2020 NESMEA

Assessment of Active Filler impact on Cold Recycled Asphalt Mixture Properties

Ph.D. student: **Francesco Preti**

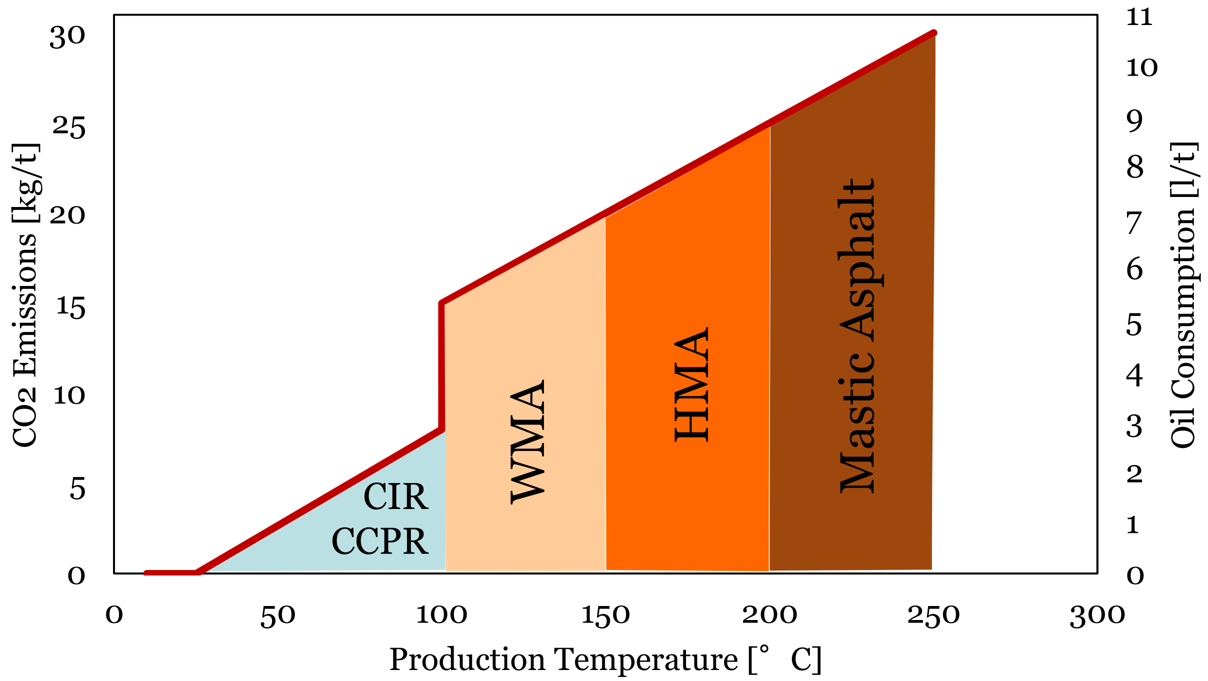
UNH advisors: **Dr. Eshan V. Dave and Dr. Jo E. Sias**
U. Parma advisors: **Dr. Gabriele Tebaldi and Dr. Elena Romeo**

Special thanks to **Beatriz Chagas Silva Gouveia**

Contents

Cold Recycling technologies

- **Recovering and re-using** material from an existing pavement **without the addition of heat.**
- **100% of the milled material** from an existing pavement (RAP) can be **recycled.**
- **No need for transporting** the material: the mixture is prepared on site or in mobile plants.



- Saving of resources,
- Reduced costs,
- Reduced emissions,
- Short construction times.

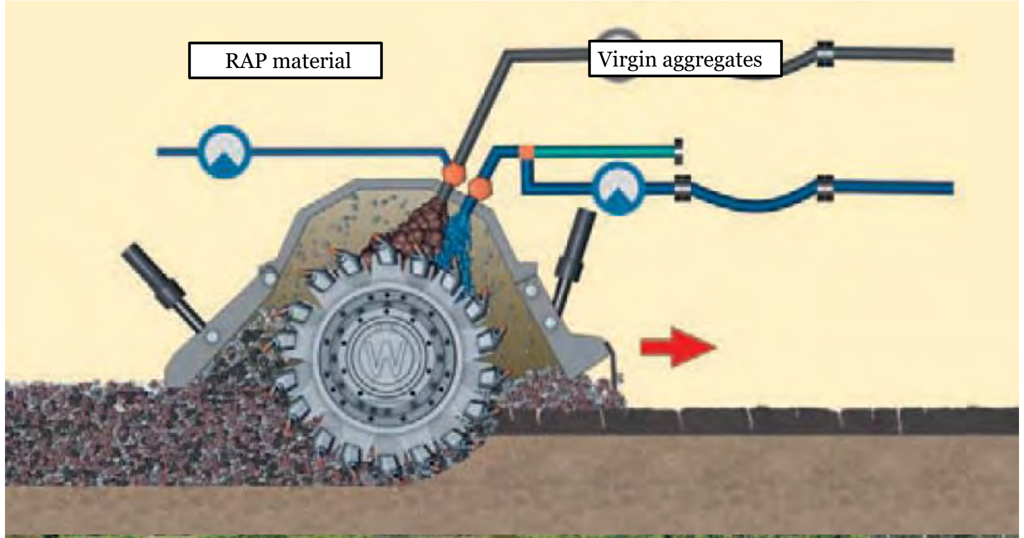
Cold Recycling technologies

Mixture components:

- Reclaimed asphalt pavement (RAP)
- Asphalt stabilizing agent (foamed asphalt or emulsified asphalt)
- Mineral filler and/or **active filler (cement, lime…)**
- Water (compaction and chemical reactions)

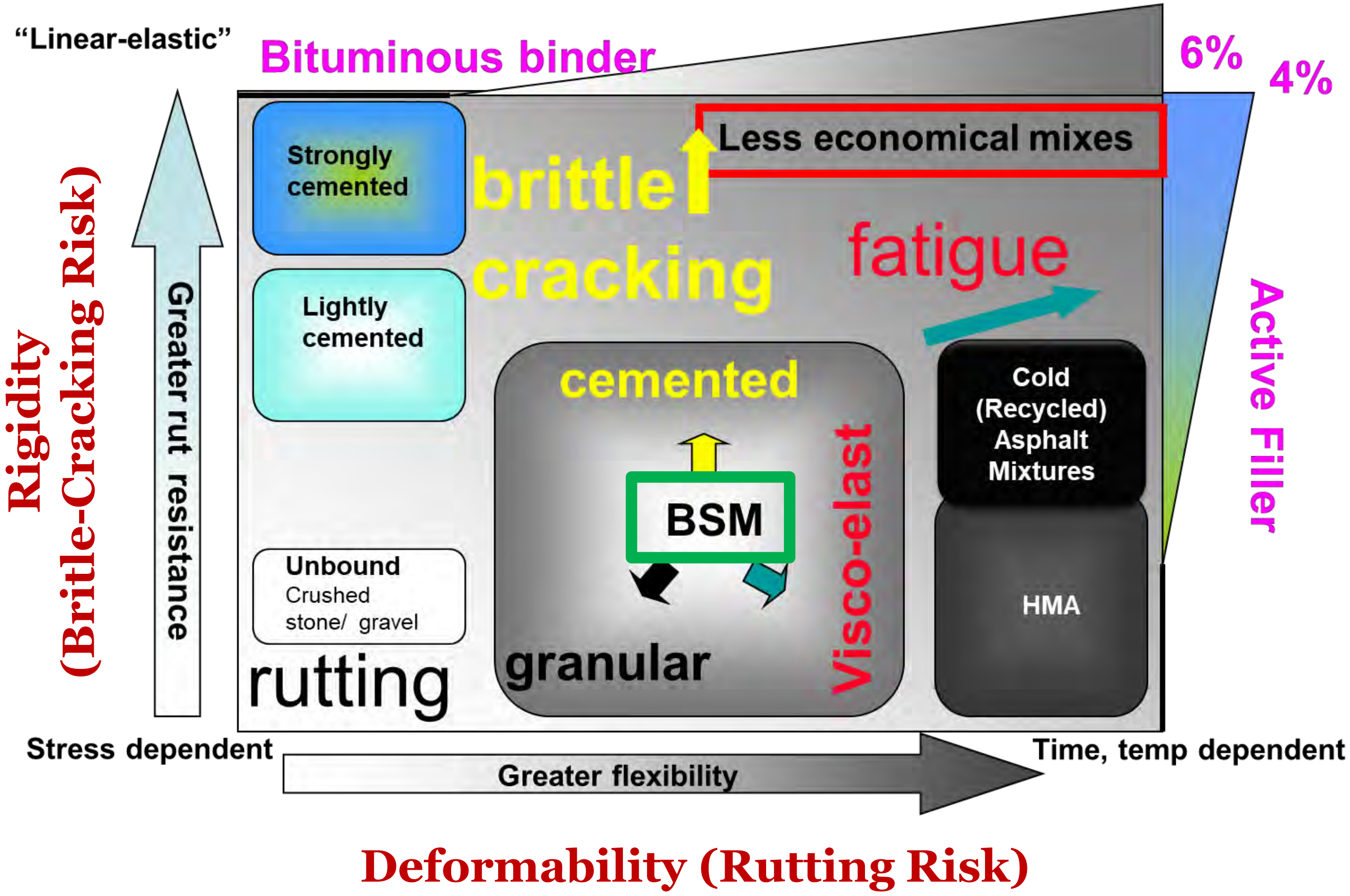
Technologies:

