



**3<sup>rd</sup> International  
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& Environment**

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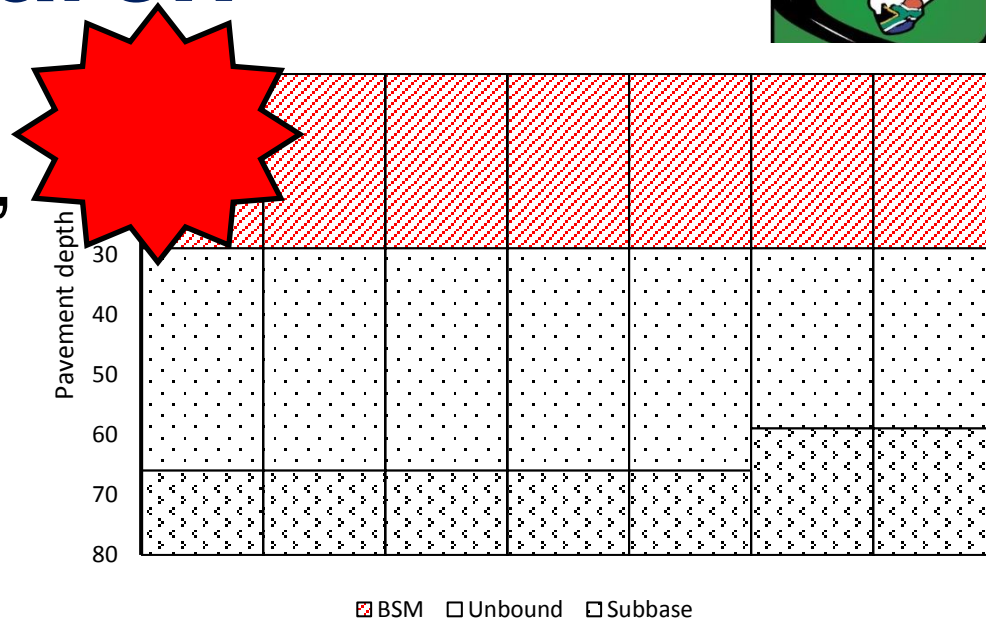
# **Tolerances for inhomogeneity of pavement structure for in-situ cold recycling**

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# Topic of research



- Pavement structure may vary (thickness, structural layers) in longitudinal and transversal direction



- In what extend structural pavement variation can be tolerated in a cold recycling project?

# Sample mixtures

Mix variations	Reclaimed asphalt (RA)	Reclaimed road concrete (RRC)	(Reclaimed) Unbound material (unb.)
<b>A</b> <b>100/0/0</b>	100%	-	-
<b>B</b> <b>75/0/25</b>	75%	-	25%
<b>C</b> <b>50/25/25</b>	50%	25%	25%
<b>D</b> <b>50/0/50</b>	50%	-	50%
<b>E</b> <b>40/20/40</b>	40%	20%	40%
<b>F</b> <b>0/50/50</b>	-	50%	50 %
<b>G</b> <b>0/25/75</b>	-	25%	75%
<b>H</b> <b>0/0/100</b>	-	-	100%



