Hrvatsko asfaltersko društvo

Croatian asphalt association

Raziličite tehonologije hladnog in-situ reciklliranja u Europi i orgraničenja uvjetovana stanjima ceste

Variety of cold-in-place recycling technologies within Europe and limits regarding varying road conditions

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Međunarodni seminar ASFALTNI KOLNICI 2017
International seminar ASPHALT PAVEMENTS 2017
Opatija, 05.– 06. 04. 2017.

Cold Recycling Technologies in Europe: CoRePaSol-Project

- Cold recycling mixtures vary considerable in Europe
  - Binder types
    - Bitumen emulsion
    - Foamed bitumen
    - Cement
  - Binder contents
- Mix design procedures
  - Laboratory Compaction methods
  - Accelerated Curing procedures
  - Mechanical test methods
  - Specification values
- Project aim: Prepare harmonisation process

Characterization of advanced cold recycled bitumen stabilized pavement solutions

Project funded by CEDR 2013-2014

Content of presentation

- Cold Recycling-Technologies in Europe
  - Construction procedure
  - Variety of mix concepts
  - Effect of mix composition
  - Proposal for mix design
- Limits regarding varying road conditions
  - Results of laboratory project
  - Recommendations

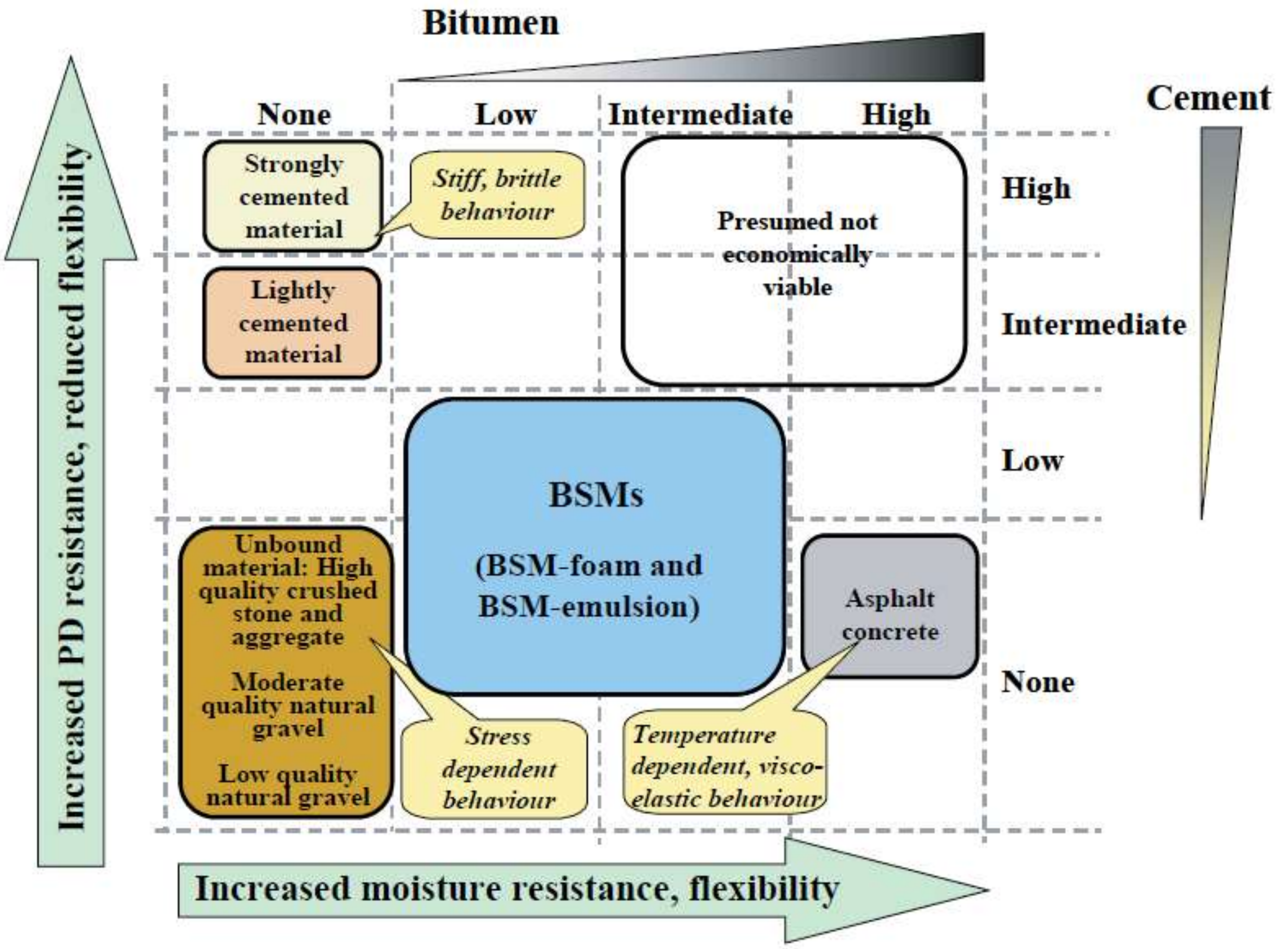
Cold Recycling: Mix and constrcution procedures