- Cold In-Place Recycling (CIR)
- Cold Central Plant Recycling (CCPR)



Cold Recycling technologies

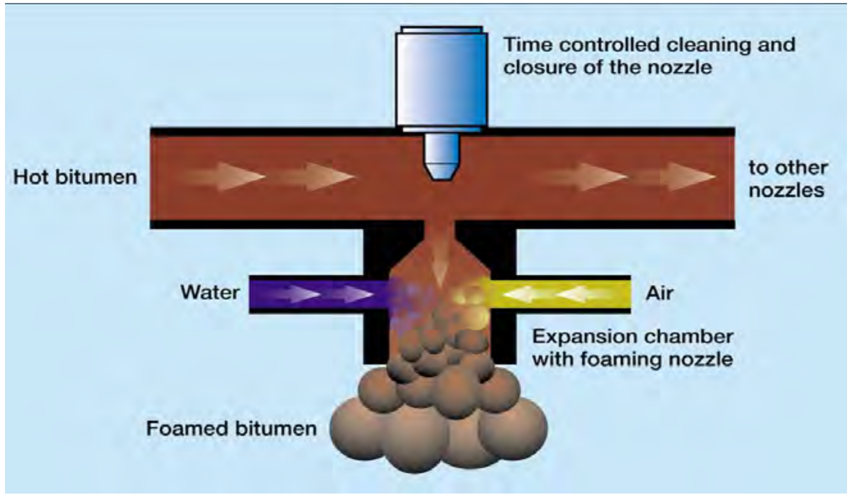
The obtained product is called **Bituminous Stabilized Material** (BSM)

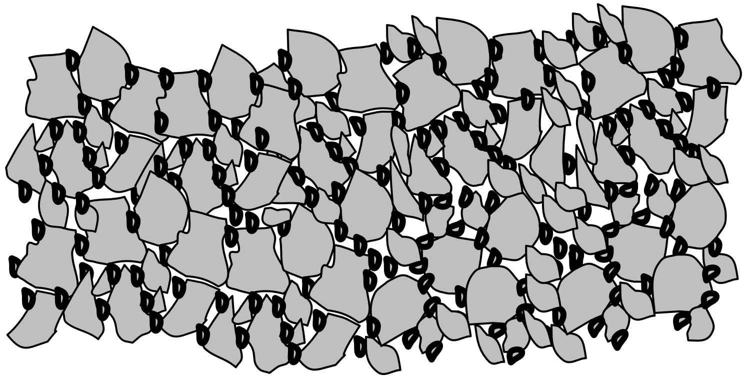


PARTIALLY-BONDED MATERIALs

Asphalt stabilizing agents

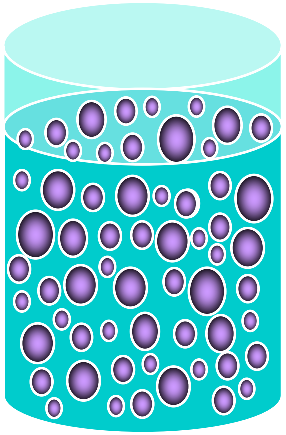
- Foamed asphalt



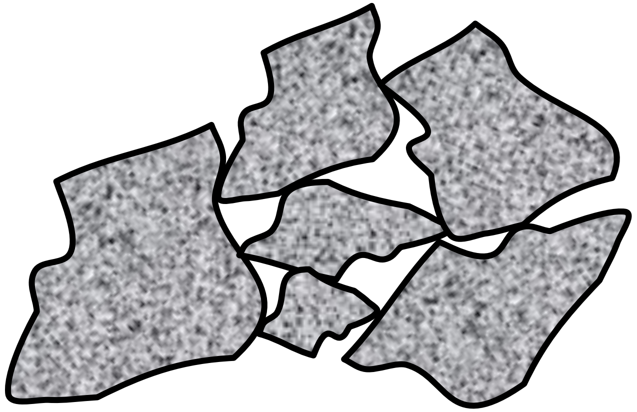


Adhesive mastic dispersed in the mixture

- Emulsified asphalt



Asphalt droplets suspended in water



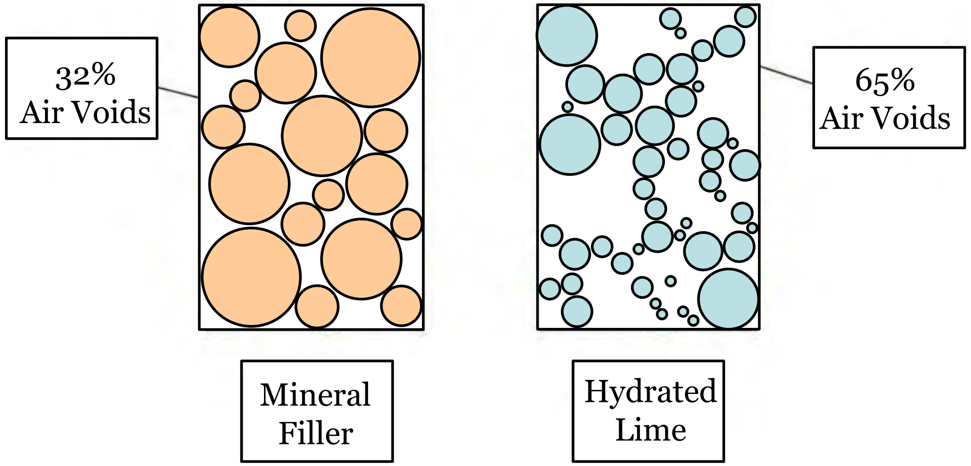
Aggregates fully coated

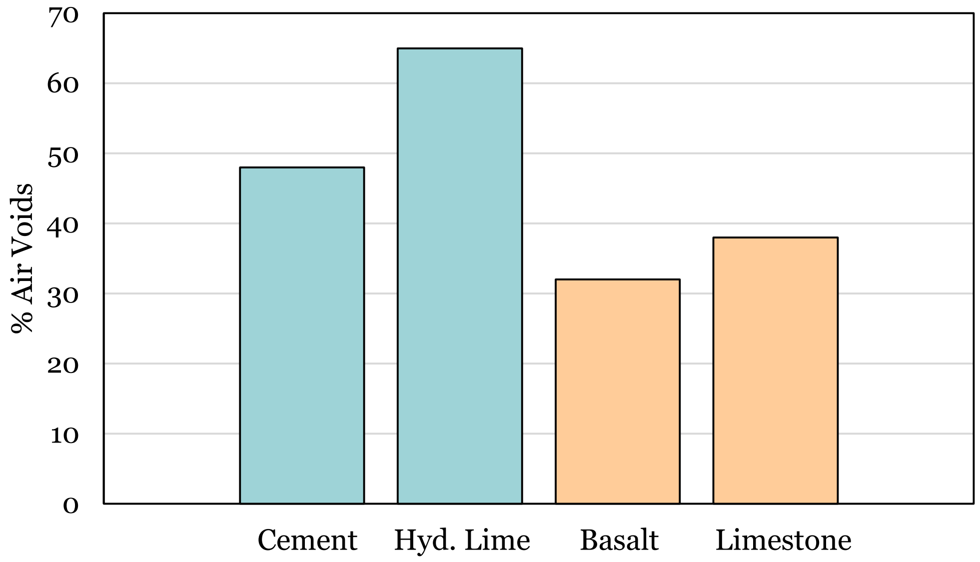
Fillers & active fillers

Active filler

The term active filler is used to define fillers that **chemically alter** the mix properties. This includes fillers such as lime, cement and fly ash but excludes natural fillers such as rock flour.

