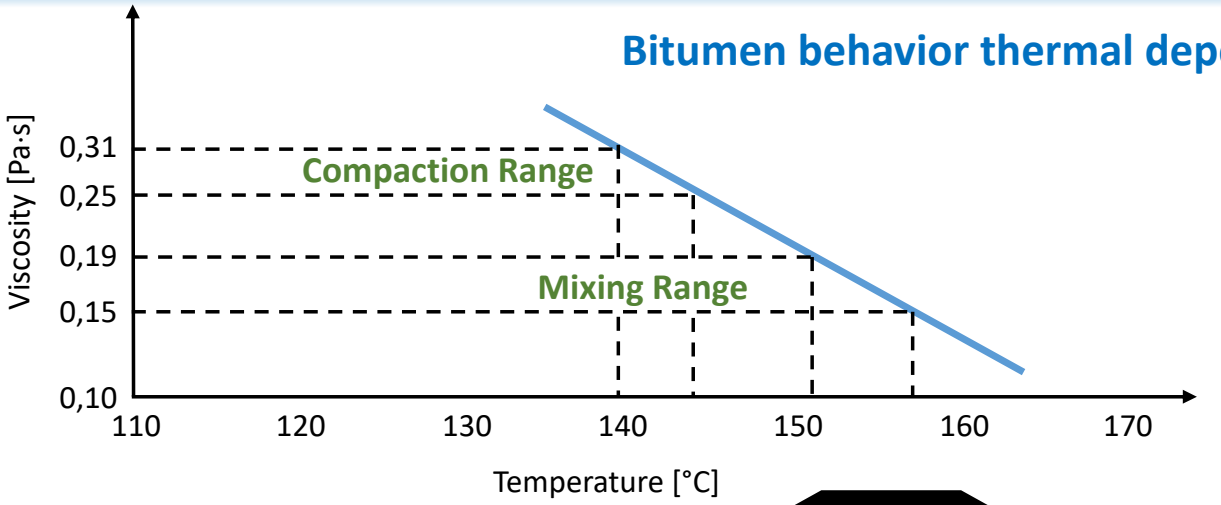
In asphalt technology, the condition “cold” and “hot” are related to the temperature of the aggregates and consequently on the possibility to use the dependency of bitumen viscosity from temperature to bring the bitumen on the aggregates and to make the condition to coat them properly



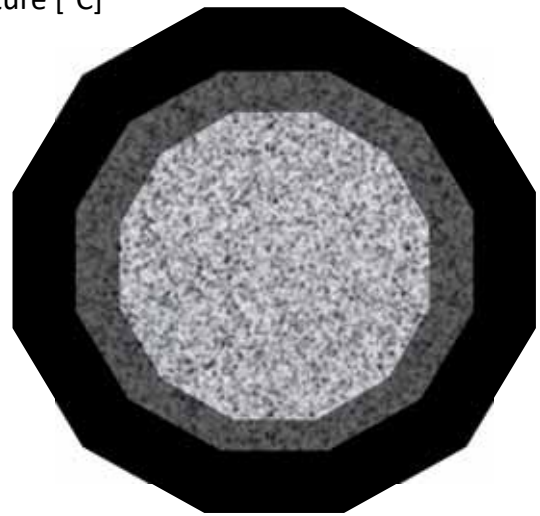
Asphalt mixtures: hot preparation technique

University of Parma

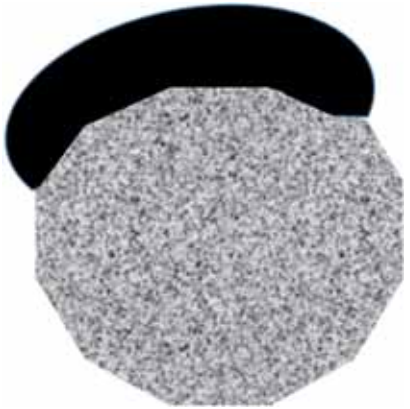
Bitumen behavior thermal dependency



Reduction of viscosity allows the coating of the aggregates and the lubricant effect necessary for compaction



Aggregates' surfaces have to be almost at the temperature that makes the bitumen a fluid



Not hot enough

Too hot

Asphalt mixtures: cold preparation technique

University of Parma

In the cold techniques, there is the need for a carrier for the bitumen because it's not possible to count on the fluid behavior of the bitumen

Asphalt mixtures: cold preparation technique

University of Parma

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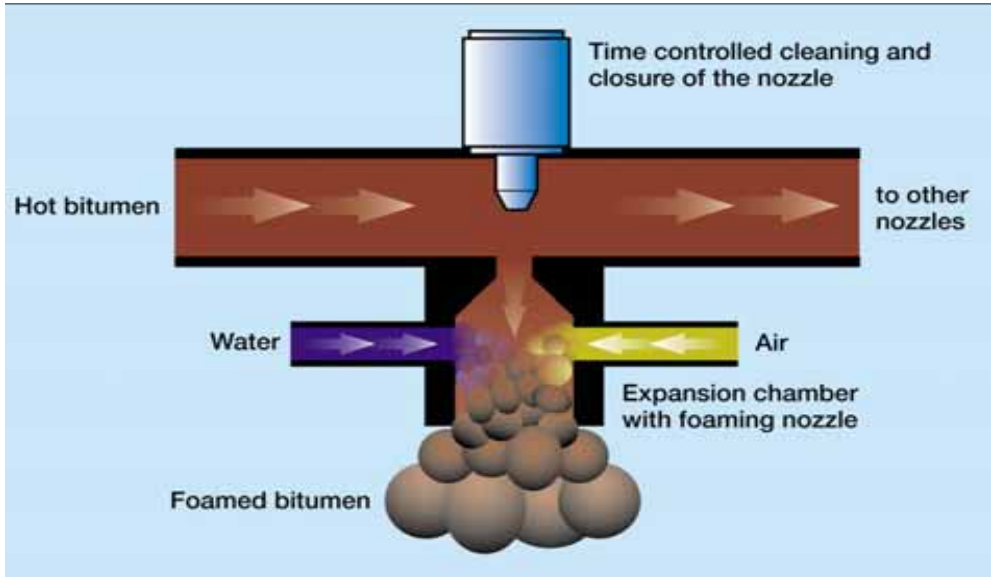
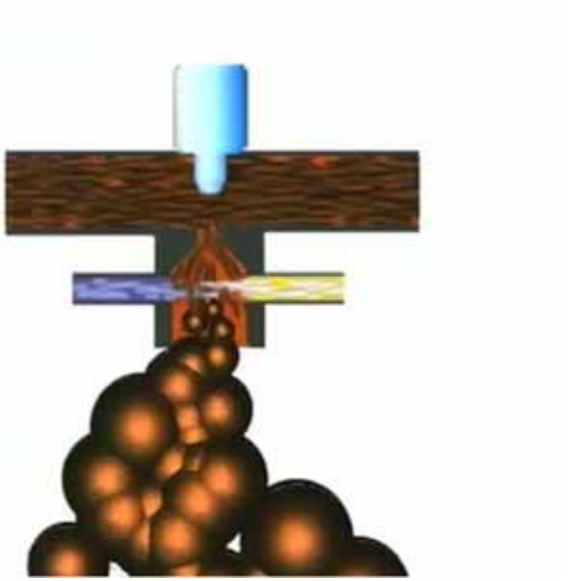
FOAM BITUMEN

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

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





Asphalt mixtures: cold preparation technique

University of Parma

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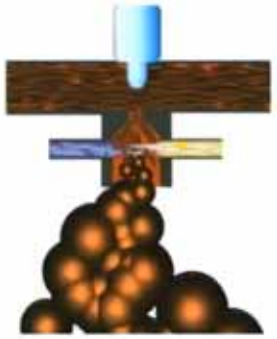
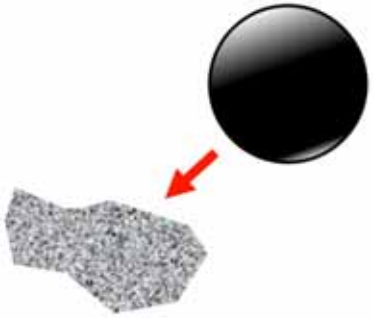
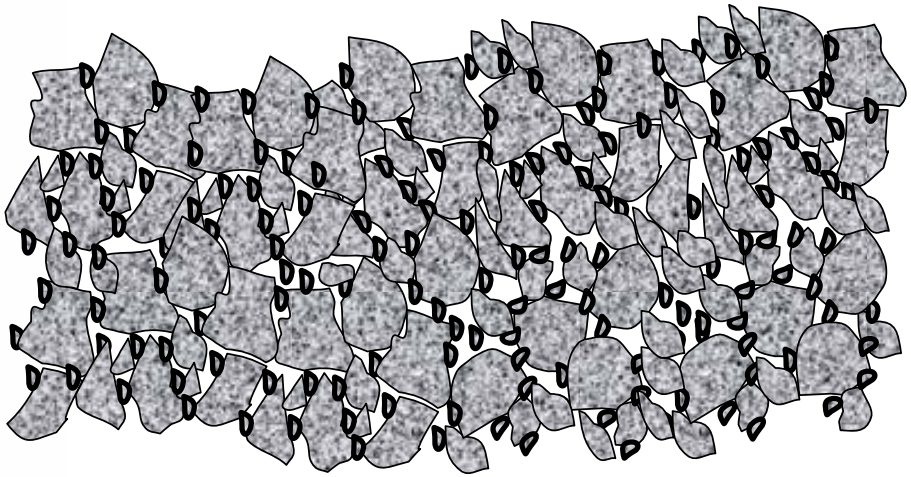


The blasting and the dust particles are the carriers of bitumen





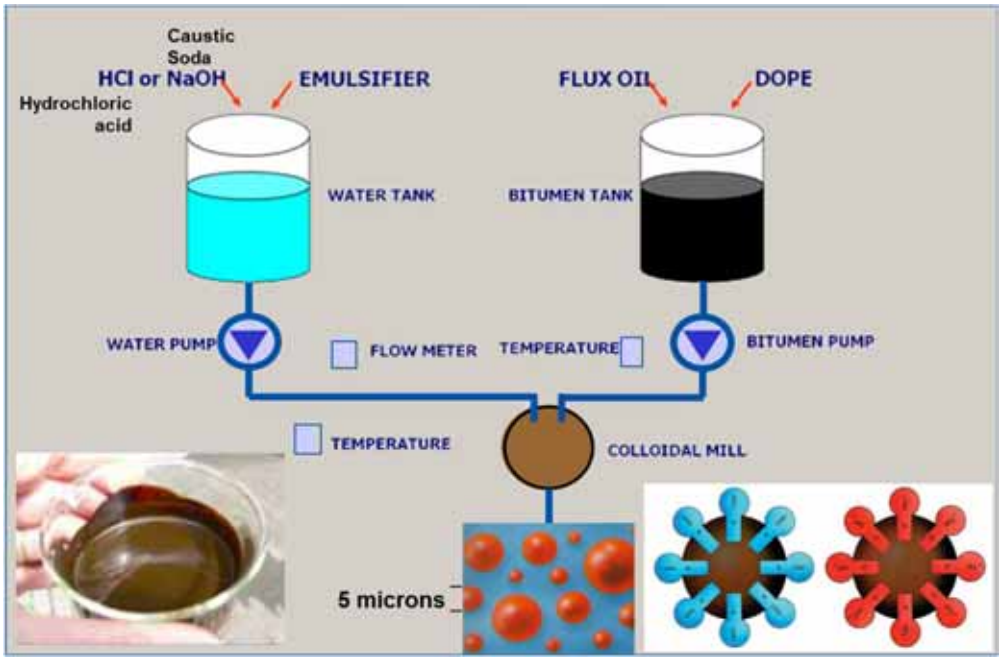
The fine particles that catch the bitumen droplets are the elements that partially bind the aggregates among them

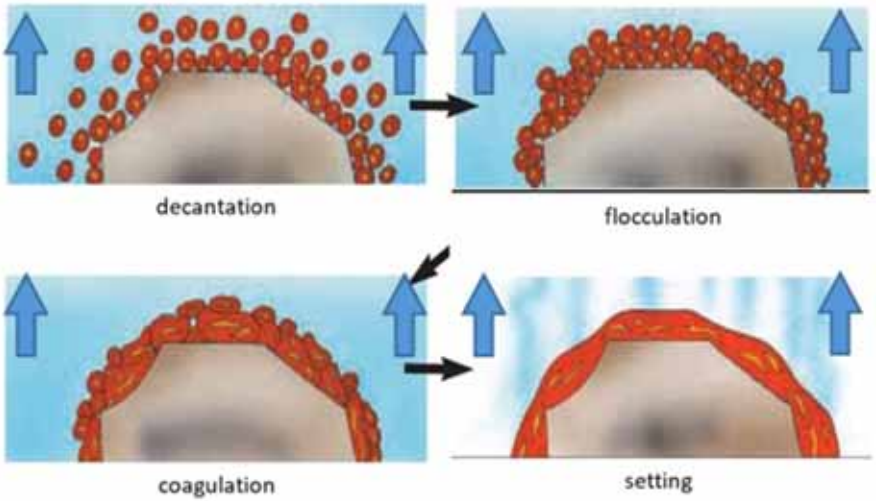
Asphalt mixtures: cold preparation technique