1. Milling / Granulation of existing pavement
2. Mixing crushed pavement material (in situ or in plant)
   - Bituminous binder (bitumen emulsion or foamed bitumen)
   - Cement (mineral binder or active filler)
   - Additional aggregates to adjust grading
3. Paving
4. Compaction
5. Construction of surface layer(s)

- Mixing and compaction at ambient temperatures require addition of water
- Water results in high voids content and reduced bearing capacity after construction and has to be removed from the layer:

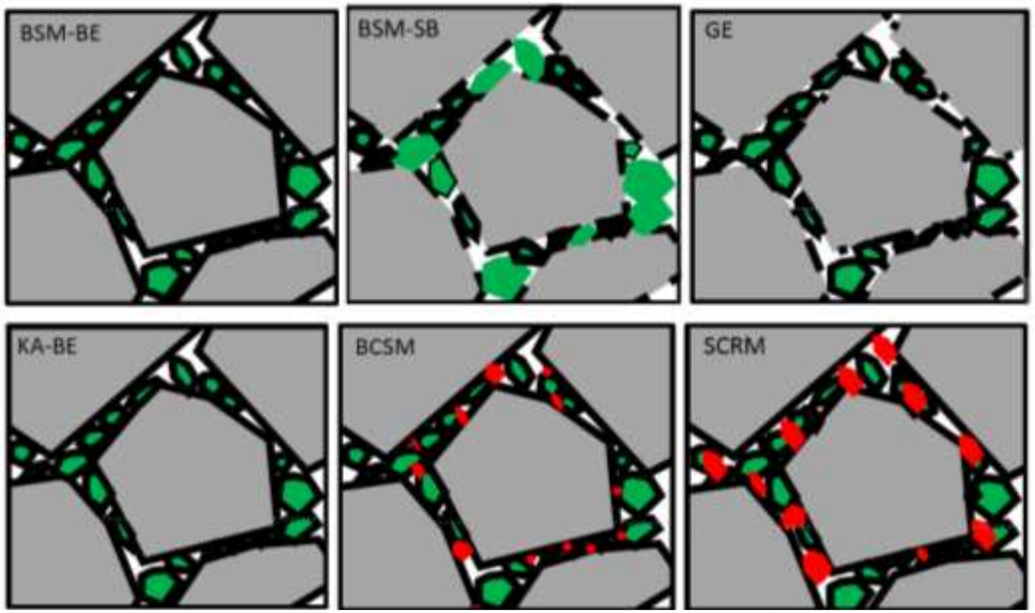
Evaporation/Drainage in warm climate – Addition of cement in moist climate

Cold recycled road materials: Variety of mixes



Collings et al., 2009

Cold recycled road materials: Variety of mixes



Type and degree of bonding affects:

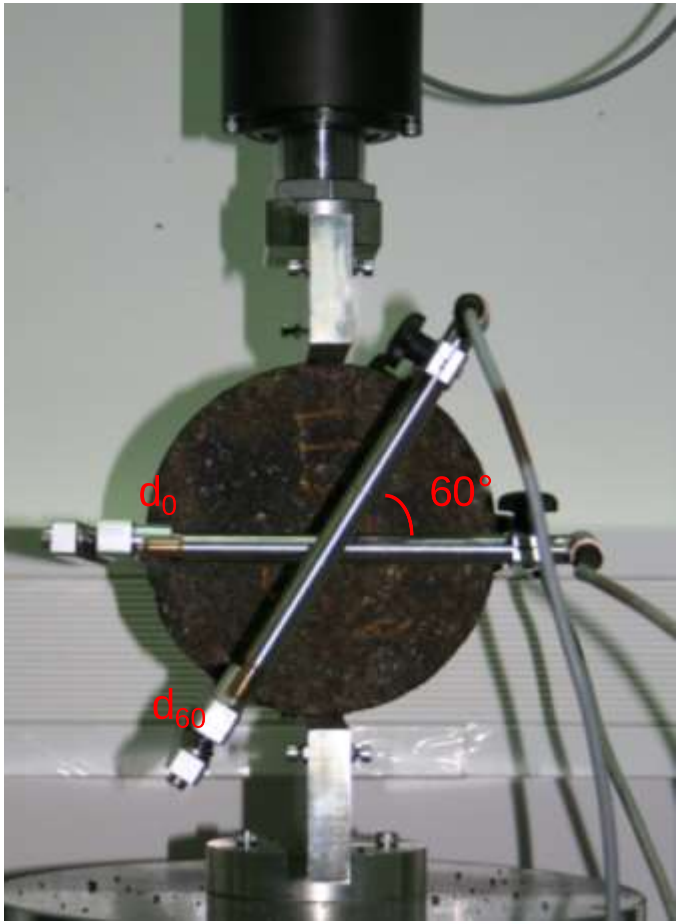
- Visco-ealsticity / stiffness
- Curing time
- Cracking / rutting resistance
- Water sensitivity

Type of material	Abb.	Binder (BE/FB)	Bitumen content	Cement content
Cold asphalt	CA	BE	~ 6 %	-
Grave Emulsion	GE	BE	≥ 3 %	-
Bitumen stabilised material	BSM-BE	BE	1 to 3 %	< 1 %
	BSM-FB	FB		
Bitumen-cement-stabilised material	BCSM-BE	BE	1 to 3 %	1 to 3 %
	BCSM-FB	SB		
Sealing cold recycled material	SCRM-BE	BE	3 to 6 %	1 to 6 %
	SCRM-FB	SB		

CoRePaSol: Proposed (harmonised) mix design procedure

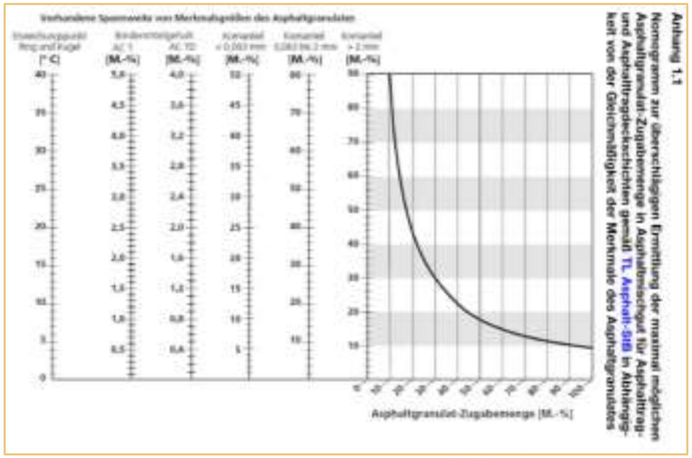
1. Pre-assessment of mix granulate
   - Continuous grading (concrete type)
   - Assessment of optimum moisture content (mod. Proctor)
2. Selection of binder content range
   - BSM for dry climate or soft subground (only with foamed bitumen)
   - CBSM for moist climate
3. Compaction of specimens for mechanical tests
4. Laboratory curing
   - BSM: 3 days oven drying @ 50 °C
   - CBSM: 28 days at room conditions
5. Specimen assessment
   - Void content (the lower the better)
   - Stiffness
   - Strength (e. g. Indirect tensile tests - ITS)

   both properties: higher values are better – however, not to be reached by excess addition of cement