# Source Materials

## Reclaimed asphalt

- Sampled from stockpile
- 5.4 % bitumen

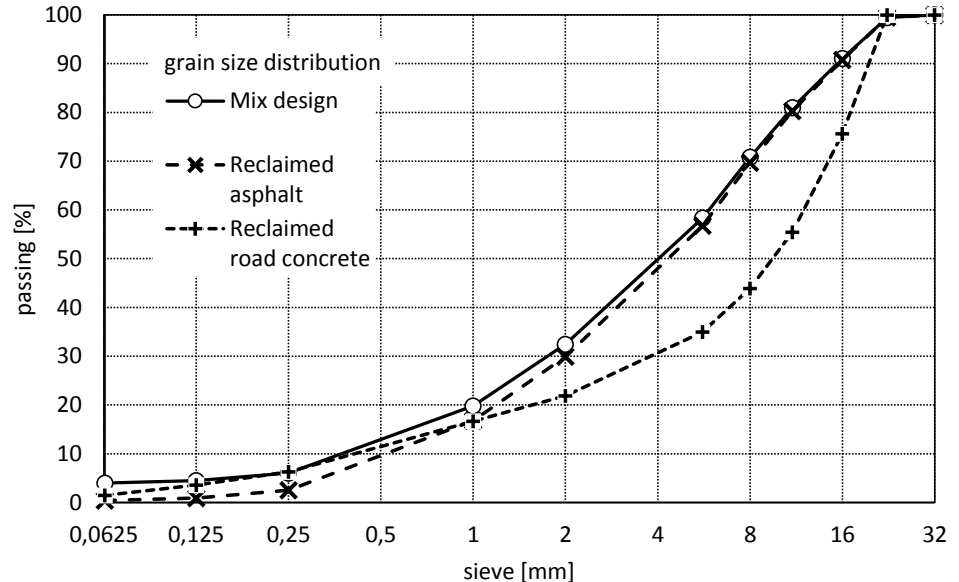
$T_{R\&B}$  63.5°C

Pen 23 1/10 mm

## Reclaimed road concrete

- Stockpile used for subbase

## Basaltic aggregates



# Mix composition

- Residual bitumen content: 4 %
- Bitumen emulsion
  - Cationic, 60 % bitumen 50/70 (emulsion content 6.4 %)
- Foamed bitumen
  - 50/70
  - Foaming @ 180 °C, 5.5 bar, 4.5 % water
- Active filler
  - 2 % portland cement
- Mixing water content (total): 7.8 %



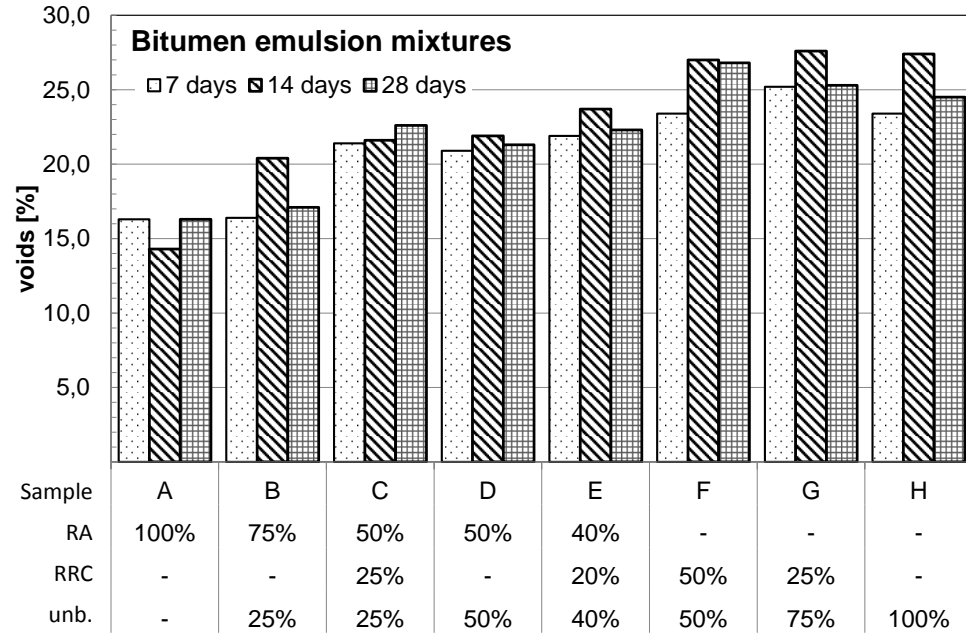
# Lab tests

- Static compaction (30 s á 45.9 kN)
- Specimen curing:
  - 1 day in mould
  - 2 days demoulded @ 20 °C, 80 % humidity
  - 25 days at room conditions
- Tests
  - Bulk density & void content
  - Indirect tensile strength (5 °C)
    - 7 day, 28 days, 14 days in water
  - CBR dry