University of Parma

In the cold techniques, there is the need for a carrier for the bitumen because it's not possible to count on the fluid behavior of the bitumen

BITUMINOUS EMULSION





Asphalt mixtures: cold preparation technique

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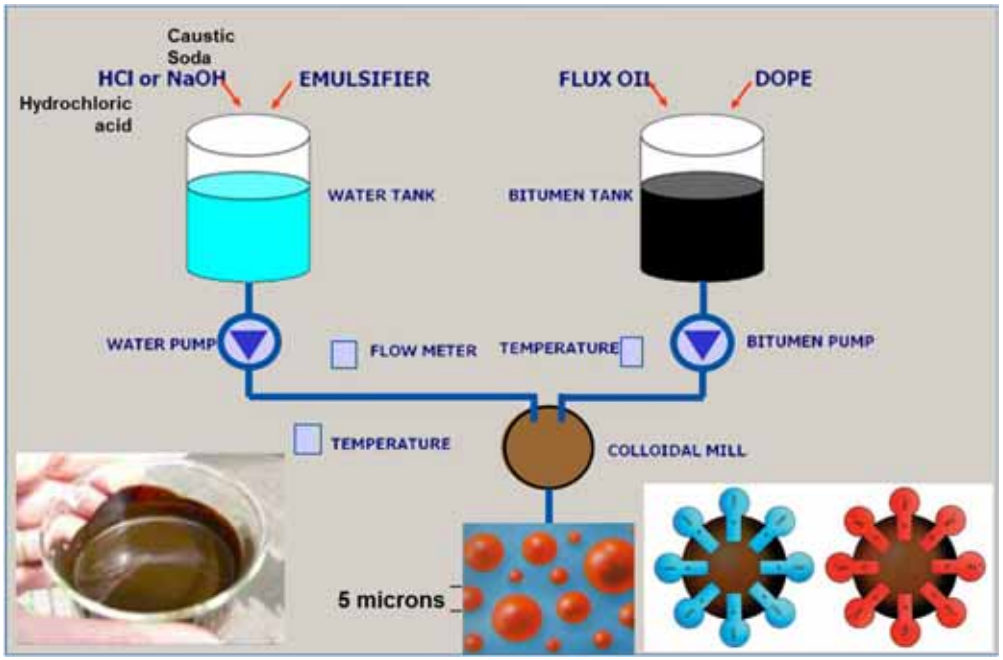

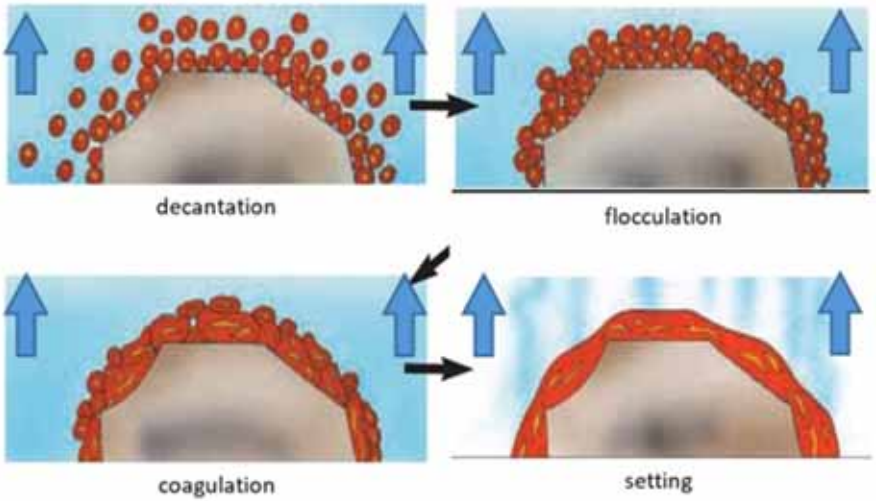

Asphalt mixtures: cold preparation technique

University of Parma

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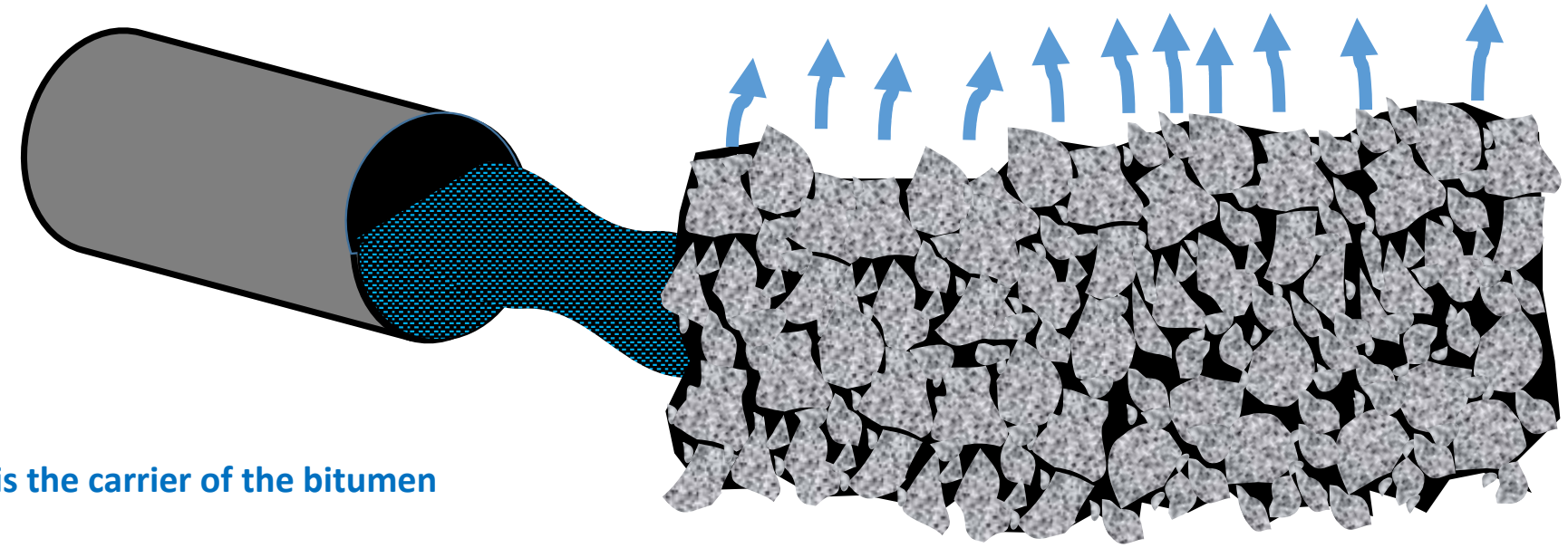

The water is the carrier of the bitumen

Asphalt mixtures: cold preparation technique

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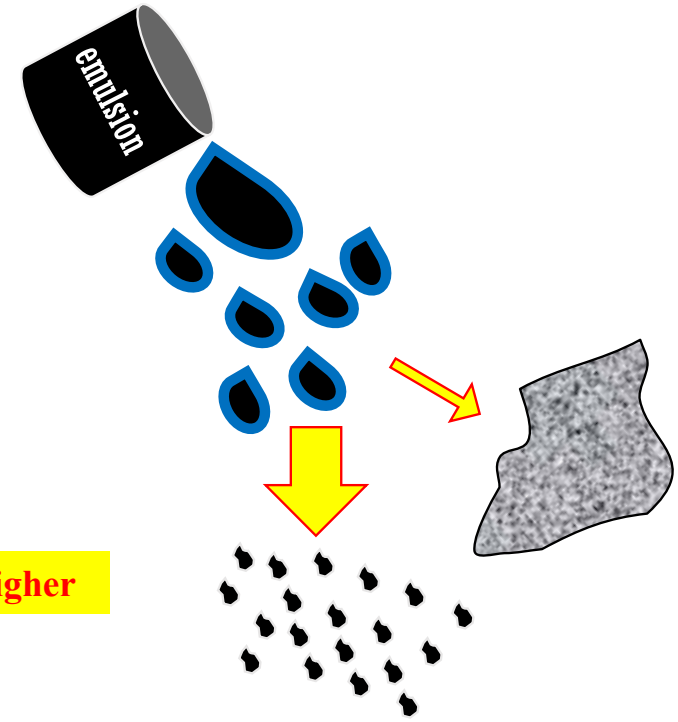
In the cold techniques, there is the need for a carrier for the bitumen because it's not possible to count on the fluid behavior of the bitumen

BITUMINOUS EMULSION

Because the surface area of the fines aggregates it is much bigger than the surface area of coarse aggregates, the emulsion will be concentrated on the fines fraction.

Particle size (mm)	Surface area factor (m^2/kg)
19	0.13
13.2	0.18
9.5	0.24
6.7	0.31
4.75	0.43
2.36	0.82
1.18	1.64
0.6	2.87
0.3	6.14
0.15	12.24
0.075	32.77

252 times higher



Asphalt mixtures: cold preparation technique

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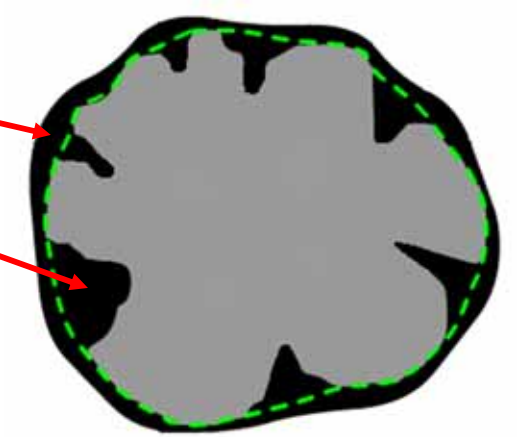
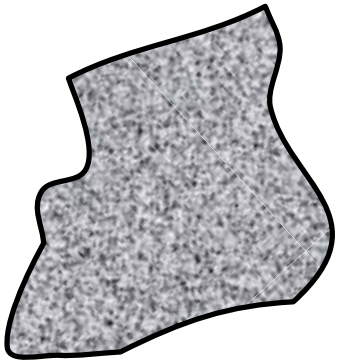
BITUMINOUS EMULSION



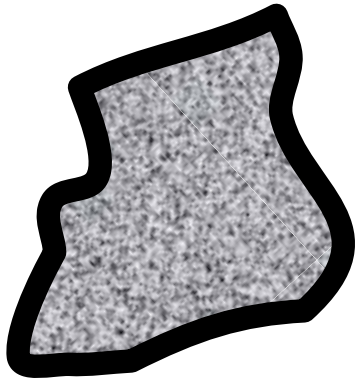
Non-continuously bounded material



Bituminous emulsion stabilized material

A bituminous emulsion stabilized materials has the aggregates fully covered by the emulsions, but the film made by the emulsion (in total around 2-3% of the weight of aggregates) it is not enough thick to make a fully bounded material

Continuously-bounded material



Hot asphalt mixture

Bituminous Stabilized Materials (BSM)

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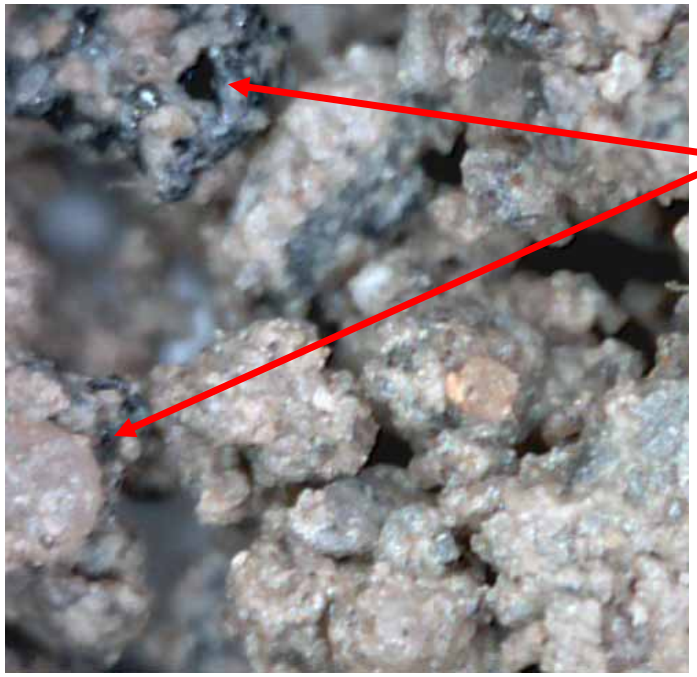
BSMs are partially bounded materials

The bitumen carried by fine aggregates (mainly by filler) it makes an adhesive mastic disperse inside the mixture

Emulsion

Partially coated aggregates or non uniformly coated aggregates



Foam

Bitumen spots
bitumen absorbed by filler of bitumen drops attached on the aggregates' surface

Bituminous Stabilized Materials (BSM)