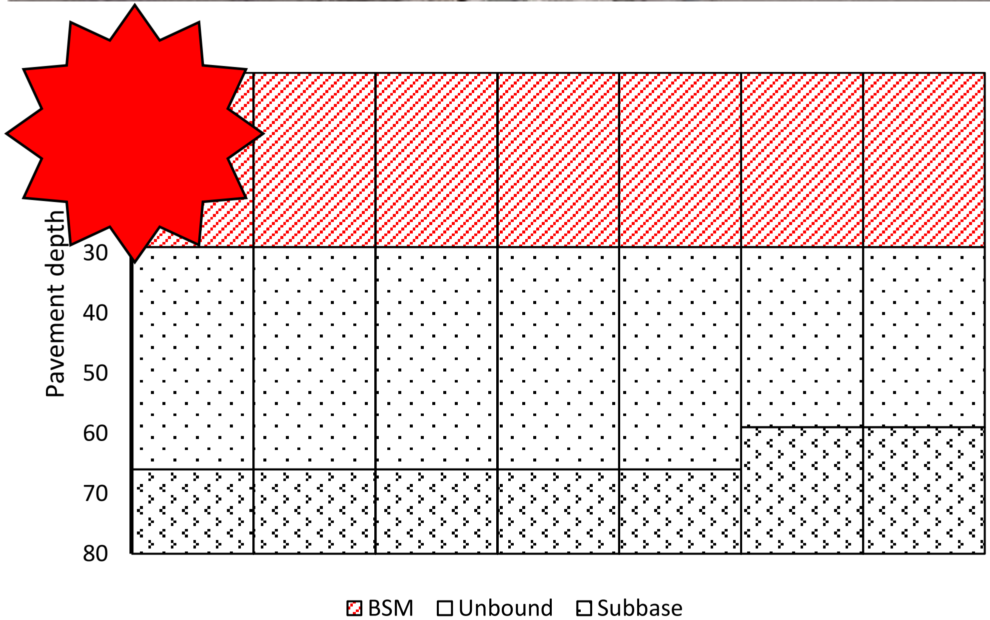


Limits for varying pavement conditions for cold recycling

- Homogeneity of reclaimed asphalt is a predominating property controlling the hot recycling process
  - Nomograms for allowed RA contents are available
  - RA content results of homogeneity of RA properties and allowed tolerances within mix composition (binder content, grading, …)
- For cold recycling, effects of non-homogeneious pavements are not known
- Changing structural properties are obstancles for Cold recycling (especially: cold-in-place)
- Research question (within CoRePaSol-project):
  - What are the limits of homogeneities for cold recycling process?
  - What is the effect of (aged) bitumen in recycled asphalt within cold recycling mixtures?



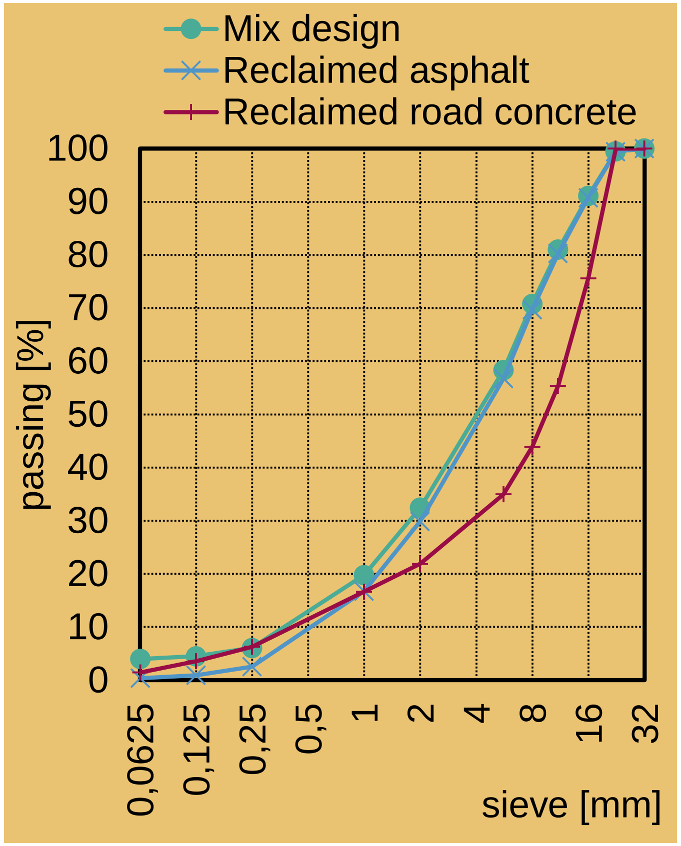
Limits for varying pavement conditions for cold recycling