Fillers micro-structure:

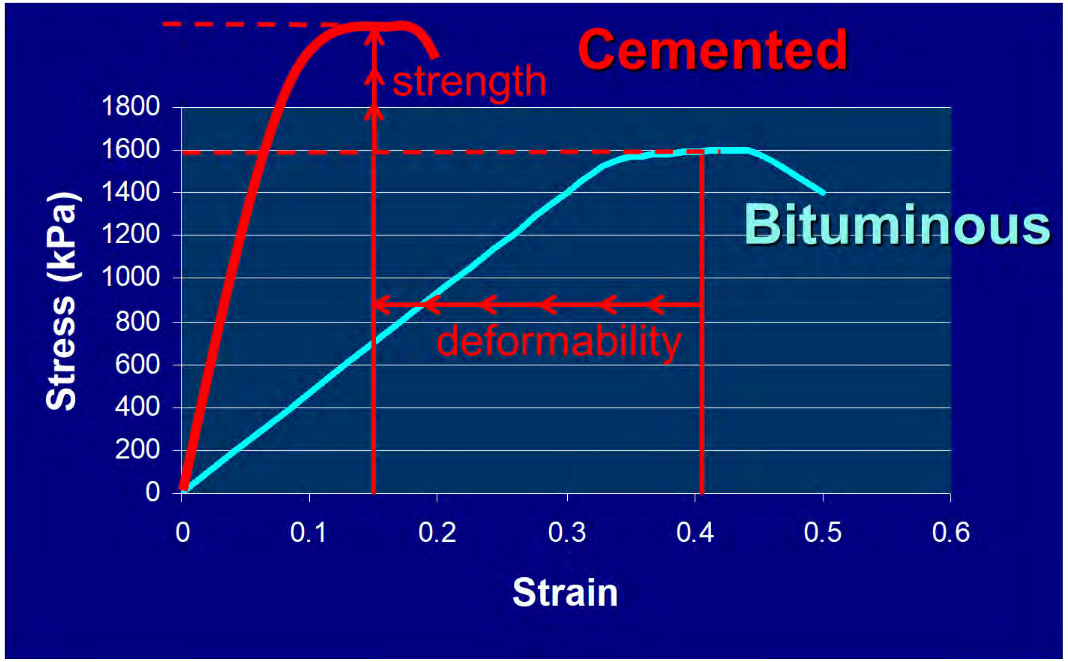


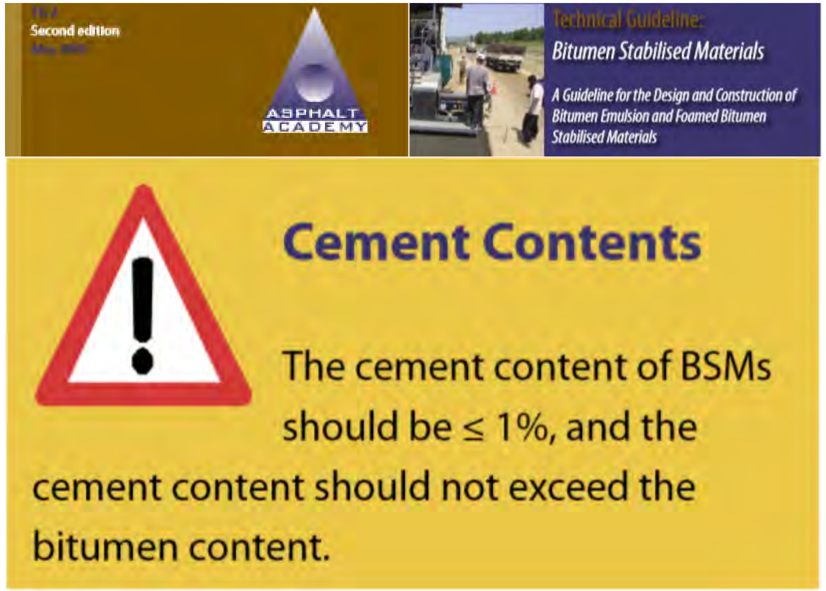


Purposes of incorporating active fillers:

- Improve **adhesion** of the binder to the aggregates
- Improve **dispersion** of the binder in the mix
- Increase **stiffness & strength gain** of mix
- **Accelerate curing** of compacted mix

Active filler: Cement





PARTIALLY BOUNDED MATERIAL (BSM) = ASPHALT IS THE BINDER

vs

CEMENT TREATED MATERIAL = CEMENT IS THE BINDER

Active filler: Hydrated lime

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

- The **application rate may be increased** with respect to cement
- Less concerns related to loss in flexibility
- A blend of cement and hydrated lime could be used

Contents

- Introduction on Cold Recycling technologies
- Objectives and motivations
- Laboratory campaign
- Experimental results
- Constitutive model
- Summary and ongoing research

Objectives

- Evaluate the **effect of introducing active fillers** in cold recycled mixtures
- Develop a **framework** to experimentally characterize BSMs
- Assess the **influence of temperature and confining pressure** on material mechanical properties
- Create a **constitutive model** for BSMs and incorporate it in pavement design and analysis

Motivations

- No many information are available on **active filler influence on cold recycled mixtures** mechanical properties

- BSMs are partially-bonded materials (heterogeneous)

Mechanical properties are simultaneously…

- temperature dependent (HMA)

- confining pressure dependent (Crushed aggregates)

<u>**need for a specific method of characterization**</u>

- Predominant mode of failure is believed to be accumulation of plastic deformation

<u>**need information on material plastic response**</u>

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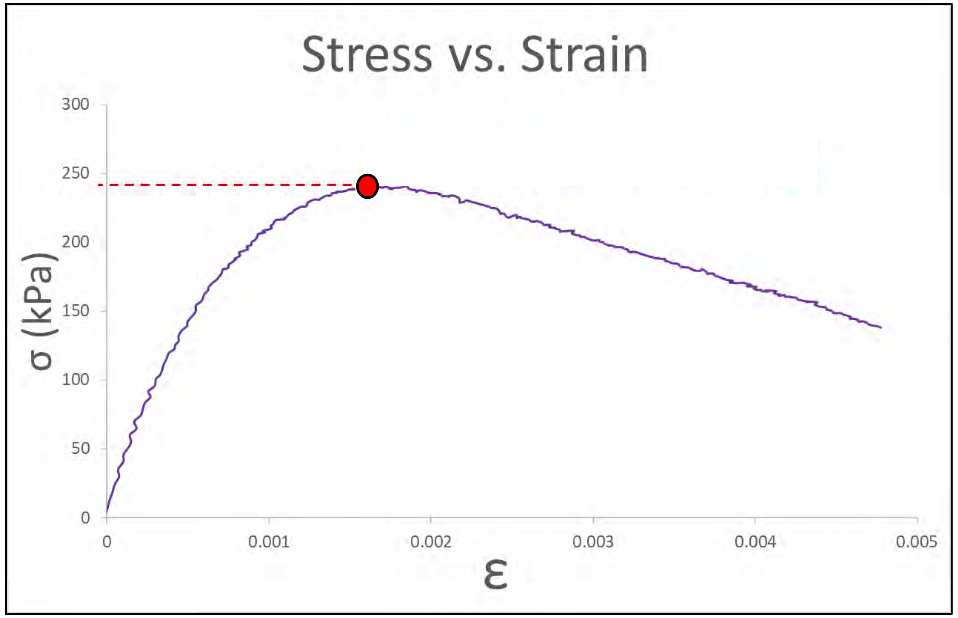
Laboratory equipment

- Asphalt foaming machine
- Laboratory mixer 30 kg capacity
- Vibrating hammer

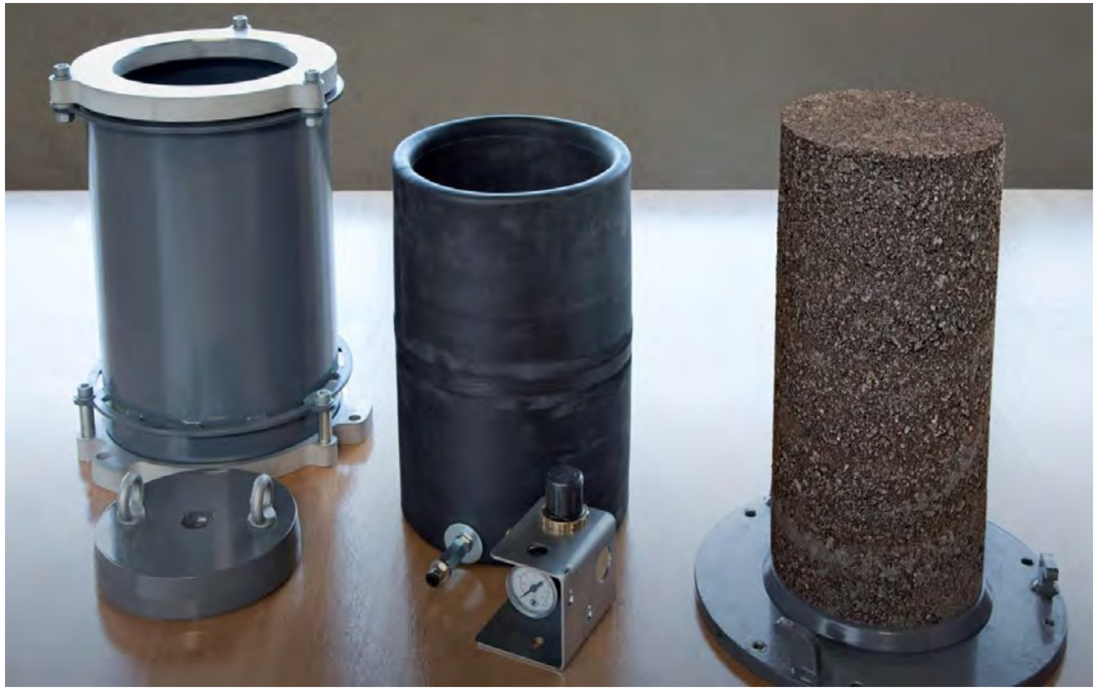
Indirect Tensile Strength (ITS)