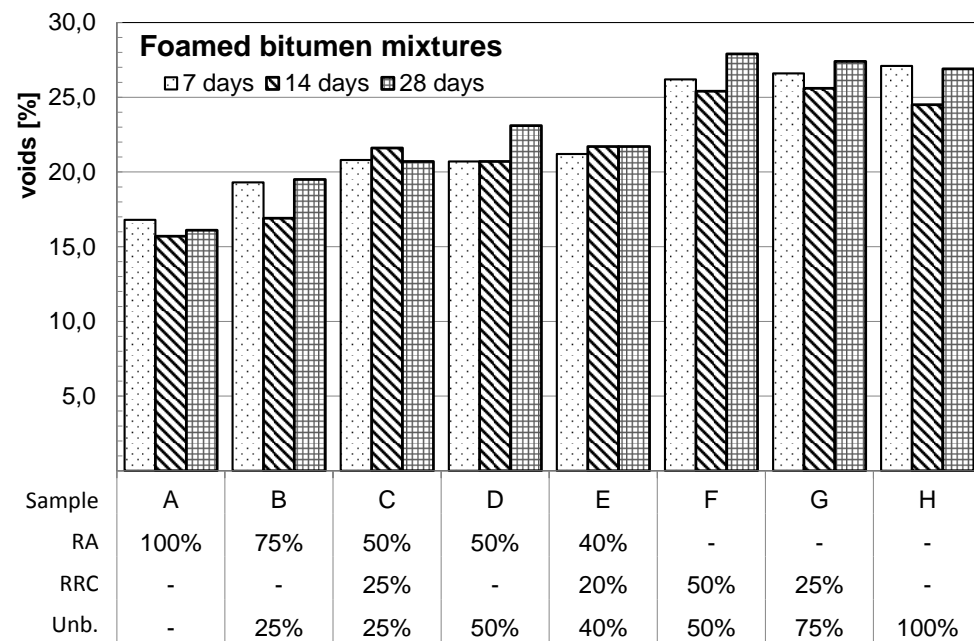
# Void content

- Insufficient compaction (German requirement: < 15 %)
- Reasons:
  - Coarse mix, low fines
  - Low compaction energy
- The higher RA content in mix granulate, the lower the void content