- Conditions of pavement to be rehabilitated can vary
  - „grown“ road with multiple maintenances during last centuries/decades
  - Road widening on one side
  - Small repair sections
- Varying parameters:
  - Layers (materials)
  - Thickness
  - Conditions
- In given milling horizon:
  - Asphalt layers
  - Hydraulically bound layers
  - Unbound layers
- Transversal and longitudinal differences

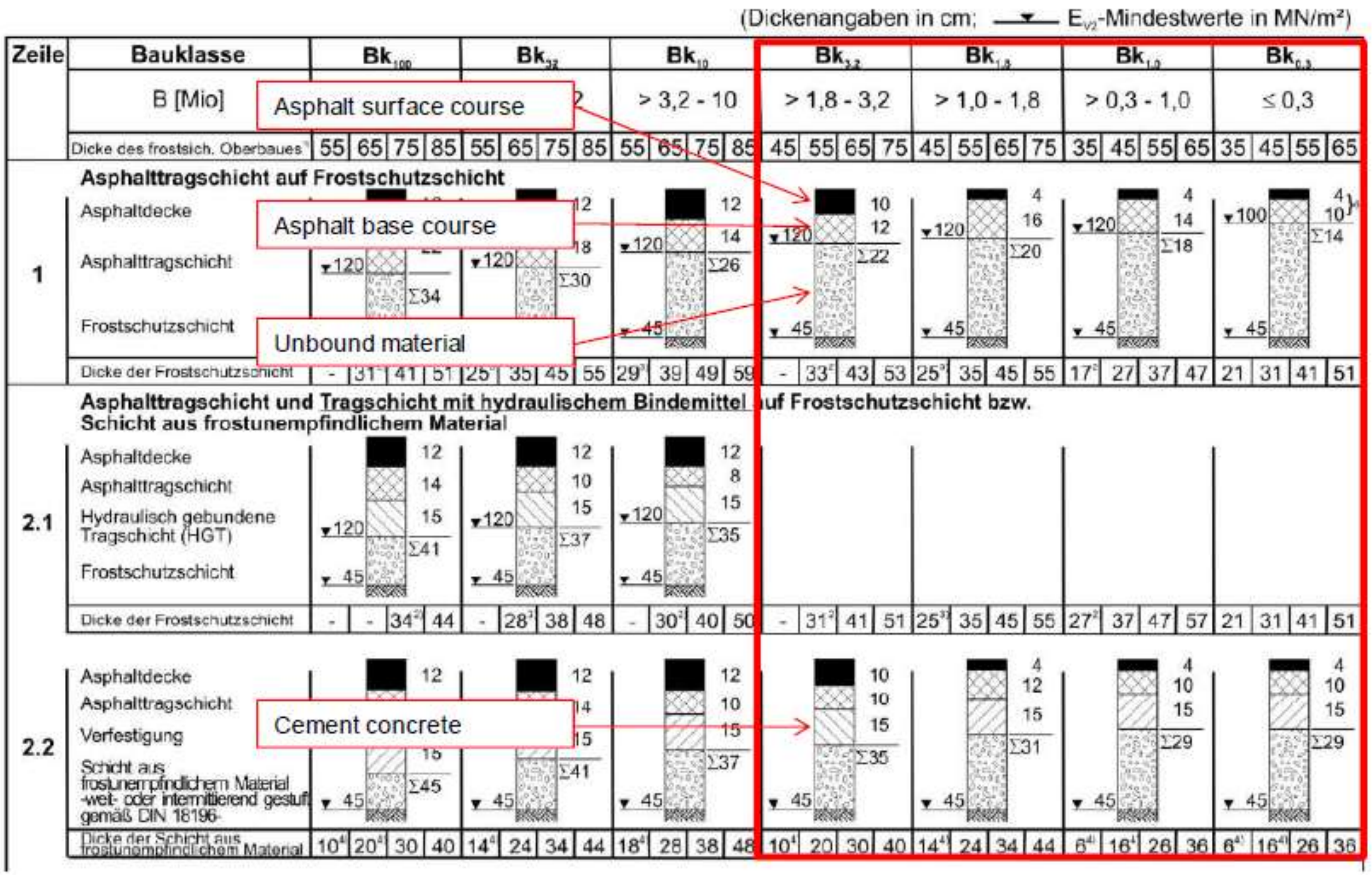
Laboratory study: Effect of mix granulate composition on cold recycled material