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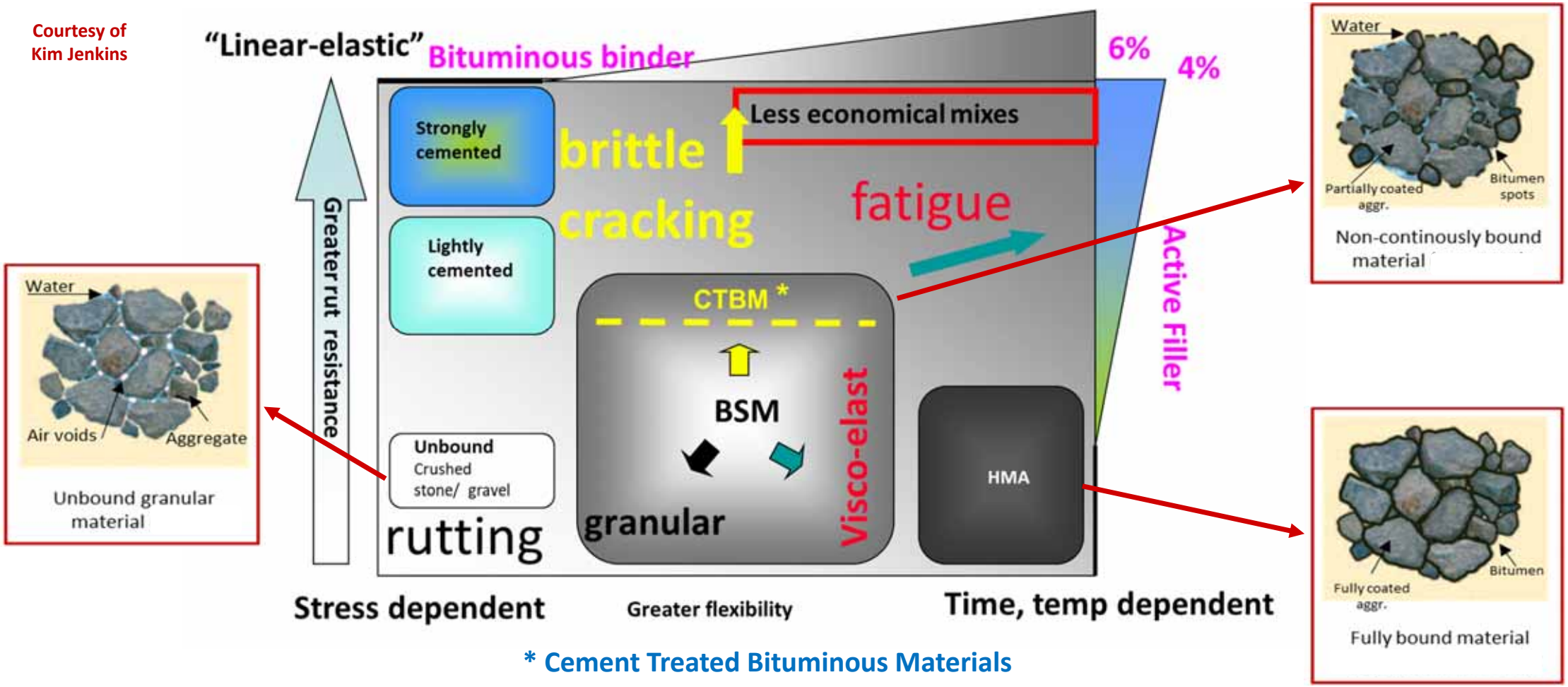
Courtesy of Kim Jenkins



* Cement Treated Bituminous Materials

BSM & Asphalt Recycling

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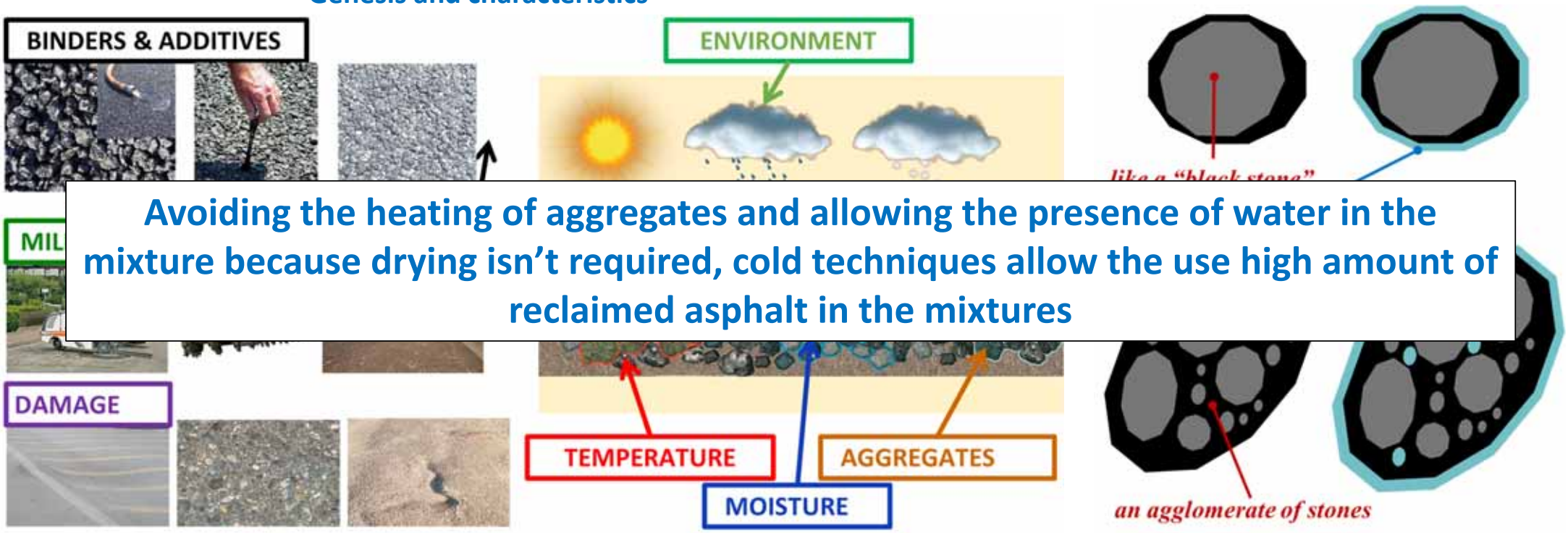
RA (Reclaimed Asphalt) or RAP (Reclaimed Asphalt Pavement)

Genesis and characteristics



Avoiding the heating of aggregates and allowing the presence of water in the mixture because drying isn't required, cold techniques allow the use high amount of reclaimed asphalt in the mixtures

BSM & Asphalt Recycling

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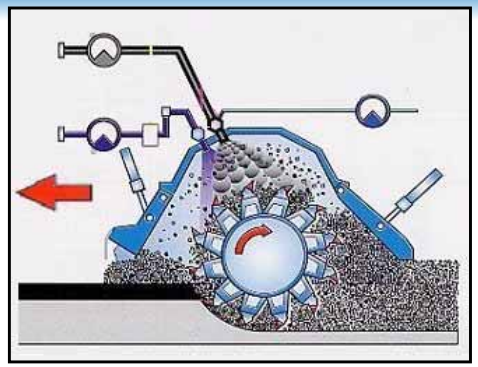
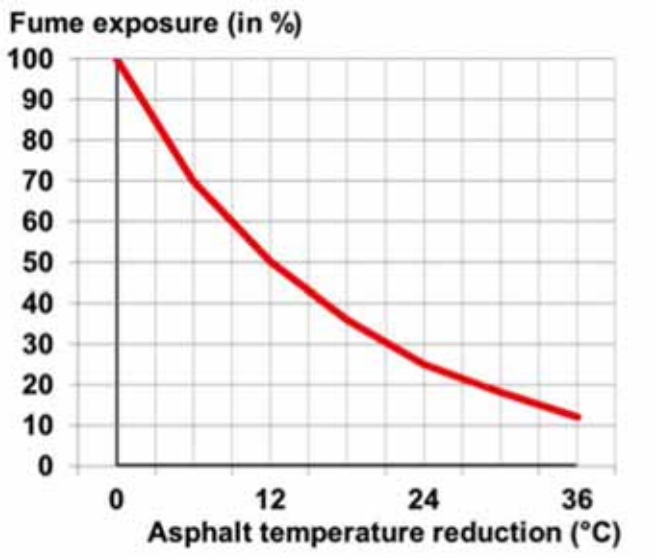
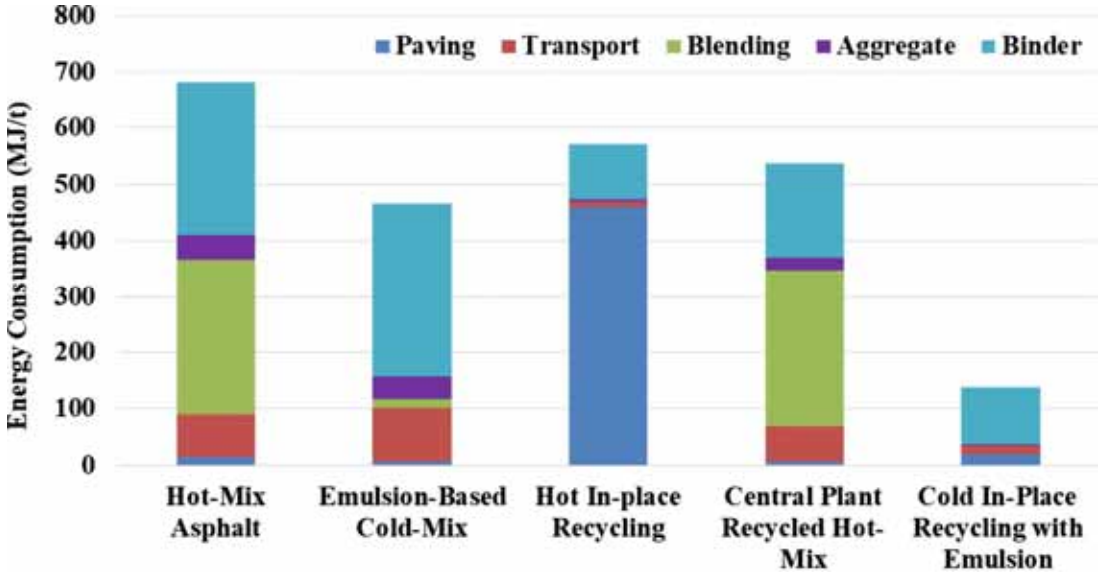




Courtesy of Dr. Martin Zaumanis



Feipeng Xiao et alt. https://doi.org/10.1016/j.conbuildmat.2018.06.006

BSM & active fillers

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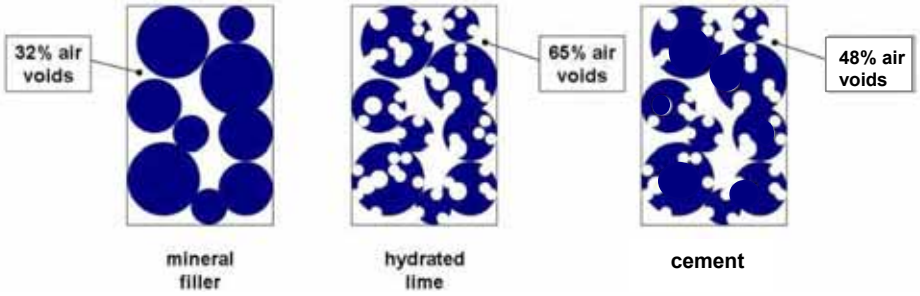
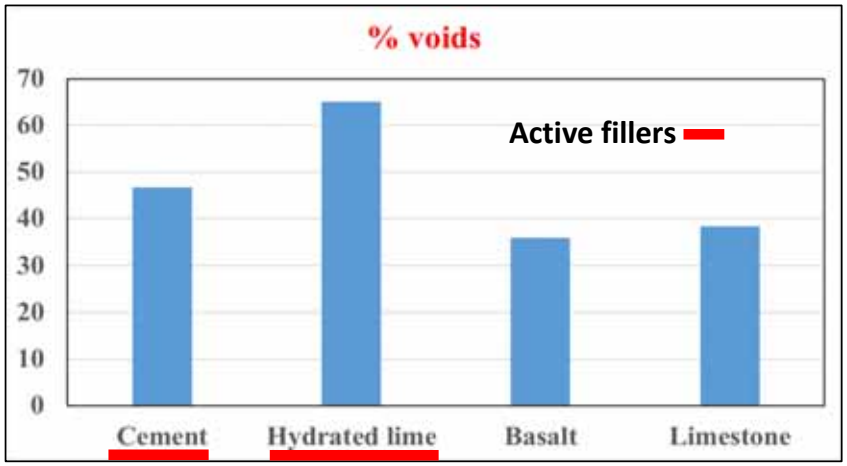
ACTIVE FILLER

It is a filler (mineral element part of the aggregates passing at sieve 0.075/0.062) that is chemically active.
The most common active fillers are lime, cement and fly ash.