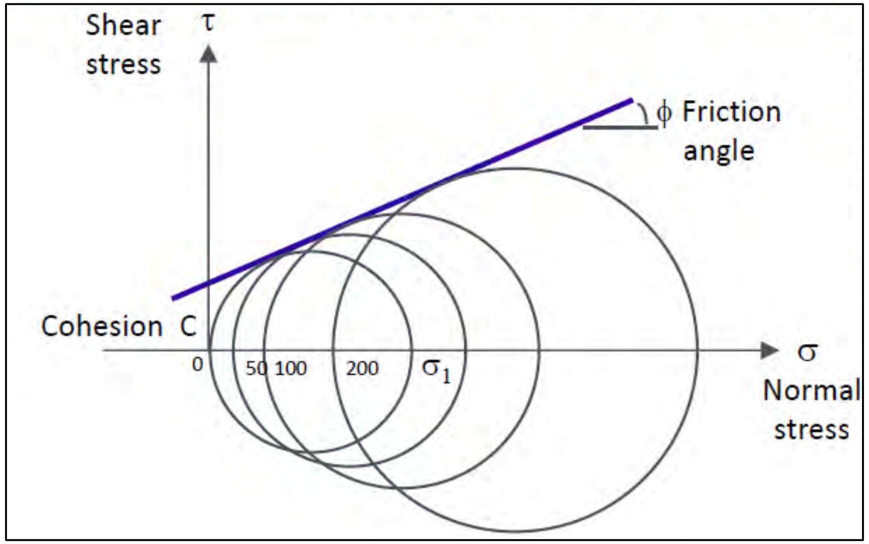
- Tests are performed at 25 deg C. only
- Does not provide information on plastic properties of the material
- Cracking risk is not the main concern for BSMs

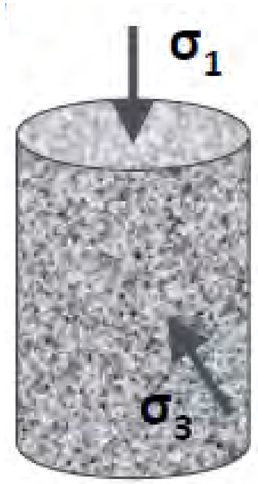
All of the tests were performed after 28 days curing period at room temperature (@25 deg C.)

Triaxial Shear Test



The **Mohr–Coulomb** (MC) **failure criterion**





- Confining pressure effect on shear capacity can be evaluated
- Provides information on plastic properties of the material: cohesion and friction angle values can be calculated
- Simple test and easy to run

All of the tests were performed after 28 days curing period at room temperature

Laboratory campaign

Mix design using **foamed asphalt** and **cement** as active filler

RAP	93%	93%	93%	93%
Mineral Filler	7%	6%	5.5%	5%
Cement	**0%**	**1%**	**1.5%**	**2%**
Foamed Asphalt	3%	3%	3%	3%

Mix design using **asphalt emulsion** and **hydrated lime** as active filler

RAP	95%	95%	95%	95%	95%
Mineral Filler	4%	3%	2%	1%	0%
Hydrated Lime	**1%**	**2%**	**3%**	**4%**	**5%**
Asphalt Emulsion	3.3%	3.3%	3.3%	3.3%	3.3%
Residual asphalt binder	2%	2%	2%	2%	2%

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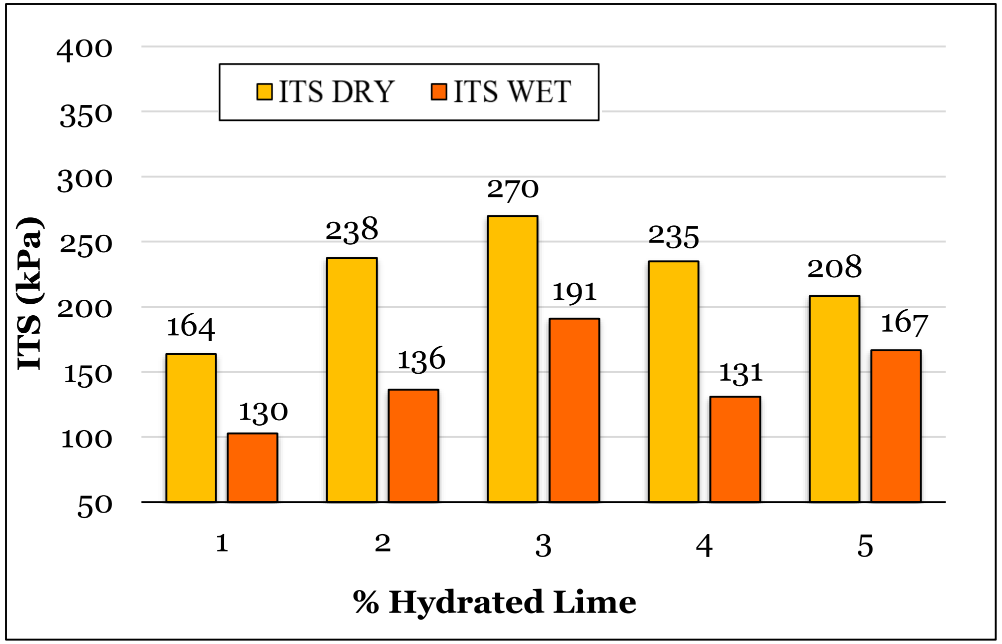
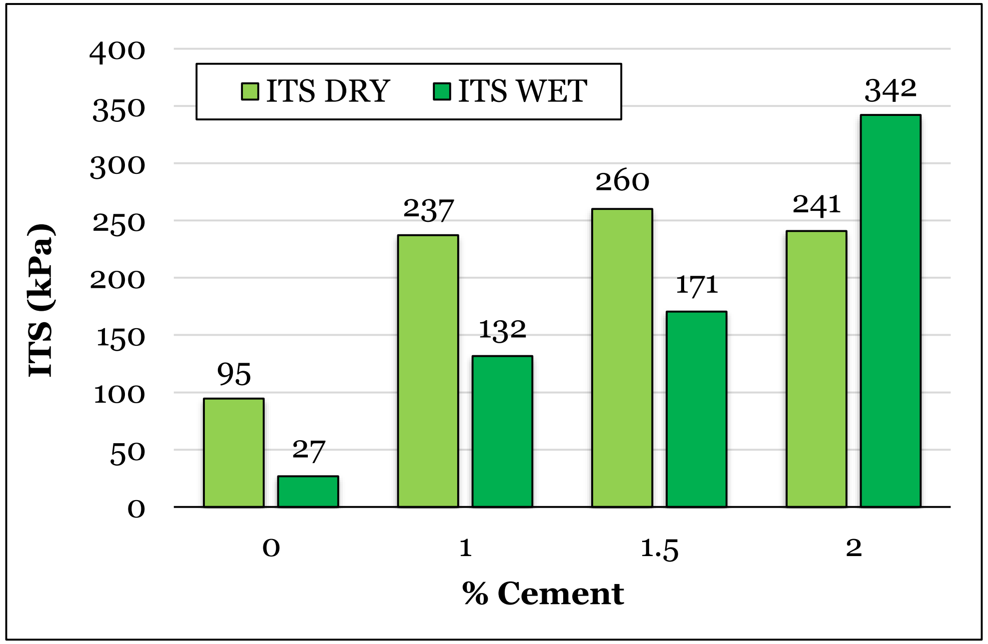
Indirect Tensile Strength