- Reclaimed asphalt 0/16
  - Binder content: 5.4 %,
  - $T_{R\&B}$: 63.5°C,
  - Pen 23 1/10 mm
- Reclaimed road concrete 0/22
- Basaltic aggregates (to simulate reclaimed unbound base)



- Mix design (BCSM):
  - Addition of 3,6 % limestone filler to adjust grading
  - 4 % added bitumen content
    - a) Foamed bitumen 50/70
    - b) Bitumen emulsion
  - 2 % cement
  - Moisture content: 7,8 %

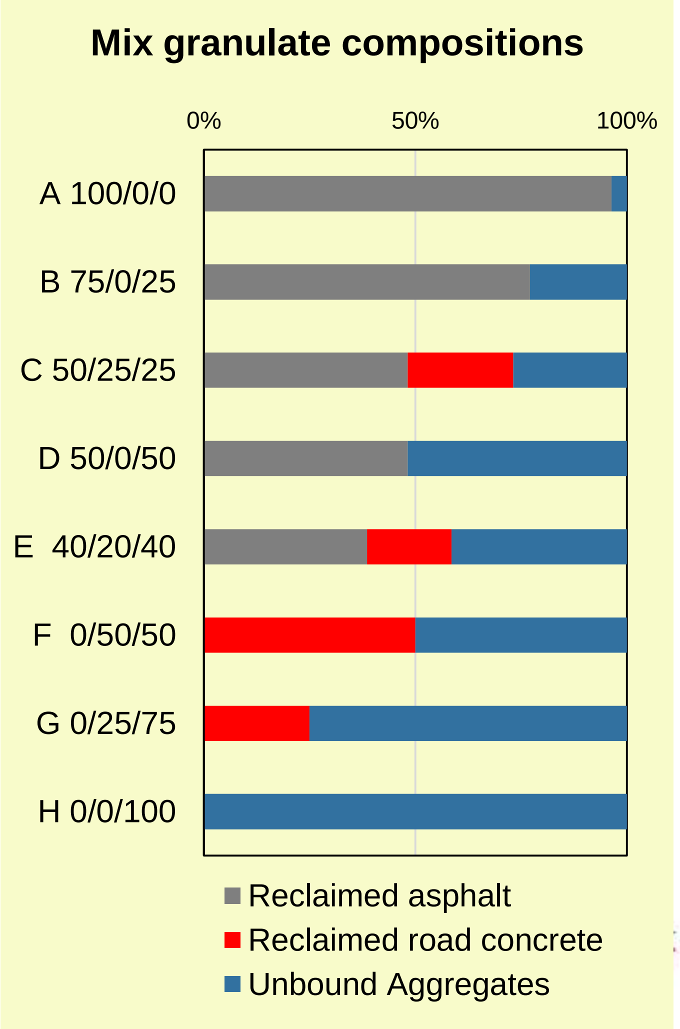
Selection of mix variations



- 100 % reclaimed asphalt
- Reclaimed asphalt + unbound base
- Reclaimed asphalt + reclaimed road concrete
- Reclaimed asphalt + reclaimed road concrete + unbound base

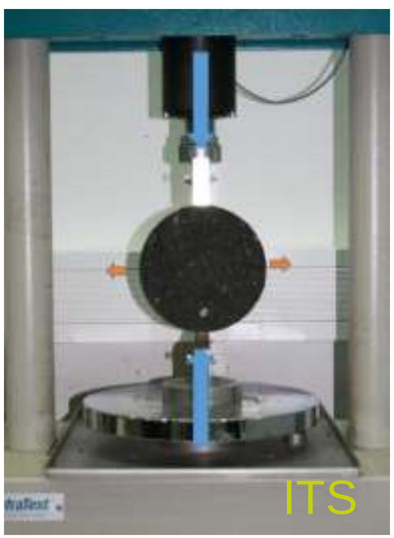
Laboratory study: Effect of mix granulate composition on cold recycled material

Mix variations	Reclaimed asphalt (RA)	Reclaimed road concrete (RRC)	Unbound material (unb.)
A 100/0/0	96,4	-	3,6
B 75/0/25	77,1		22,9
C 50/25/25	48,2	25,0	26,8
D 50/0/50	48,2	-	51,8
E 40/20/40	38,6	20,0	41,4
F 0/50/50	-	50,0	50,0
G 0/25/75		25,0	75,0
H 0/0/100	-	-	100,0