- At same grading, RA allows for better compaction
- Similar results for emulsion and foamed bitumen mix



# Void content

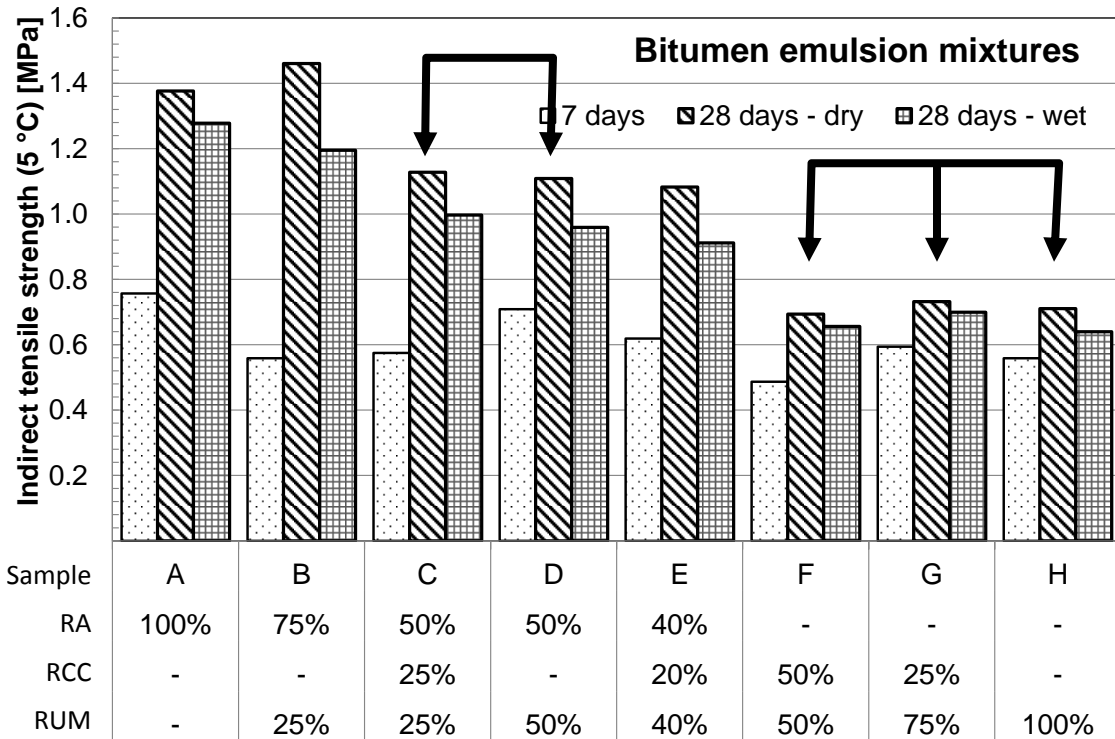
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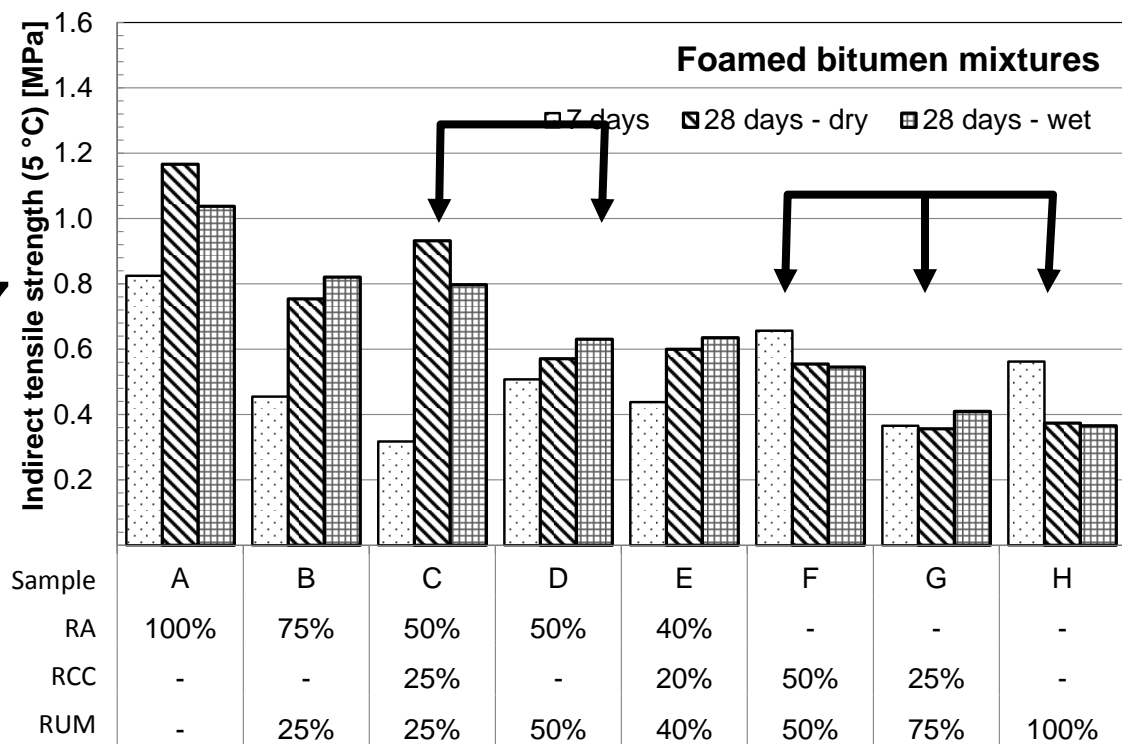
# ITS(5°C)