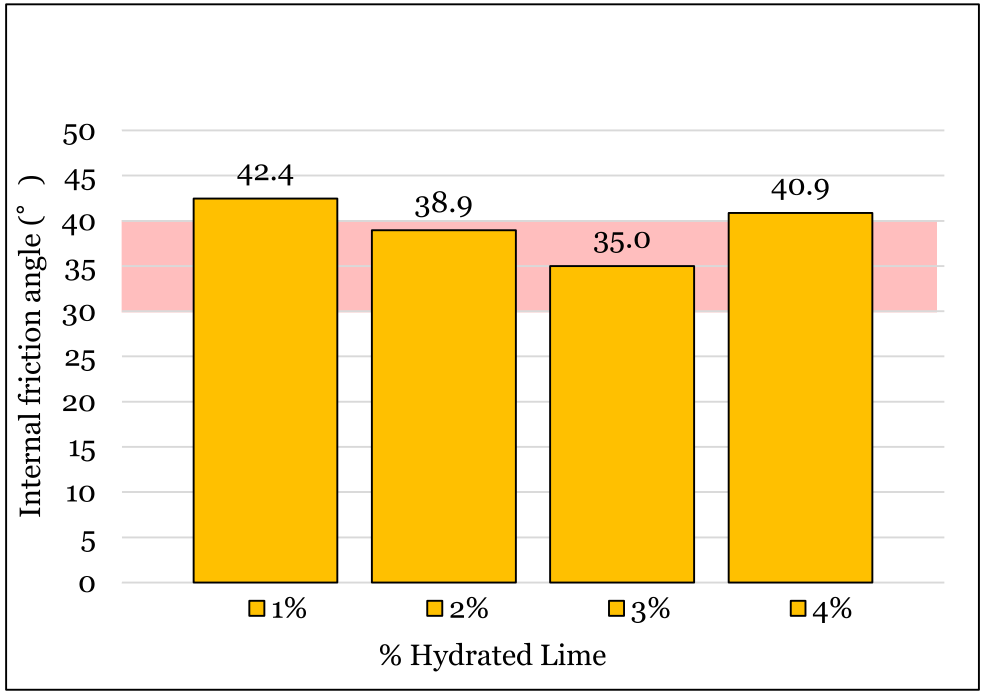


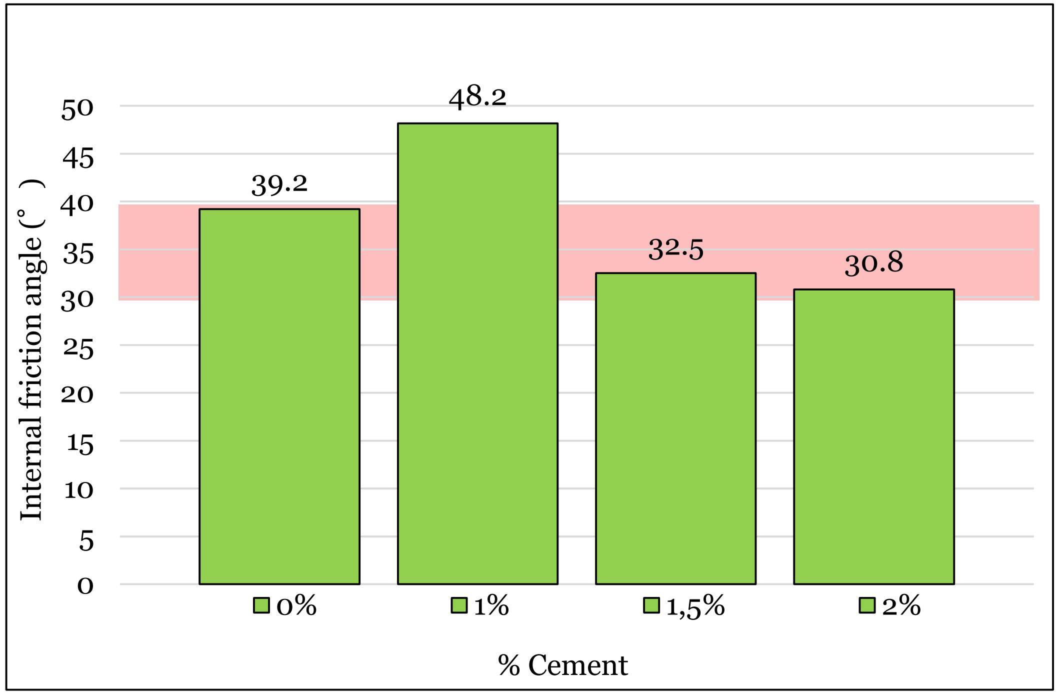


- ITS reaches a maximum value when **3%** hydrated lime is added to the mix
- High application rates (> 3%) of hydrated lime seem to have a **negative effect on ITS**
- ITS reaches high values already at **1%** cement application rate
- ITS wet > ITS dry for the 2% cement content suggests that there was **unreacted cement** in the mix

Internal friction angle

Typical values for BSM are in between 30 and 40°

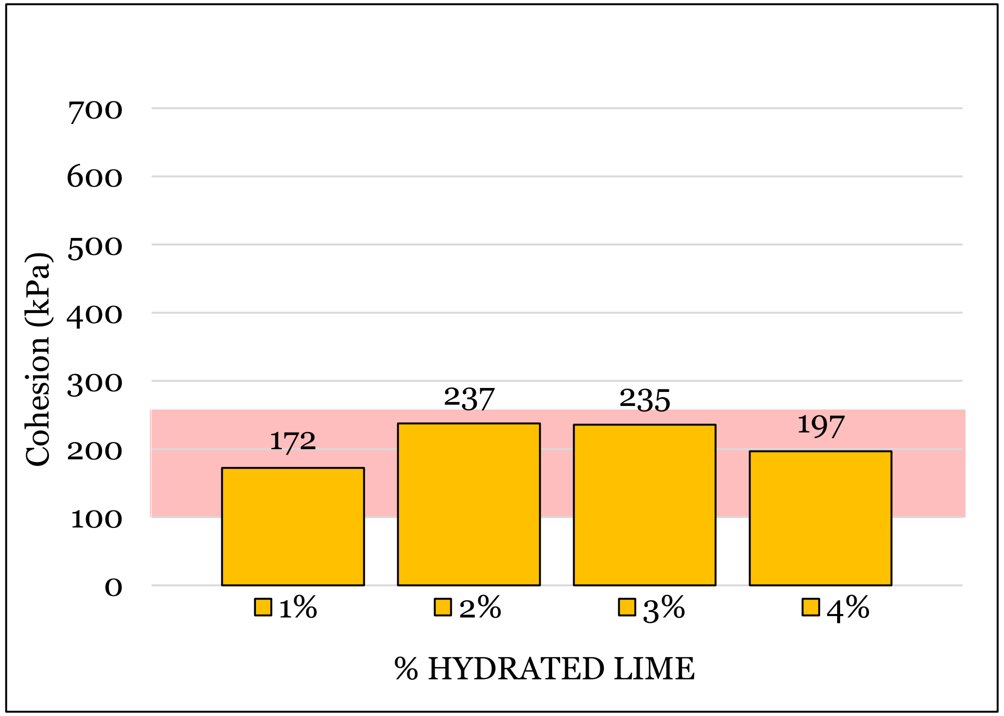


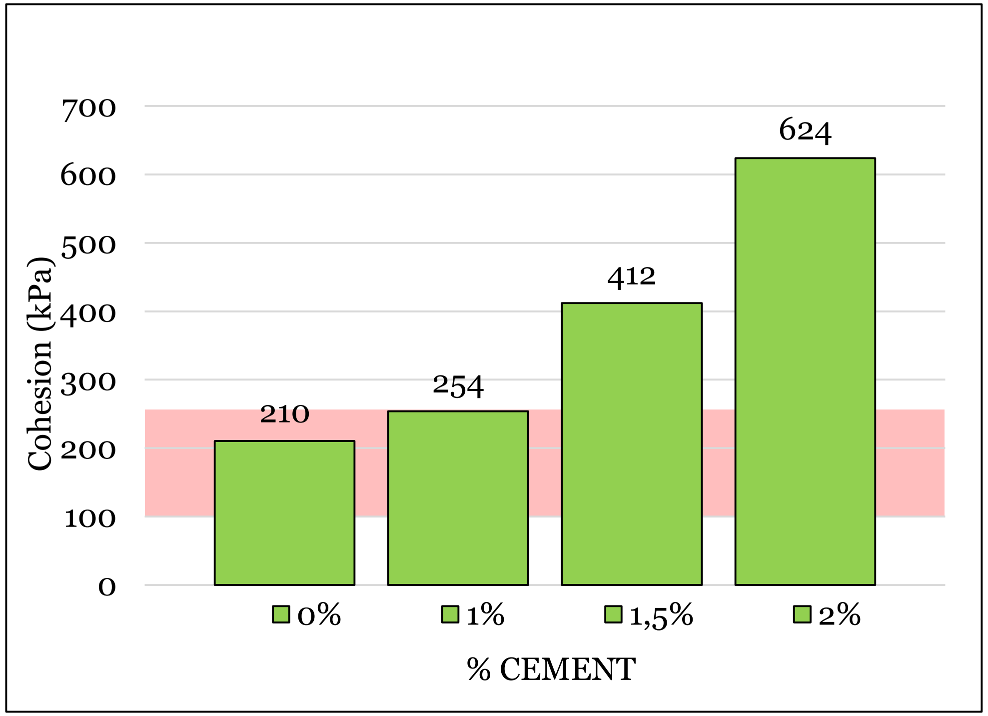


- Internal friction angle value is **not influenced by the presence of active filler**
- It is believed to be mostly dependent on **RAP gradation**