The purpose of incorporating active filler in BSM is to:

- **Improve dispersion of the bitumen in the mix**
- Accelerate curing of compacted mix } **hydration**
- Control emulsion's breaking time } **hydration**
- Increase stiffness & strength of mix → **setting & hardening**
- Improve adhesion of the bitumen to the aggregate
  - → **mainly lime with acid aggregates: it makes basic salts that are able to avoid the "acid-acid contact" between bitumen and aggregate surface**

The main collateral effect of active fillers is the impact on mechanical performances

BSM & active fillers: collateral mechanical effects

University of Parma

Technical Guideline: Bitumen Stabilised Materials

A Guideline for the Design and Construction of Bitumen Emulsion and Foamed Bitumen Stabilised Materials

TG2 Third Edition August 2020

sabita

excellence in bituminous products

Technical Guideline:
Bitumen Stabilised Materials

APPENDIX A: Material Classification System

Table A.8 Interpretation of Indicators and Tests for Classification of Bitumen Stabilised Materials

Test or Indicator	Material[1]	Design Equivalent Material Class			Not suitable for treatment	CF
		DE-BSM1	DE-BSM2	DE-BSM3		
Soaked CBR (%)	CS (98%)	> 80	25 to 80	10 to 25	< 10	0.4
	NG (95%)		> 25	10 to 25	< 10	
Cohesion (kPa)	All	> 250	100 to 250	50 to 100	< 50	0.45
Friction Angle (°)	All	> 40	30 to 40	< 30		0.4

BSM & active fillers: collateral mechanical effects

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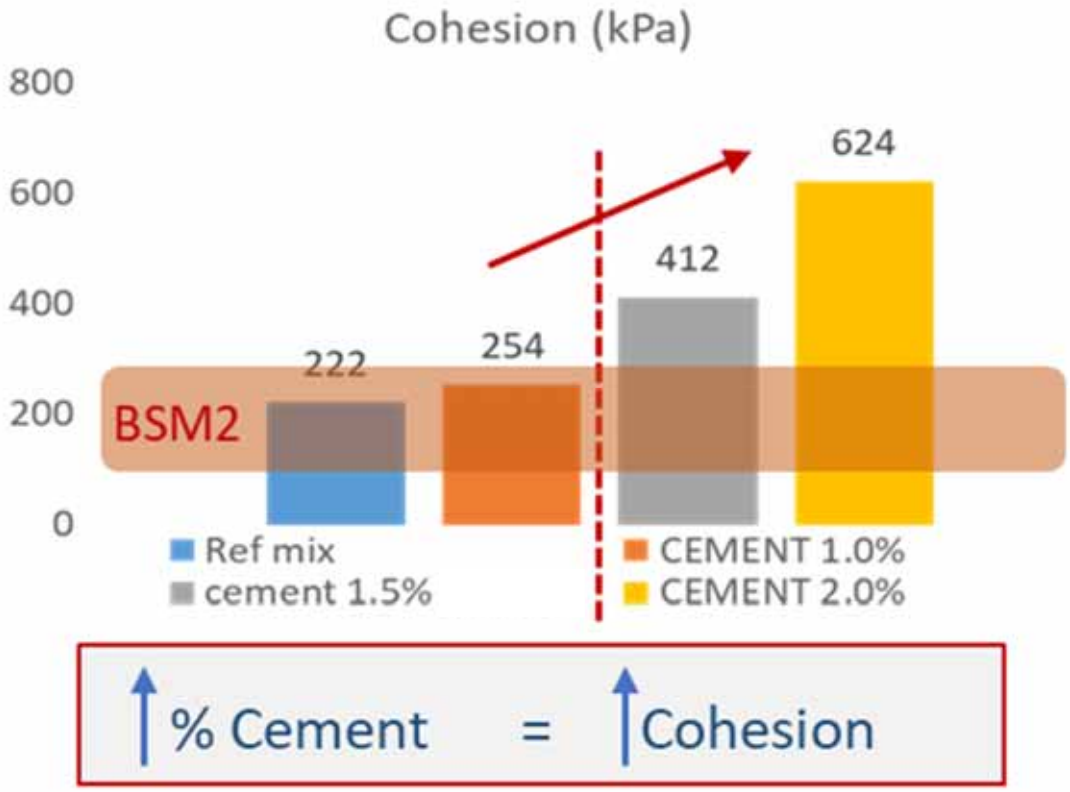
Cement

RILEM Technical Committee 264-RAP
Asphalt Pavement Recycling

Interlaboratory Project to evaluate Cold Recycled Mixes

Mix Design FB-C	*FB-C0*	*FB-C1*	*FB-C1.5*	*FB-C2*
RAP-A	93%	93%	93%	93%
Mineral Filler	7%	6%	5.5%	5%
Active Filler (cement)	**0%**	**1%**	**1.5%**	**2%**
Foamed Bitumen	3%	3%	3%	3%
Total Water	3%	3%	3%	3%



BSM & active fillers: collateral mechanical effects

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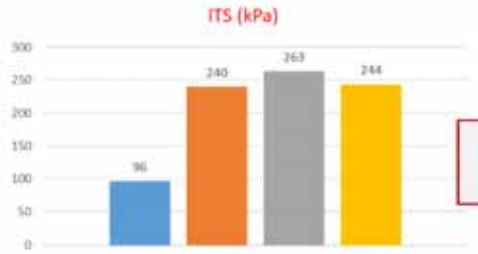
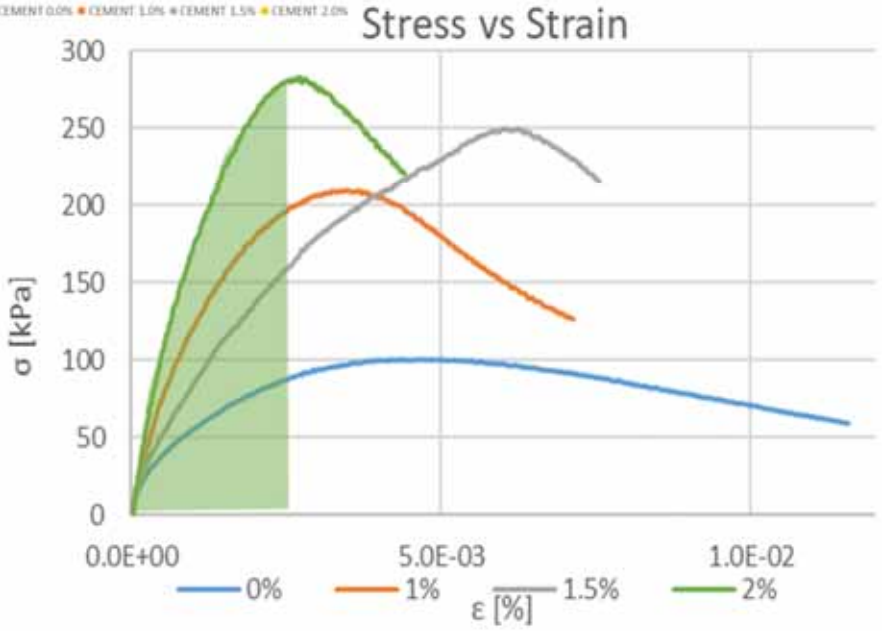


↑ % Cement → Mix becomes **Fragile**



BSM & active fillers: collateral mechanical effects

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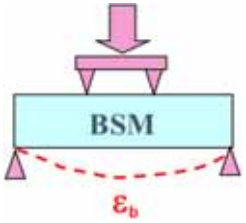
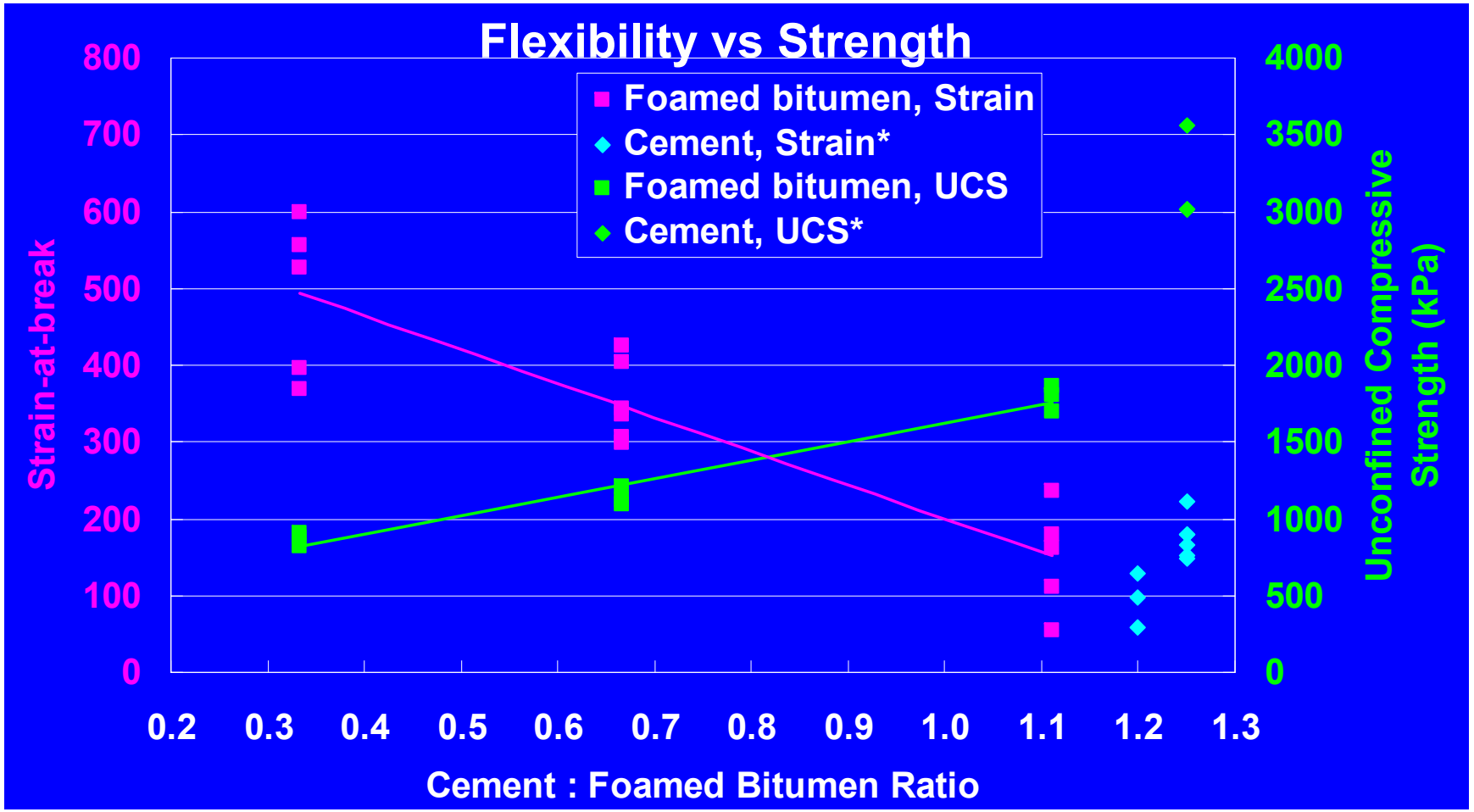
Cement



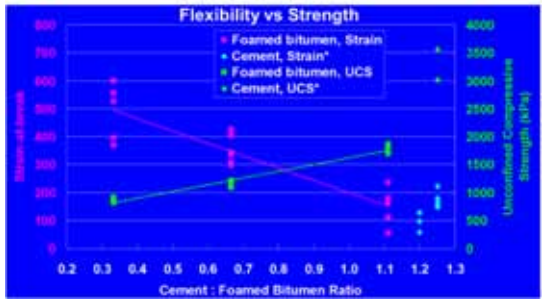
Courtesy of Kim Jenkins

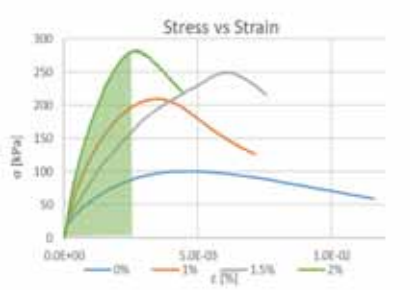


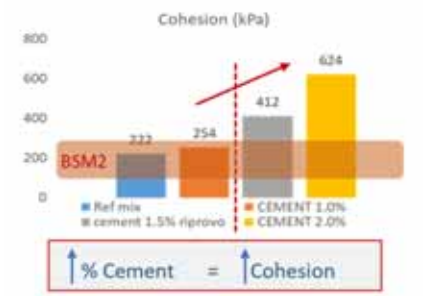
BSM & active fillers: collateral mechanical effects