- Strength increase between 7 and 28 days
- The higher RA content, the higher the ITS obtained
  - Void content
  - Flexibility
- No difference between crushed concrete and crushed natural aggregates



# ITS(5°C)

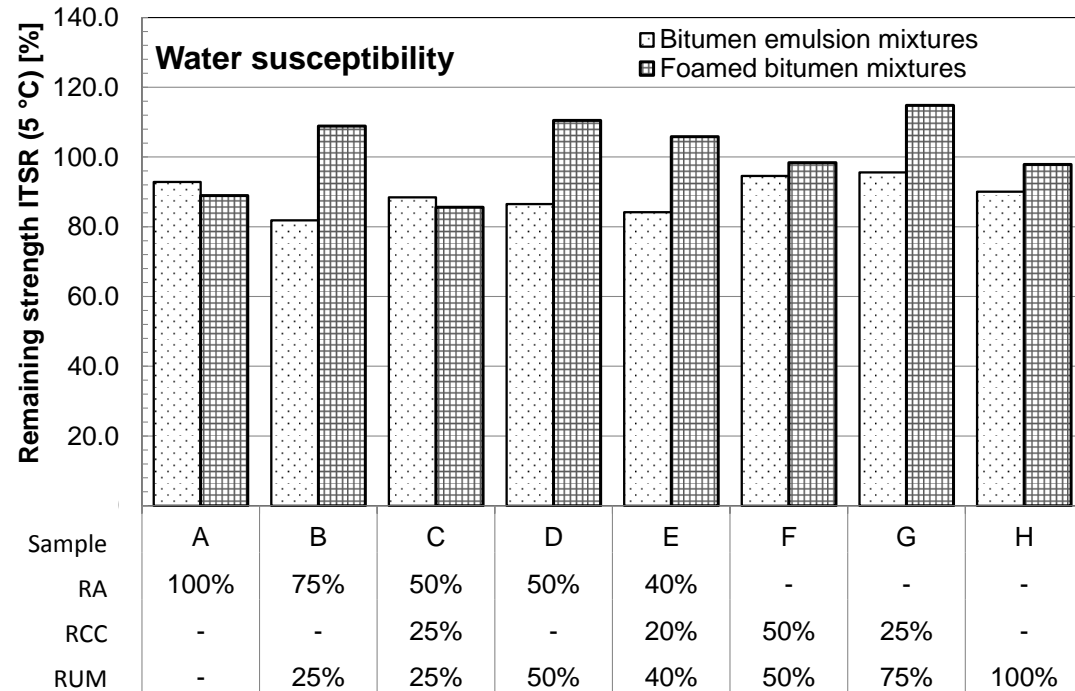
- Smaller strength increase between 7 and 28 days
- The higher RA content, the higher the ITS obtained
  - Void content
  - Flexibility
- At same RA content, RCC results in higher strength compared to crushed natural aggregates