Cohesion

Typical values for BSM are in between 100 and 250 kPa

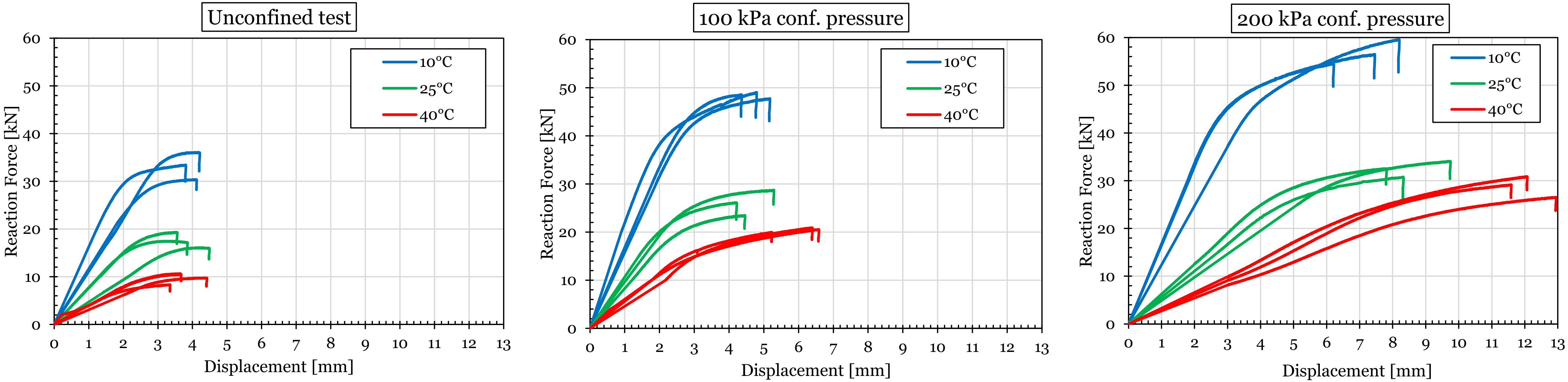




- Cohesion is in the BSM boundaries for **all hydrated lime application rates**
- Lime does not have a major impact on plastic properties

- Cohesion **exponentially increases** for cement application rates higher than 1%
- Cement strongly impacts plastic response

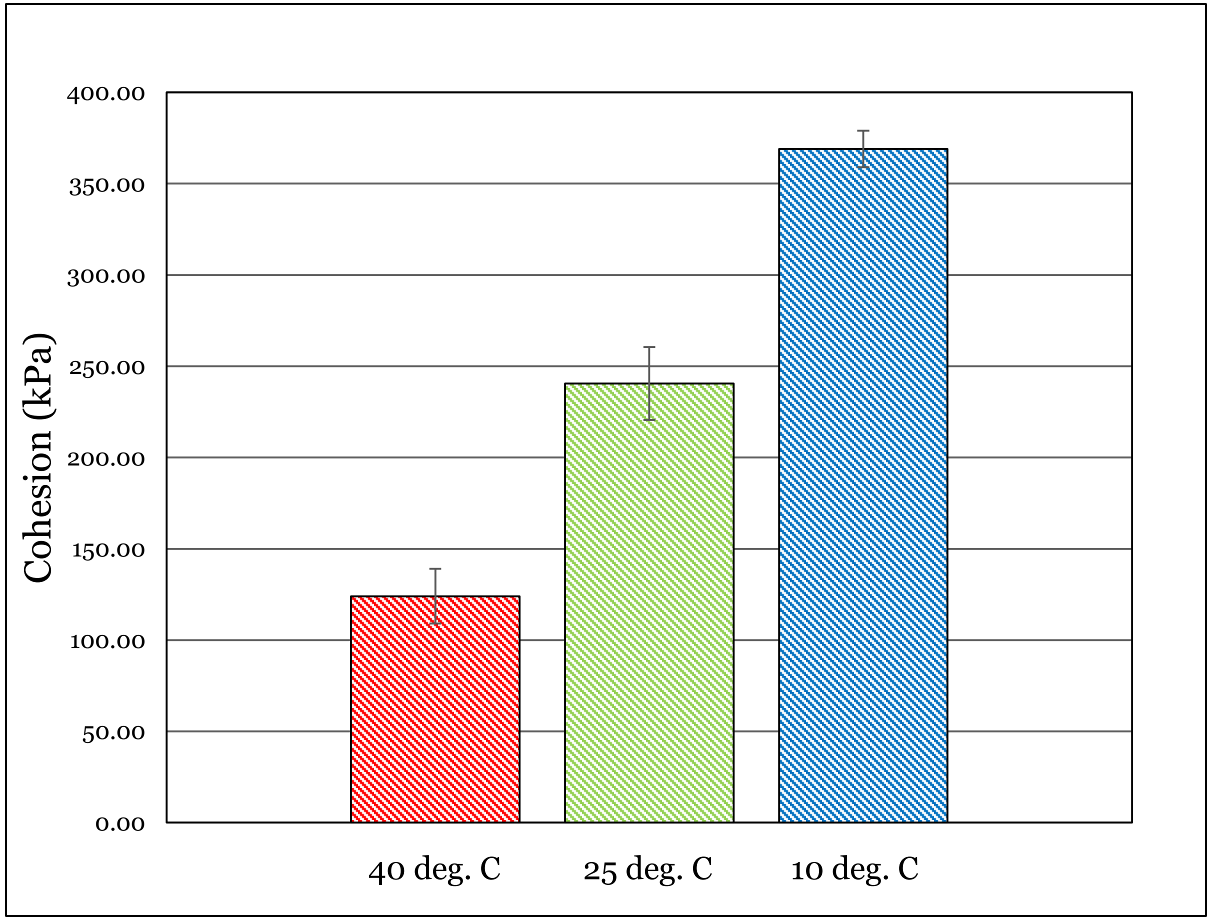
Effect of Temperature on Mechanical Properties

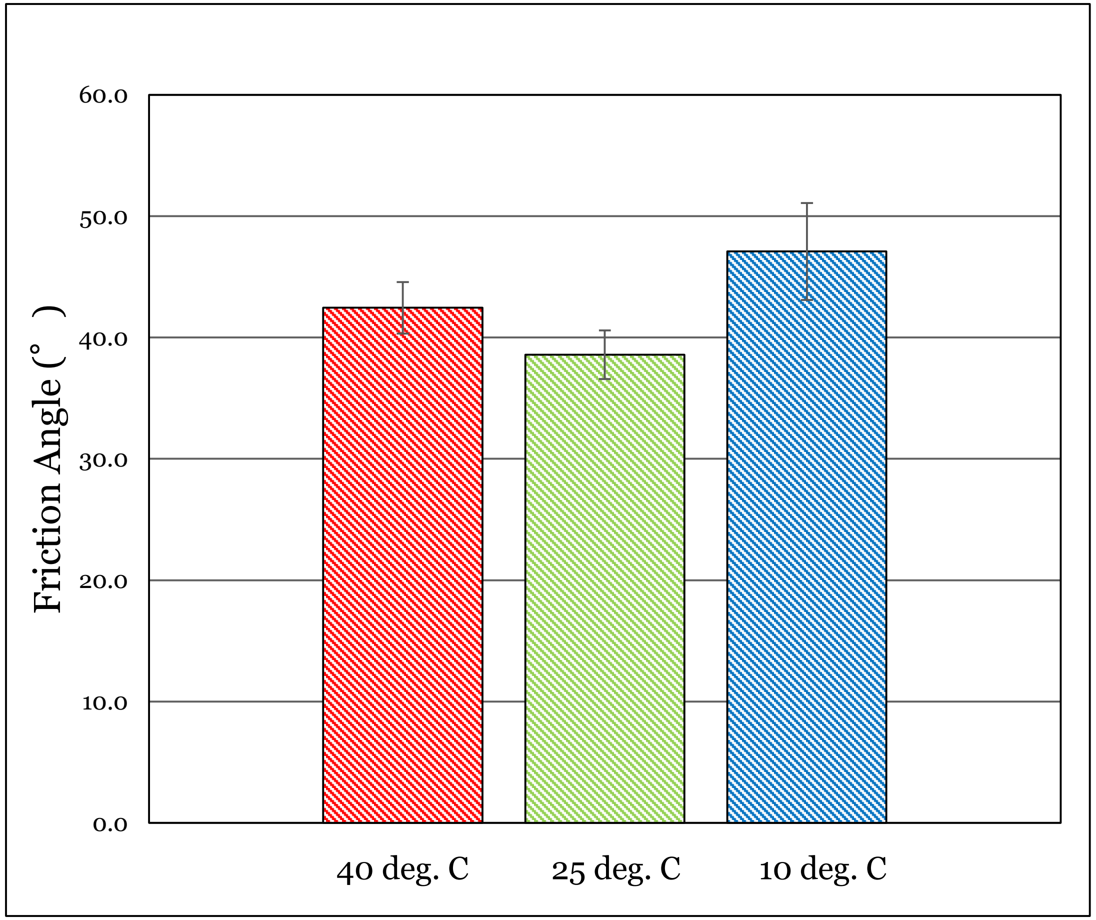


- Replicates gave very **consistent results** (repeatability of triaxial test)
- Material does **not give a linear response**
- When **temperature decreases** and **confining pressure increased** the material stiffens
- Importance of considering triaxial test for **analysis and design**