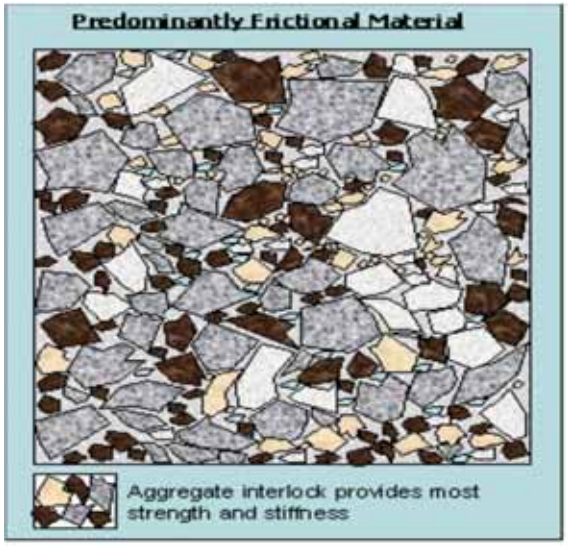
University of Parma

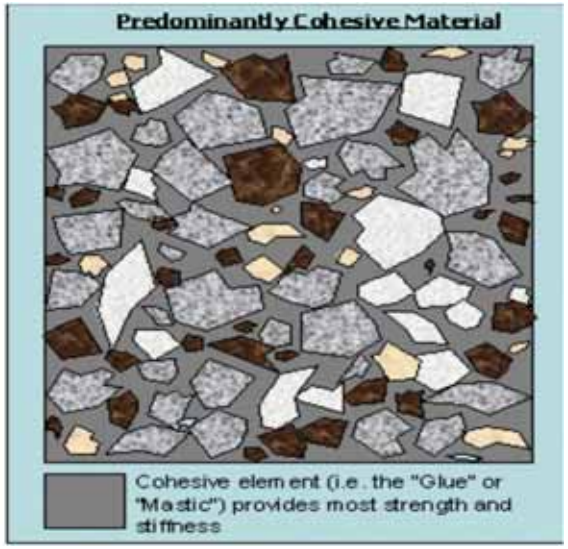
Cement











BSM & active fillers: collateral mechanical effects

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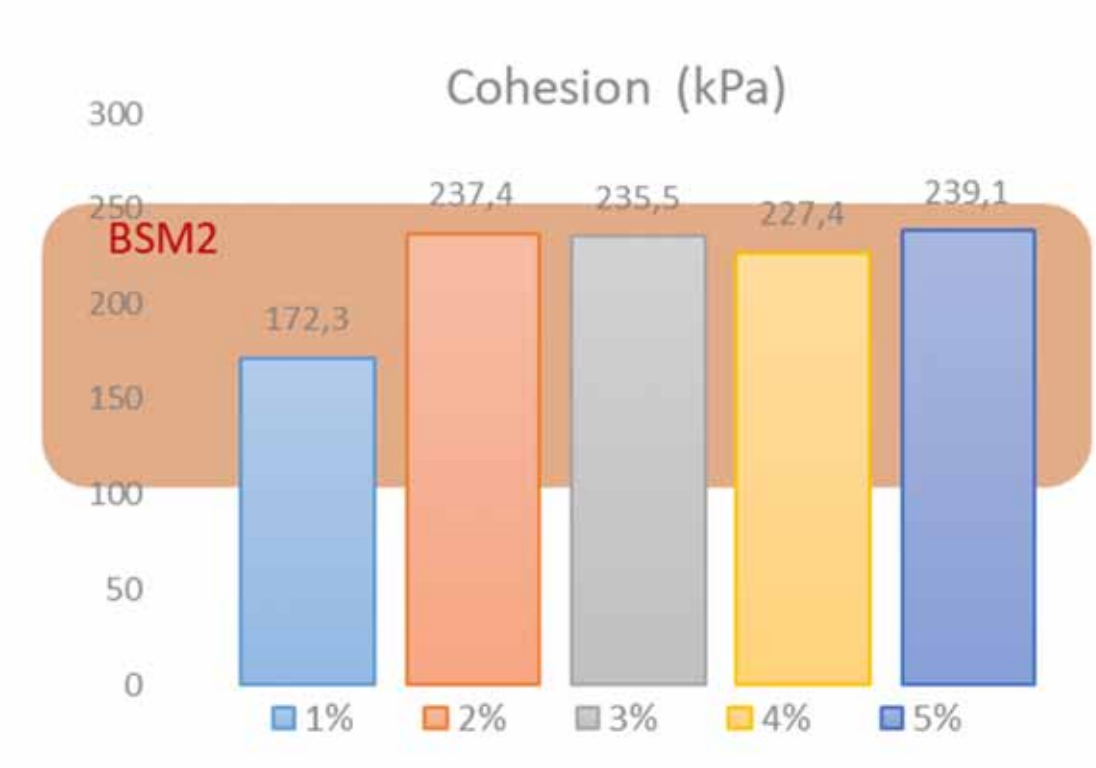
Lime (with emulsion)

Mix Design EM-L	EM-L1	EM-L2	EM-L3	EM-L4	EM-L5
RAP EM-L	95%	95%	95%	95%	95%
Mineral Filler	4%	3%	2%	1%	0%
Active Filler (Lime)	1%	2%	3%	4%	5%
Total Emulsion	3.3%	3.3%	3.3%	3.3%	3.3%
Residual Bitumen	2%	2%	2%	2%	2%
Optimum Fluid Content (emulsion + added water)	5.2%	5.2%	5.2%	5.2%	5.2%



BSM & active fillers: collateral mechanical effects

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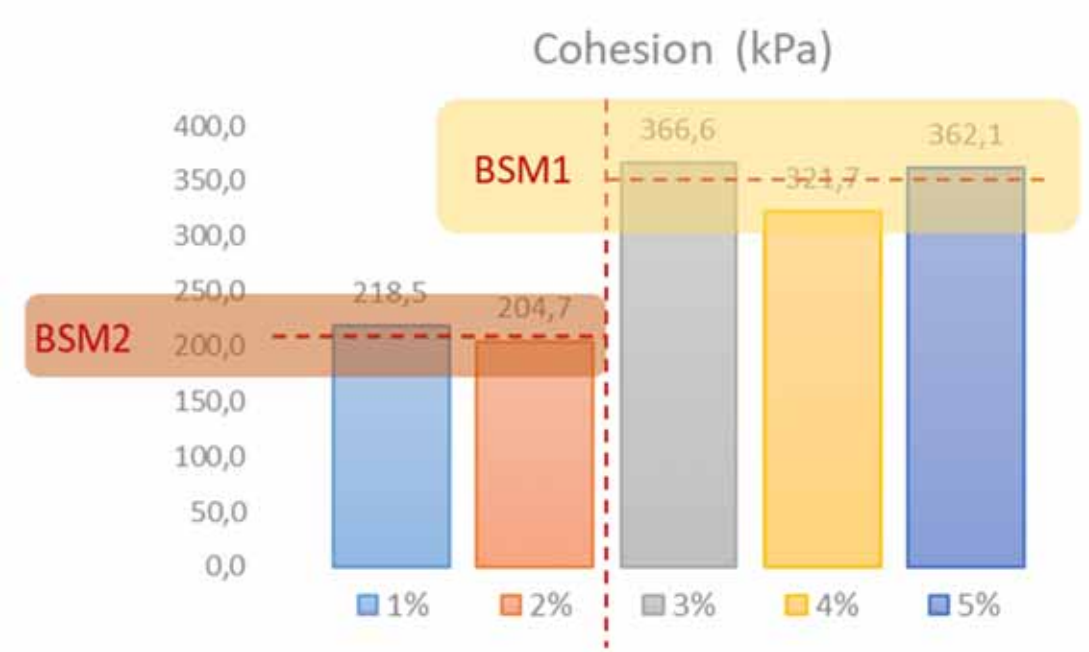
Lime (with foam bitumen)

Mix Design FB + L	FB-L1	FB-L2	FB-L3	FB-L4	FB-L5
RAP	95%	95%	95%	95%	95%
Mineral Filler	4%	3%	2%	1%	0%
Active Filler (lime)	1%	2%	3%	4%	5%
FOAM Bitumen	2%	2%	2%	2%	2%
Optimum Water Content	4.7%	4.7%	4.7%	4.7%	4.7%



BSM in pavement

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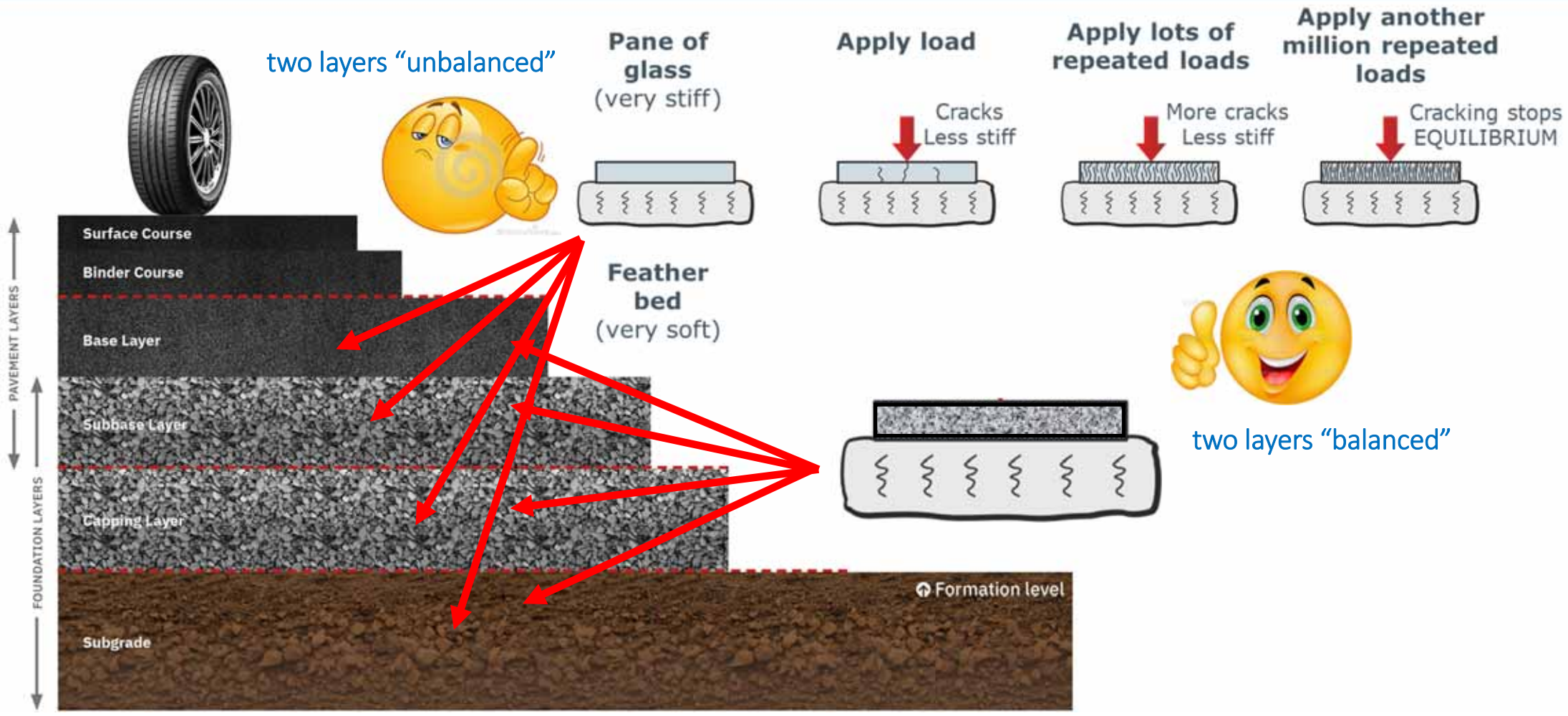

BSM & active fillers: fracture behaviour

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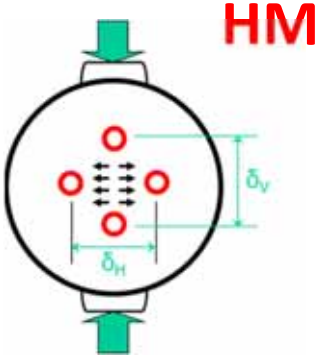
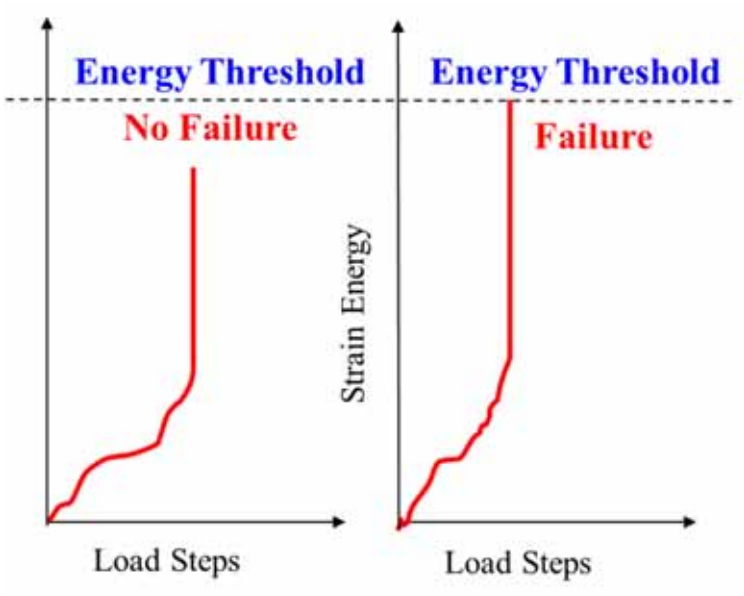
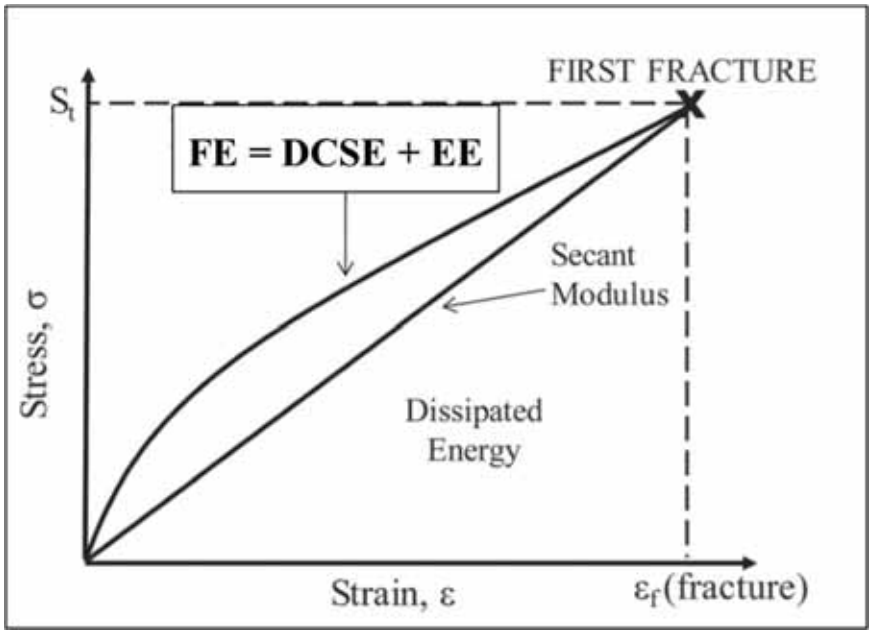
HMA Fracture Mechanics [Roque et alt., 2011]