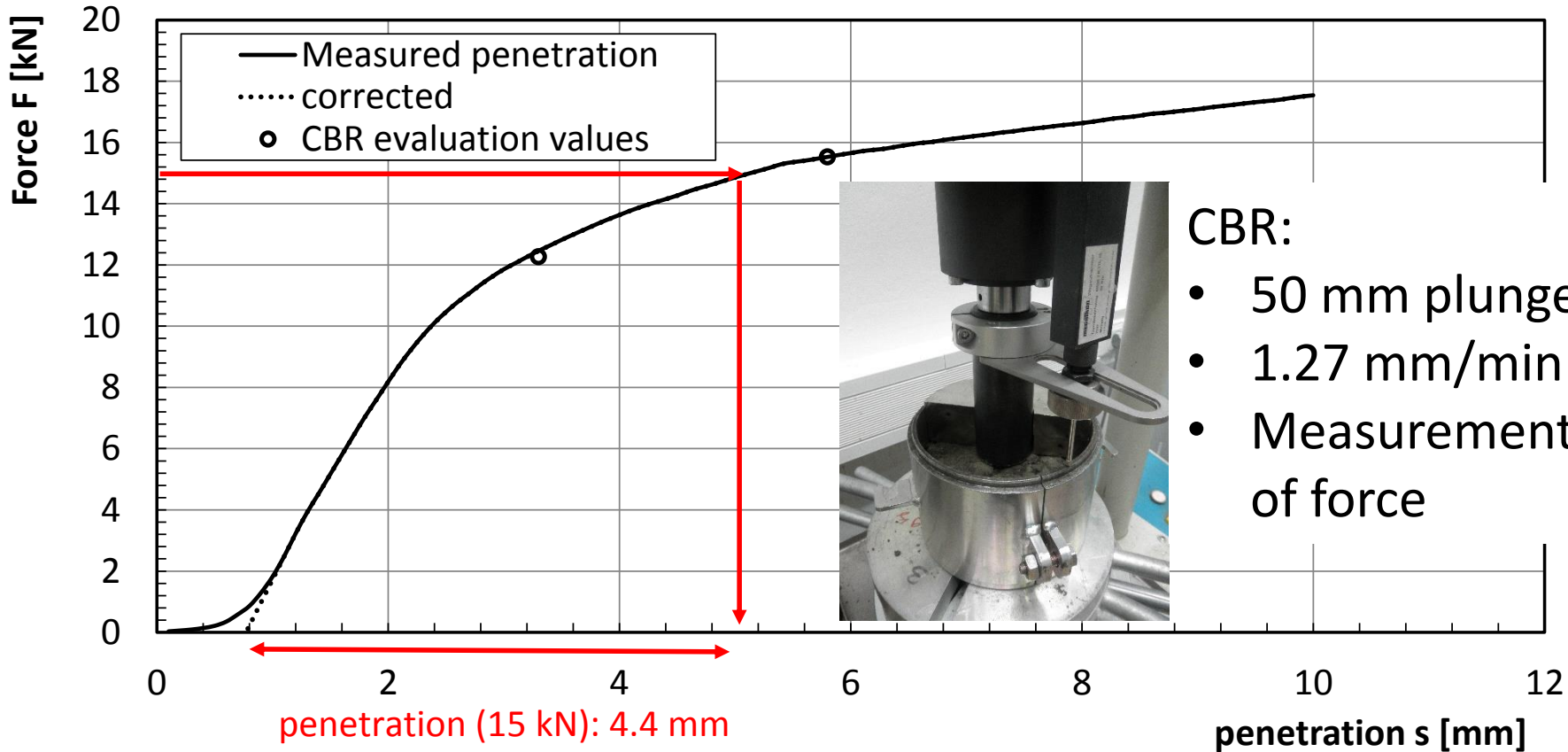
# Water susceptibility



- Water conditioning:  
14 days @ 40 °C
- Emulsion mixtures:  
Strength loss  
(re-emulsification)
- Foamed bitumen  
mixtures:  
Strength increase  
(hydration of active binder)