Effect of Temperature on Plastic Properties

Reference mixture: 2% hydrated lime and asphalt emulsion

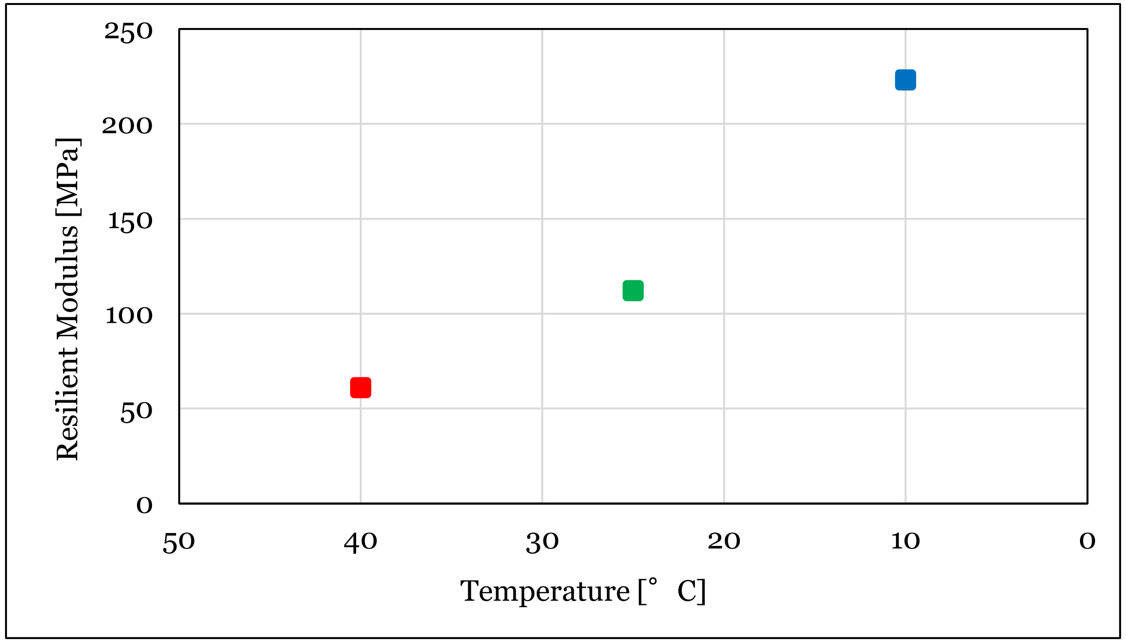




- Cohesion is a **temperature dependent property**
- Internal friction angle is not affected by testing temperature (controlled by particle to particle contact)

Effect of Temperature on Elastic Properties

Reference mixture: 2% hydrated lime and asphalt emulsion

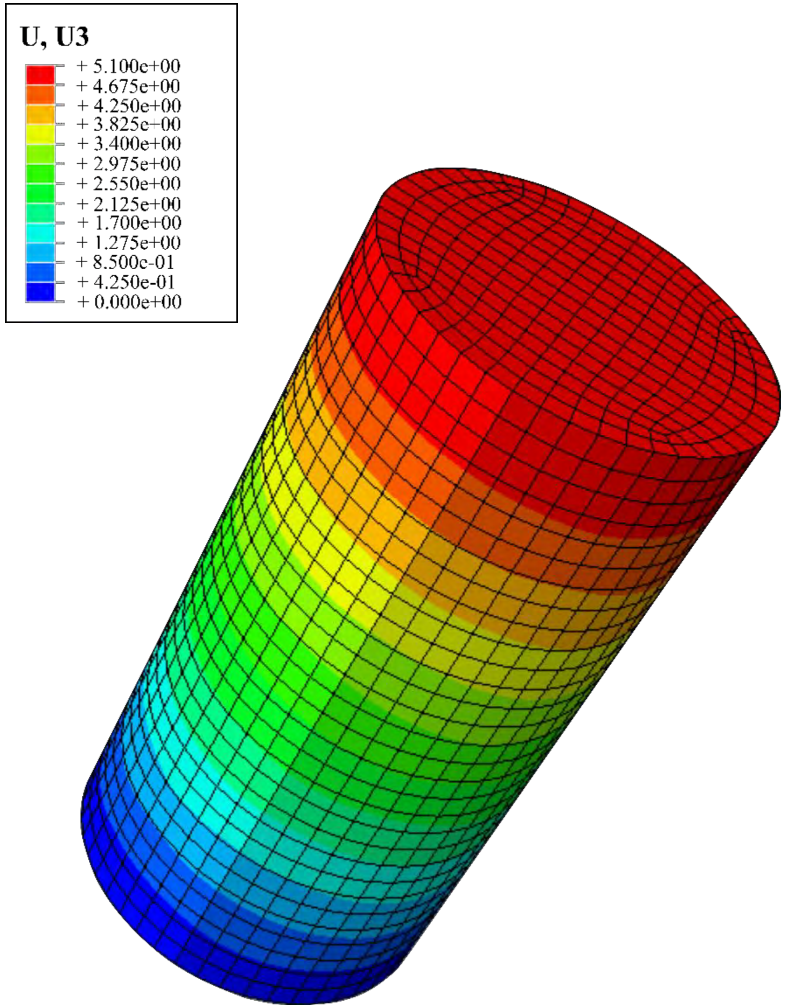


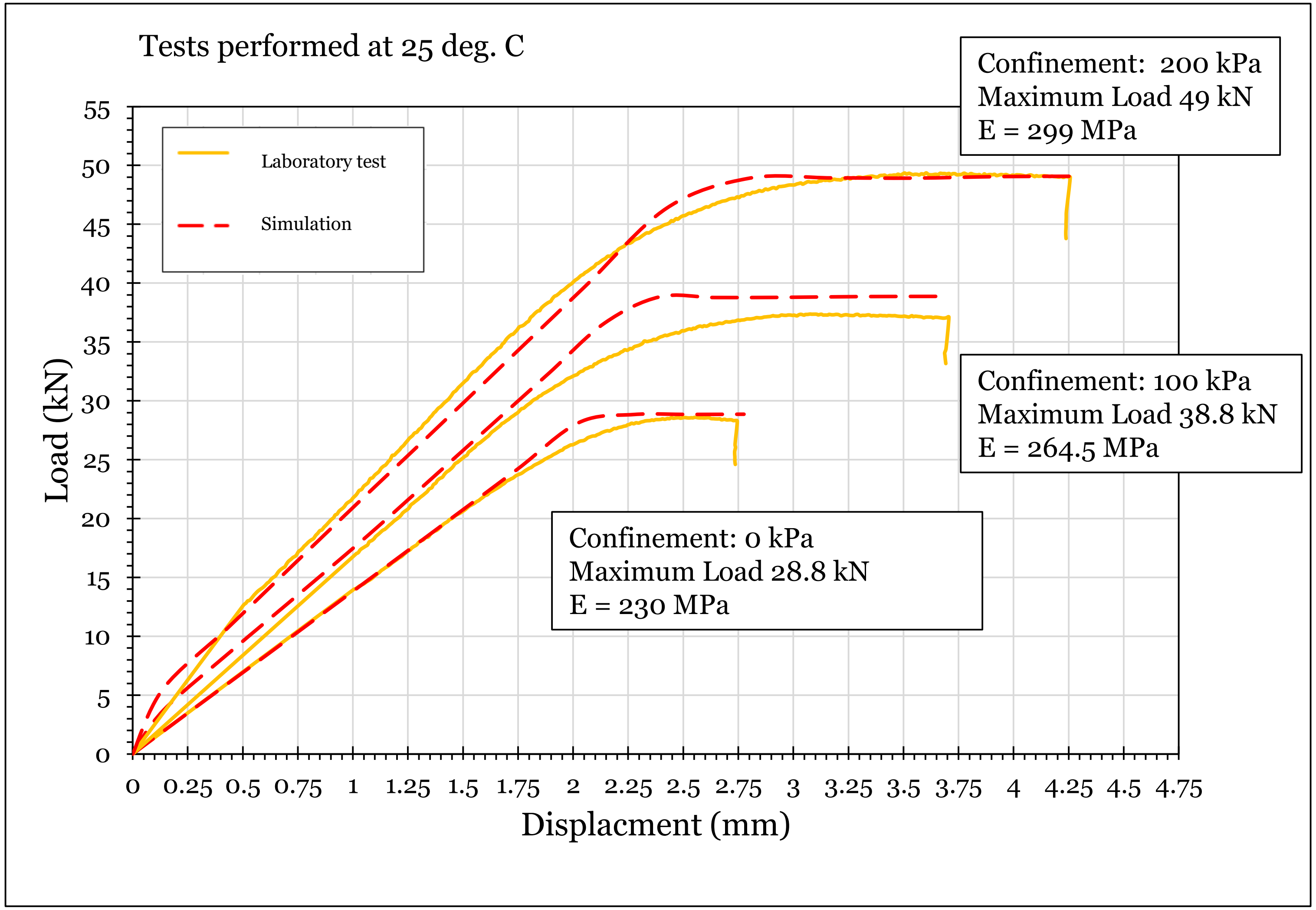
- Resilient Modulus is a **temperature dependent property** in BSMs