approach for quasi-brittle materials

Total Fracture Energy (FE) → dissipated energy + strain energy







BSM & active fillers: fracture behaviour

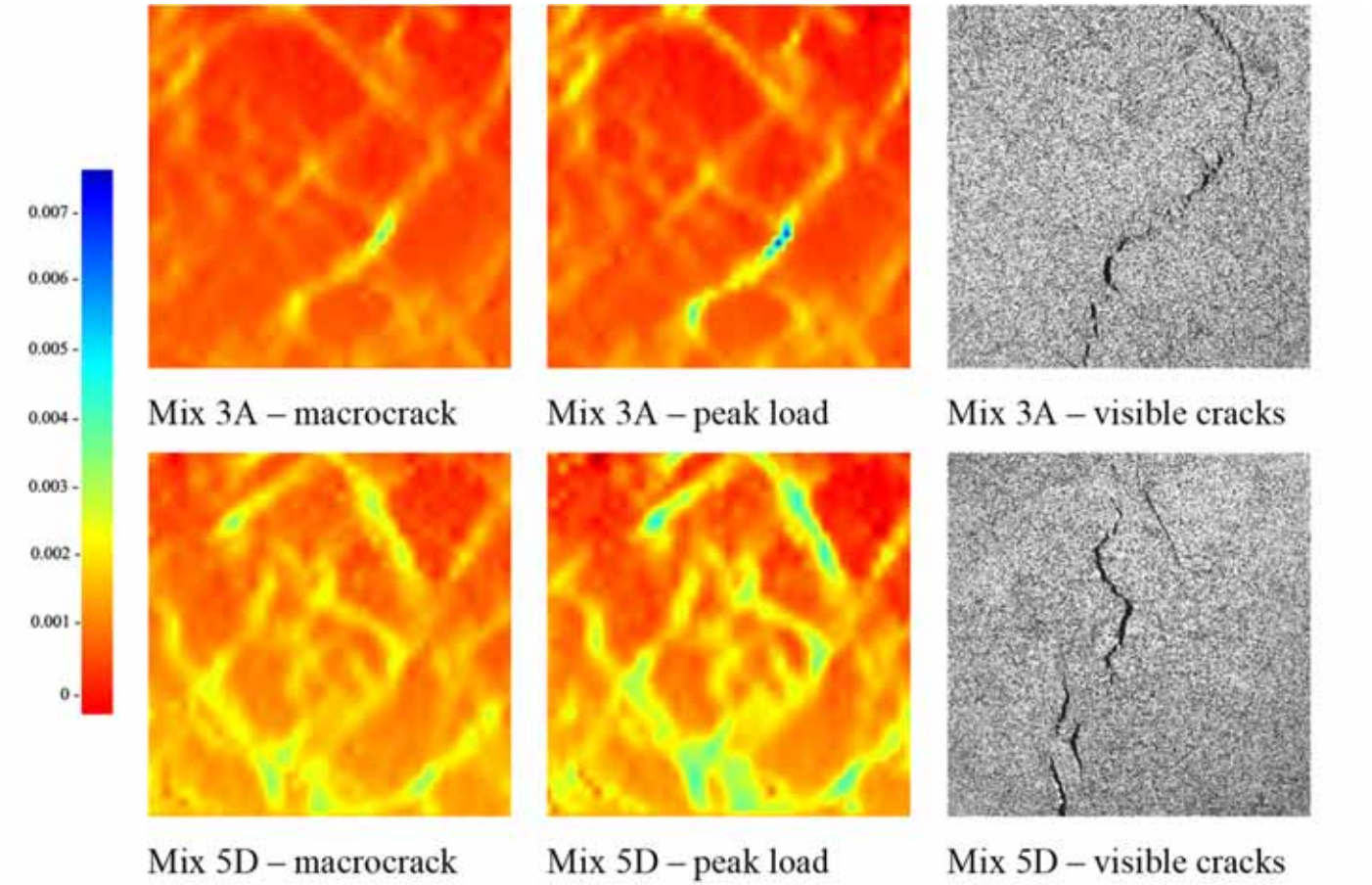
University of Parma

MIX	% foam bitumen	% cement	% hydrated lime	St [MPa]	Failure Strain [με]	FE [Kj/m³]	Dissipated Energy [Kj/m³]	Strain Energy [Kj/m³]
3A	2	1	2	0.32	1624	0.81	0.261	0.552
3B	2	1	0	0.29	938	0.40	0.138	0.258
5C	3	2.5	2.0	0.29	702	0.61	0.103	0.504
5D	3	2.5	0	0.36	636	0.47	0.114	0.359
5E	3	0	2.0	0.19	1092	0.51	0.103	0.408
5F	3	0	3.0	0.23	1091	0.59	0.123	0.464

BSM & active fillers: fracture behaviour

University of Parma

Horizontal Strain Field & Cracking



with lime

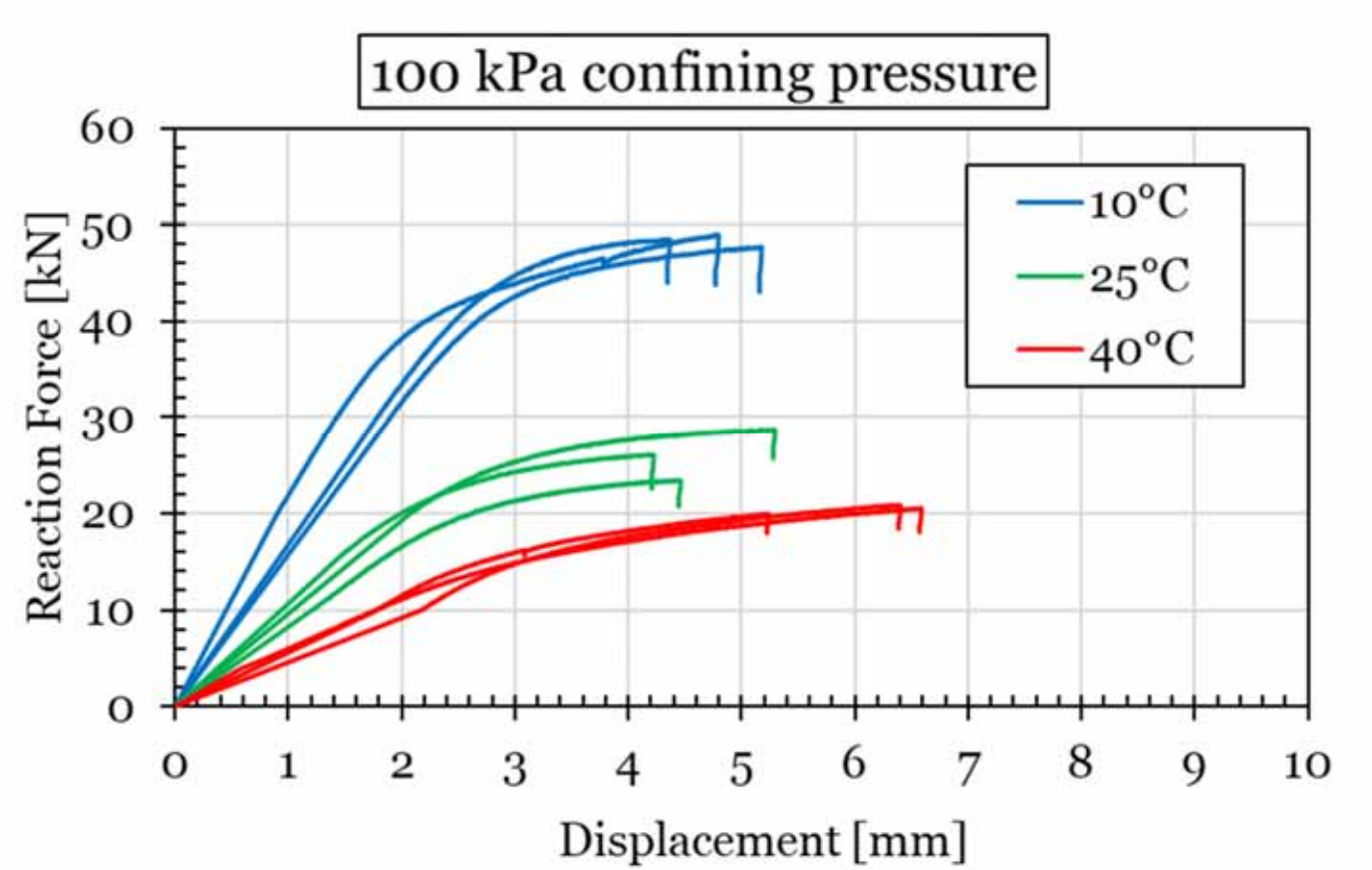
without lime

Effect of temperature and confining pressure

University of Parma

2% hydrated lime and 2% residual asphalt binder from emulsion

- **Material does not give a linear response.**
- **When temperature decreases the material stiffens**