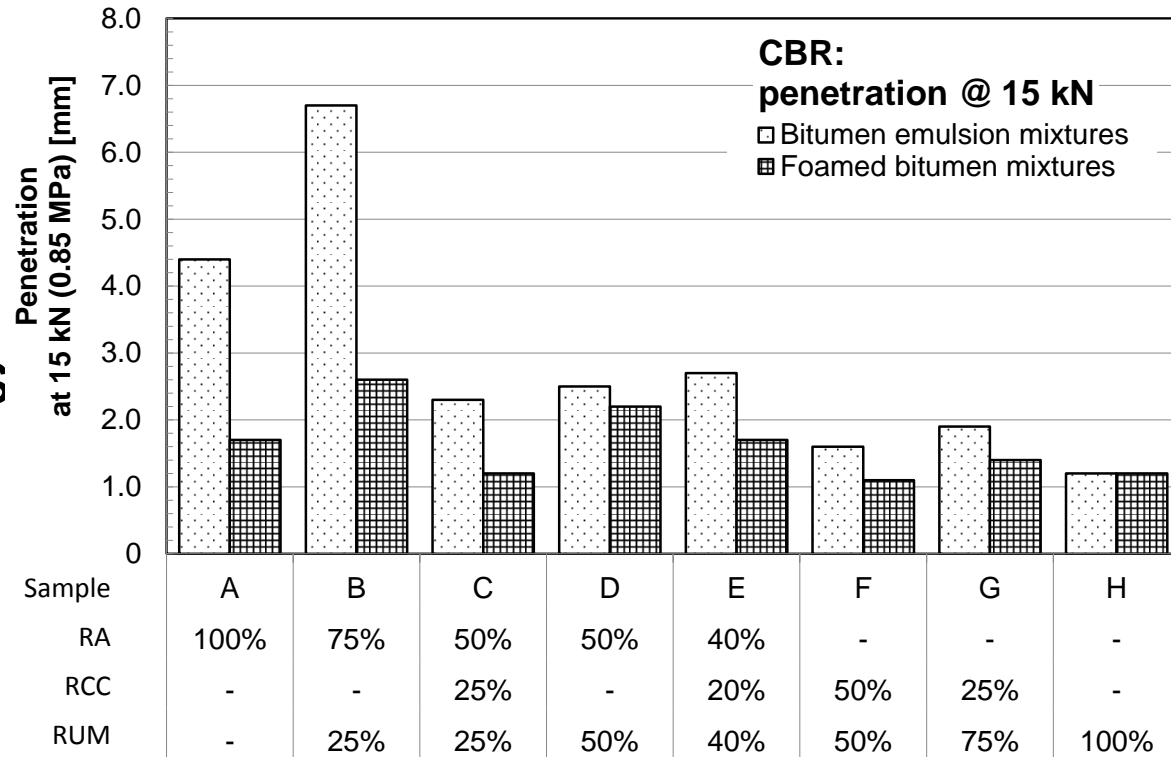
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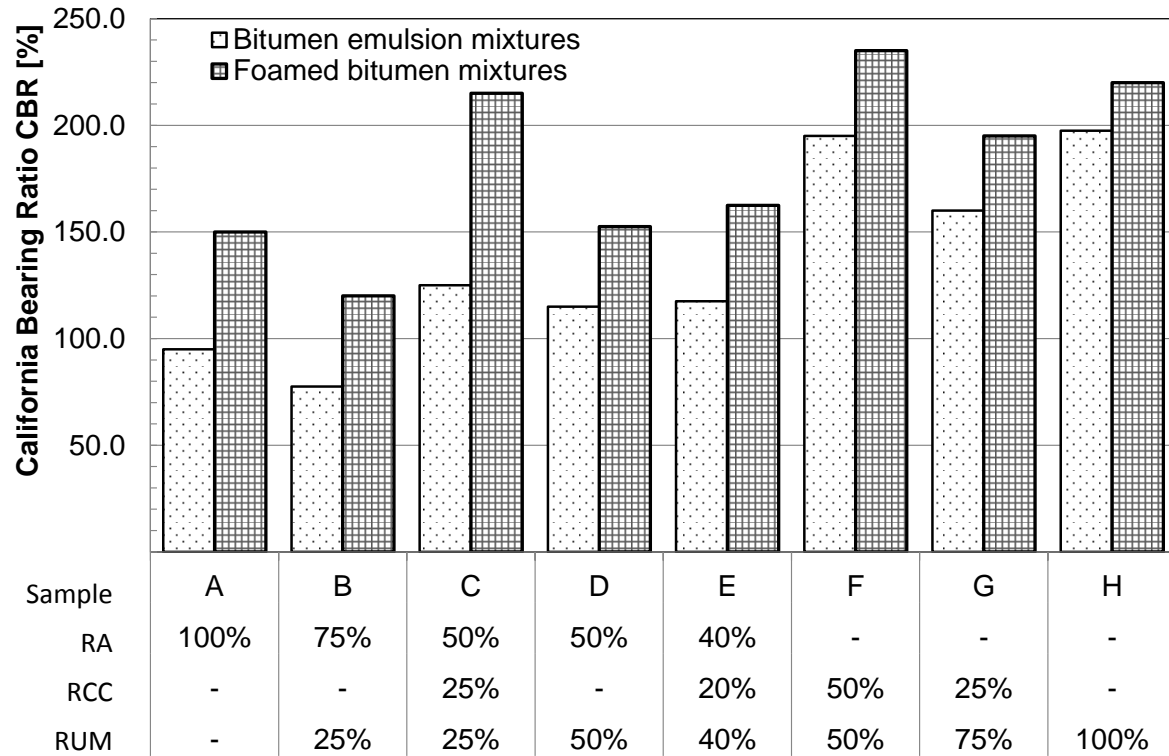
- Mixtures with RA indicate higher deformations in CBR
- Emulsion mixtures indicate higher deformations compared to foamed mixes