Contents

3D Elasto-Plastic Finite Element Model for BSM

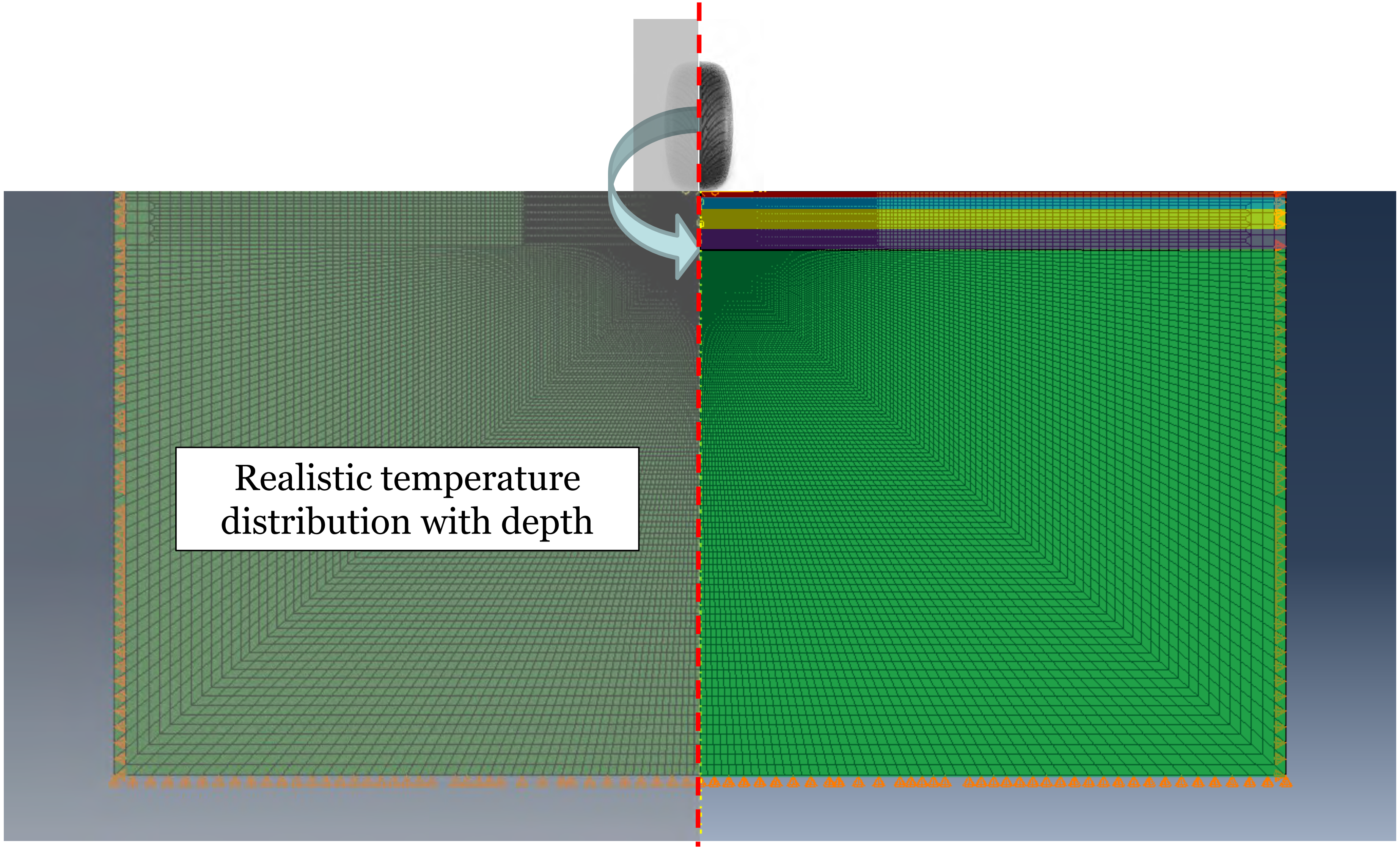
Paper accepted for publication: RILEM International Symposium on Bituminous Materials – Lyon, France 2020





Multilayer 2D Axisymmetric Model

Paper selected for presentation TRB 2021 and accepted for publication TRR 2021



Contents

Summary

- **Triaxial shear and resilient modulus tests are better suited** characterization method than ITS for partially-bonded materials like BSMs
- **Friction angle is controlled by particle to particle contact** in BSMs: the asphalt content is not high enough to contribute to friction
- **Cement strongly impacts the cohesion** of the material (does not happen with lime)
- Cohesion and elastic modulus in BSMs are **temperature and confining pressure dependent properties**
- The introduction of BSM plastic properties in the design and analysis of pavement structure can help **predict rutting potential**

Ongoing research

- Evaluate the influence of **curing time** on mechanical properties of cold recycled mixtures

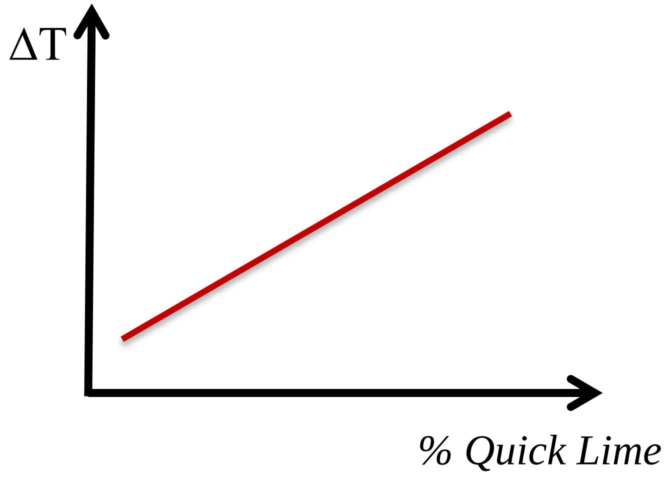
(MnDOT-LRRB CIR curing project)

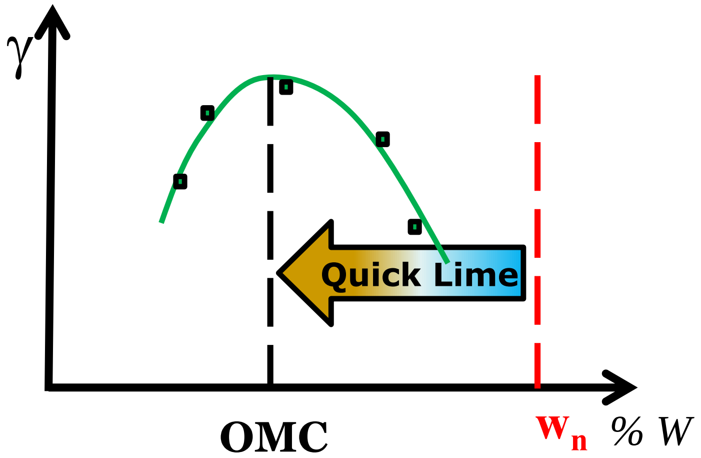
- Investigate the use of **quick lime** as active filler

(In collaboration with University of Stellenbosch, South Africa)

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

1. The reaction produces heat, that could allow to **extend the construction season**
2. Control of **water content** (reaction + evaporation)





Thank you for your time!