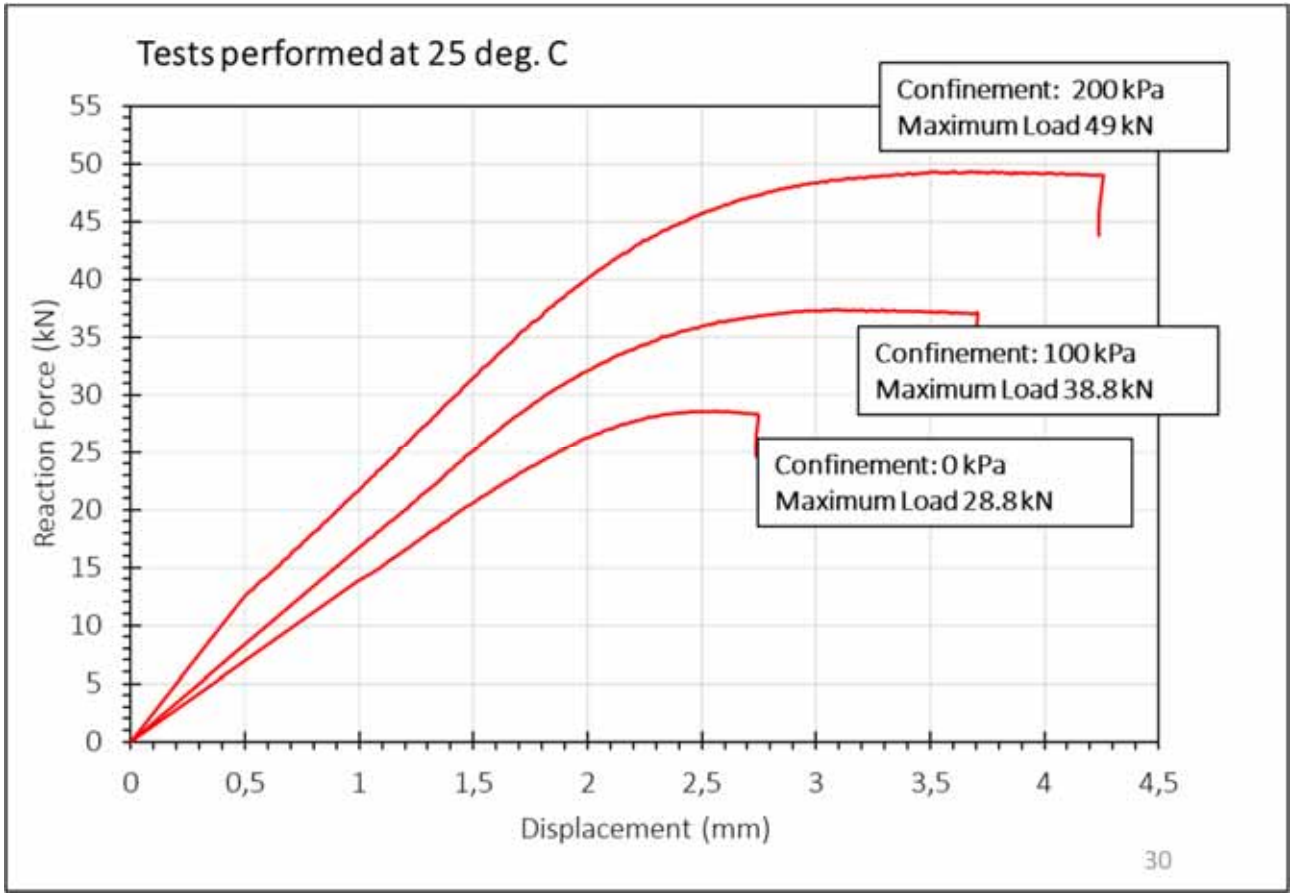


Effect of temperature and confining pressure

University of Parma

2% hydrated lime and 2% residual asphalt binder from emulsion

- **Confining pressure influences material response**

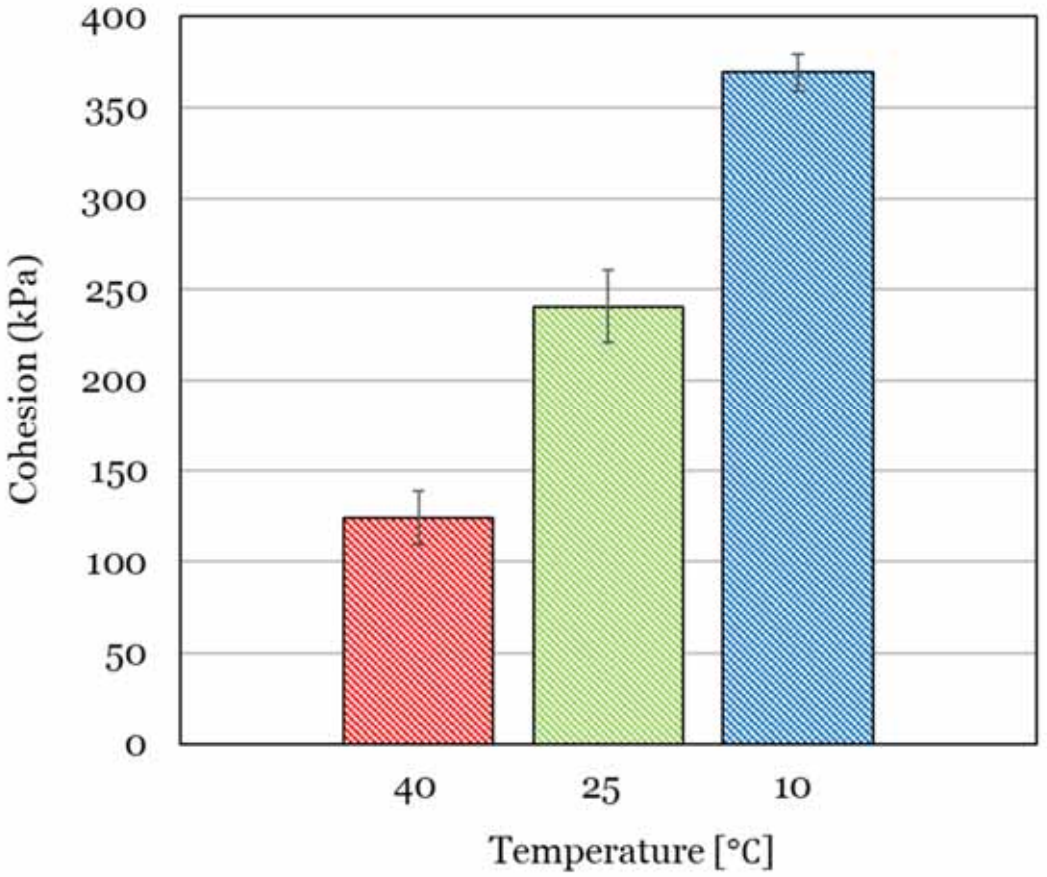


Effect of temperature and confining pressure

University of Parma

2% hydrated lime and 2% residual asphalt binder from emulsion

- **Cohesion is a temperature dependent property.**

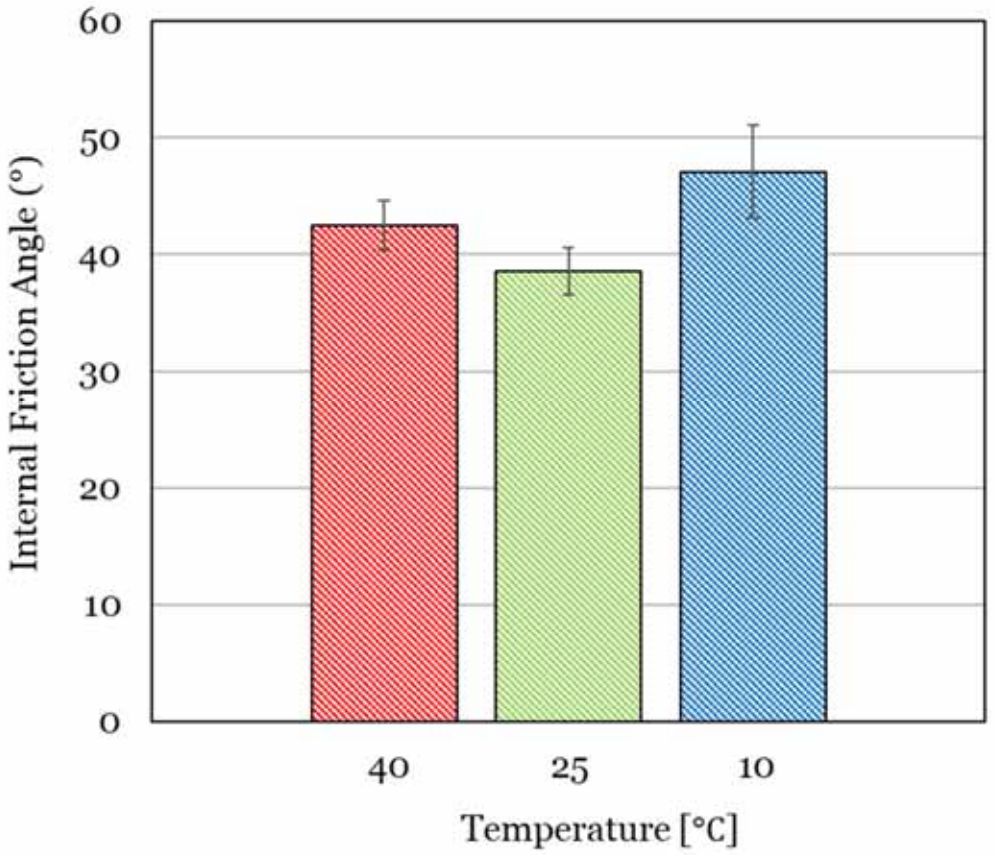


Effect of temperature and confining pressure

University of Parma

2% hydrated lime and 2% residual asphalt binder from emulsion

- **Internal friction angle is not affected by testing temperature in the range of temperatures considered (controlled by particle-to-particle contacts).**



BSM & Quicklime

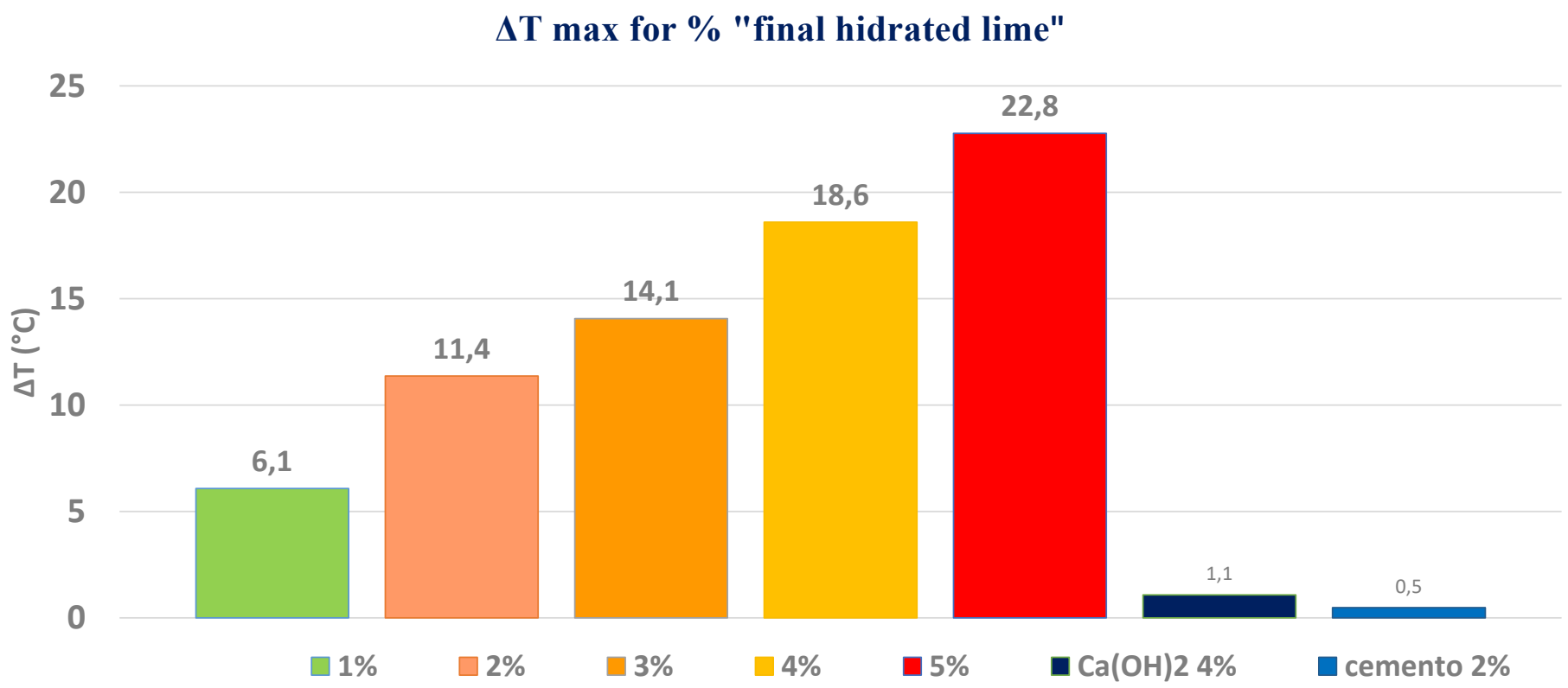
University of Parma

$$CaO + H_2O \rightarrow Ca(OH)_2 + 15.5\ kCal$$

BSM & Quicklime

University of Parma

Emulsion + Quicklime → Effects on mix's temperature



BSM & Quicklime

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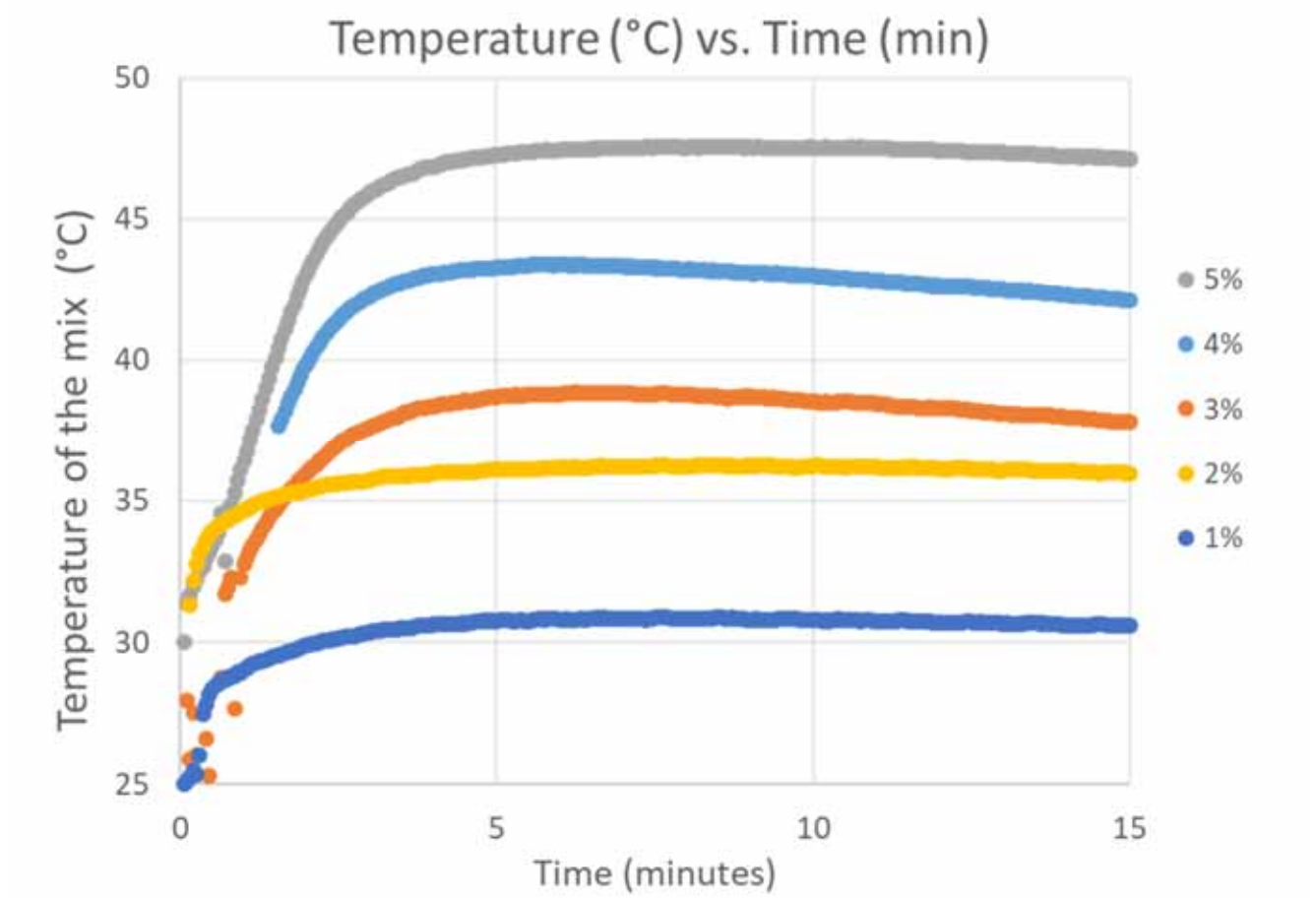
Emulsion + Quicklime → Effects on mix's temperature