# CBR (rutting indicator)



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- Emulsion mixtures indicate higher deformations compared to foamed mixes

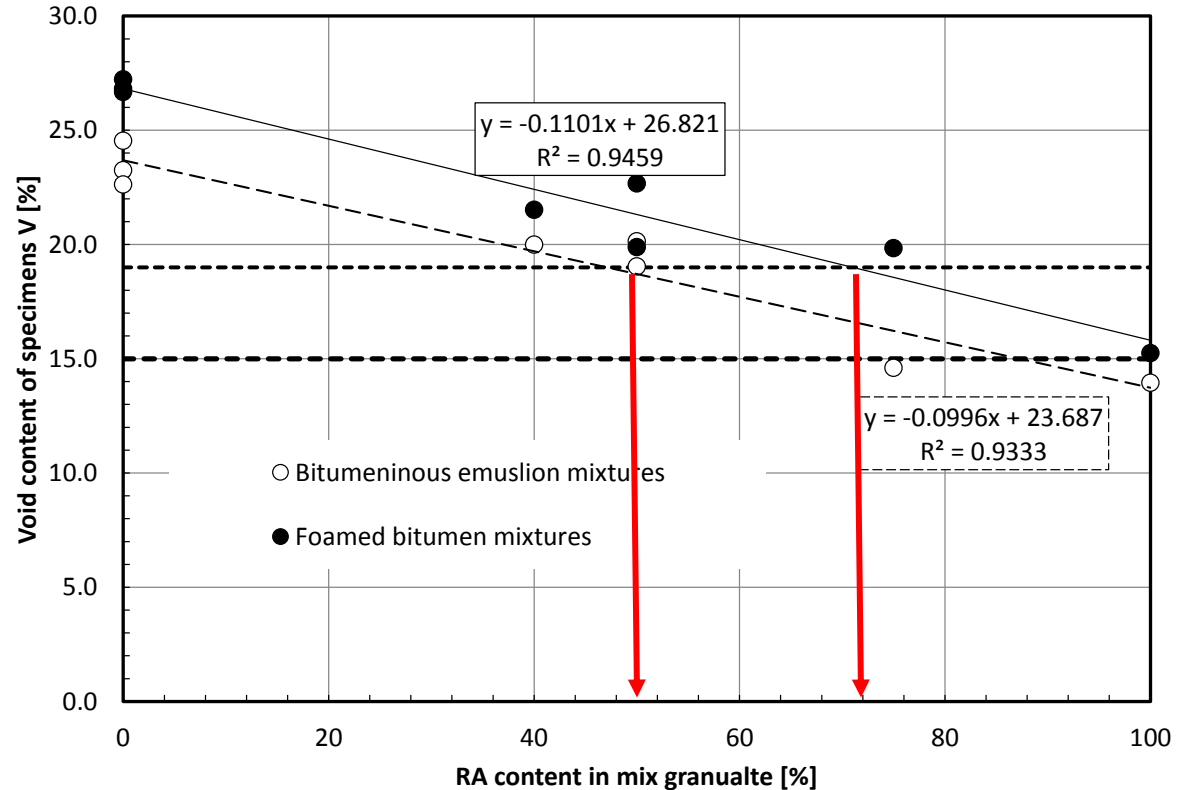


# Discussion of tolerances



German requirements on site conditions:

- $V < 19\%$
- $ITS > 0,75\text{ MPa}$

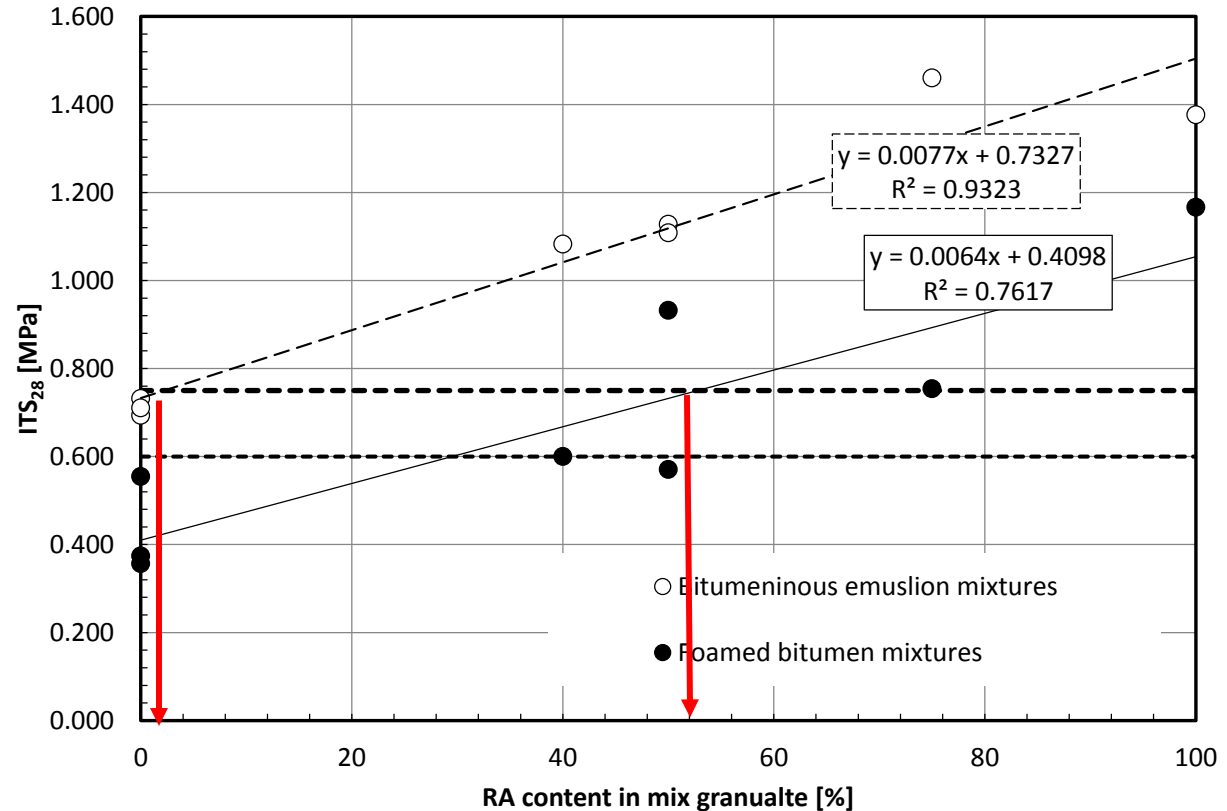


# Discussion of tolerances



German requirements on site conditions:

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# Conclusions

- Increased content of RA will result in:
  - Increased strength (ITS)
  - Increased deformation (by CBR) } RA binder activity
- Varying pavement composition may be tolerated, as identified by a maximum remaining RA content:
  - 75 % for foamed bitumen mixtures
  - 50 % for emulsion mixtures } Void content is limiting factor
- Recommendation to detailed mix design for known pavement variation



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