BSM & Quicklime

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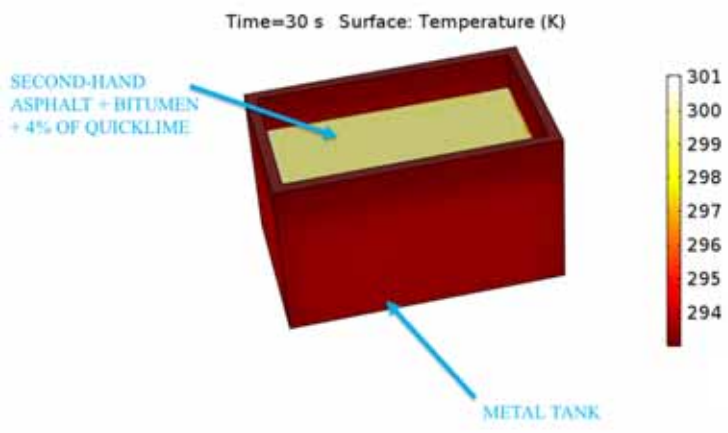
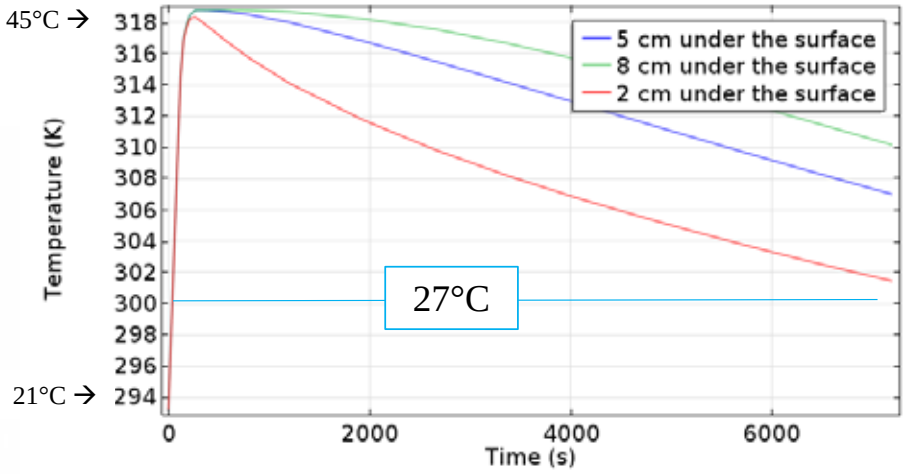
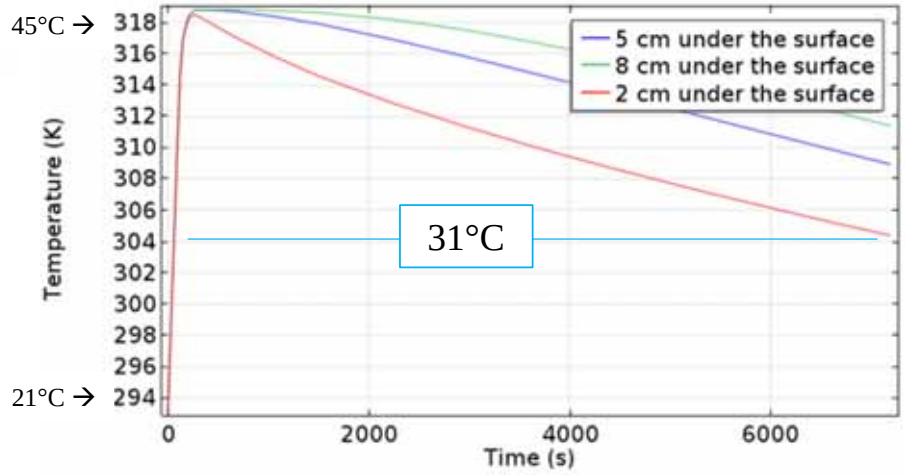
FEM MODEL [tetrahedral elements]





Improving the insulation →



BSM & Quicklime

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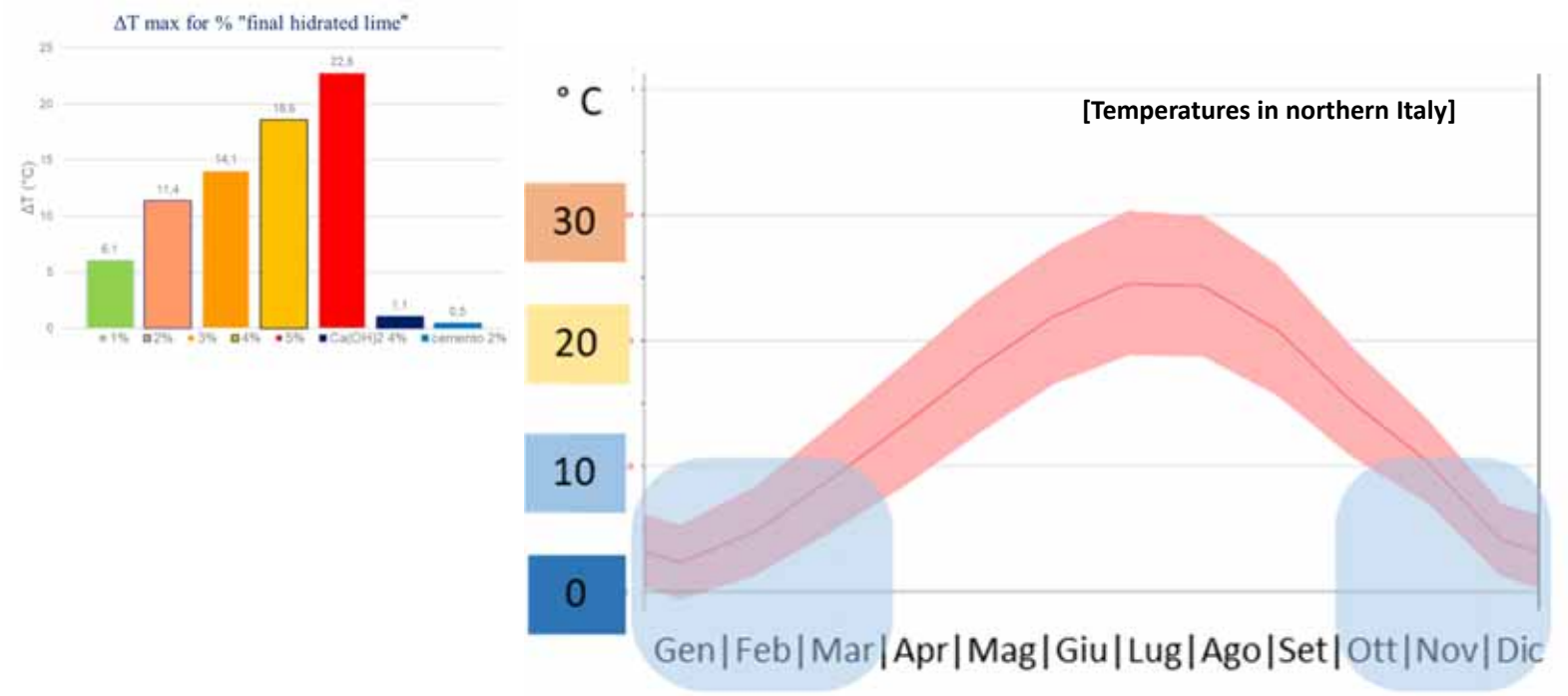

Increasing of operational period

Final remarks

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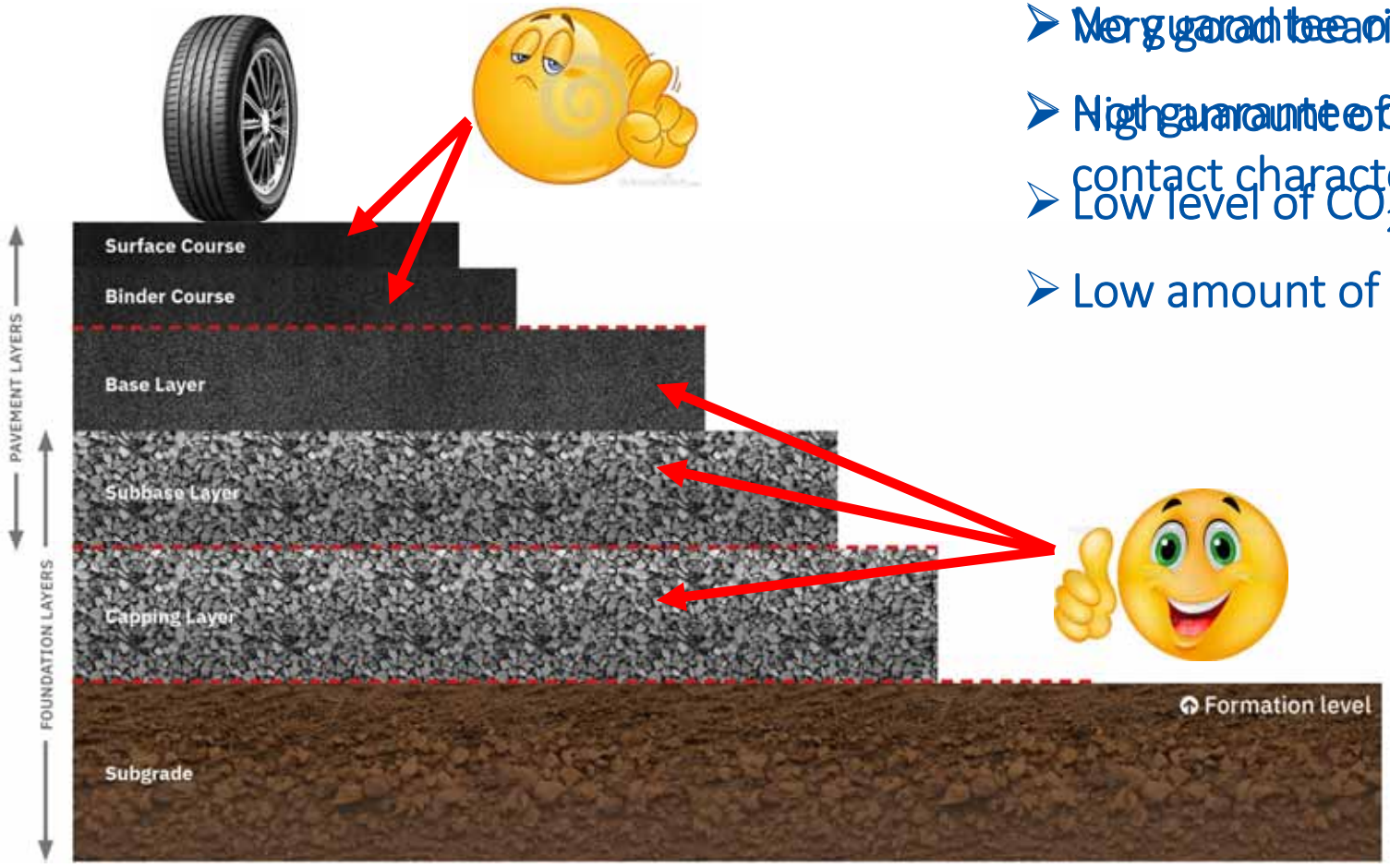
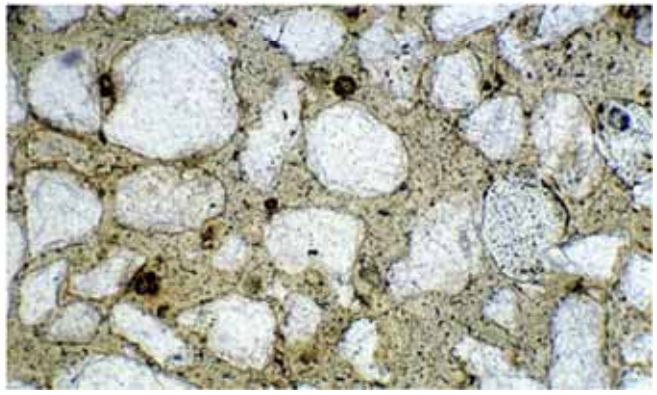


- Very good bearing capacity
- High guarantee of proper interlayer contact characteristics
- Low level of CO_2 emissions
- Low amount of bitumen required



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