Cold recycling mix composition and test program

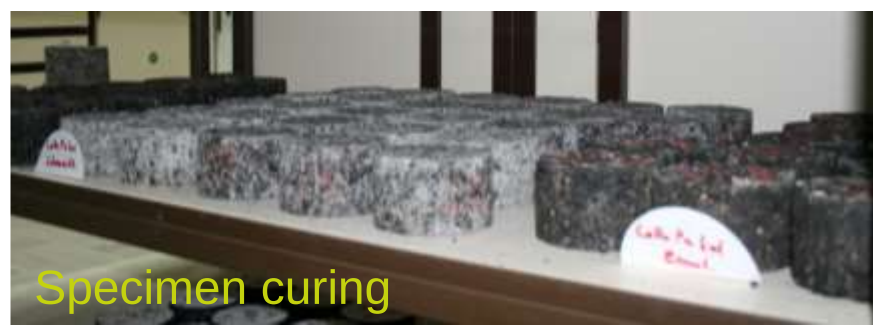
Mix preparation


ITS

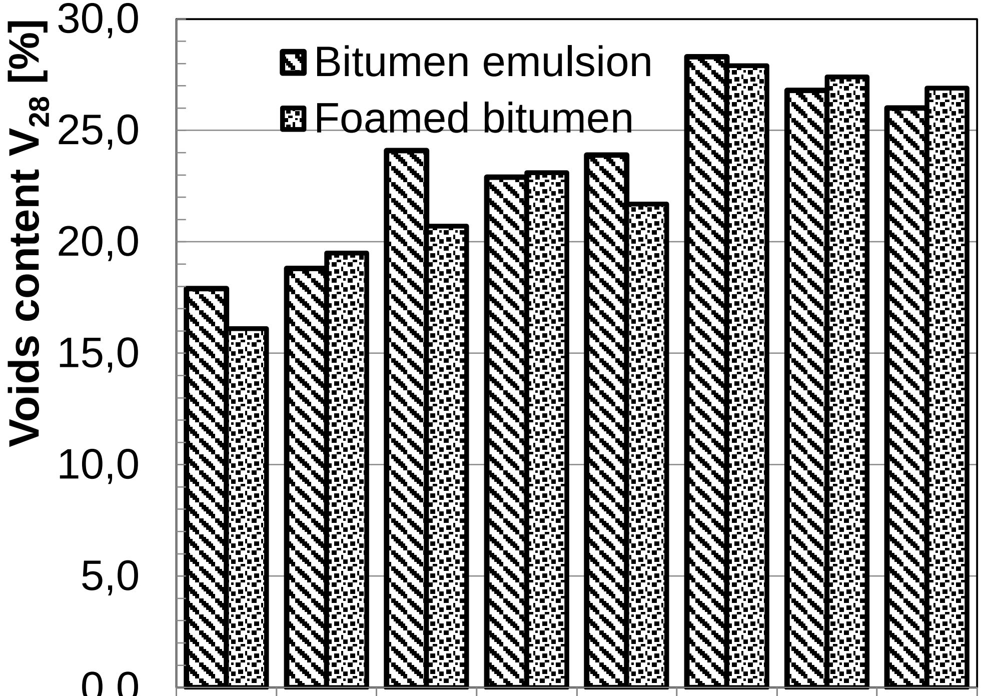
CBR

Test program:

- Static compaction (30 s á 45.9 kN)
- Specimen curing:
  - 1 day in mould
  - 2 days in mould (~ 20 °C)
  - 25 days at room conditions
- Tests
  - Bulk density & void content
  - Indirect tensile strength (5 °C)
  - Water sensitivity (ITS dry vs. 14 days in water)
  - CBR_{dry} (California Bearing Ratio)


Specimen curing

Results: Void content after 28 days of (dry) curing at room conditions



Sample	A	B	C	D	E	F	G	H
RA	100%	75%	50%	50%	40%	-	-	-
RRC	-	-	25%	-	20%	50%	25%	-
unb.	-	25%	25%	50%	40%	50%	75%	100%

- Comparably high void contents
  - Low compaction energy (lower compared to field compaction)
  - Coarse mix with low fines content
- Mixtures containing RA are better to compact compared to mixtures without RA
- Little effect of reclaimed road concrete vs. unbound aggregates
- Similar void content for emulsion and foamed bitumen mixtures

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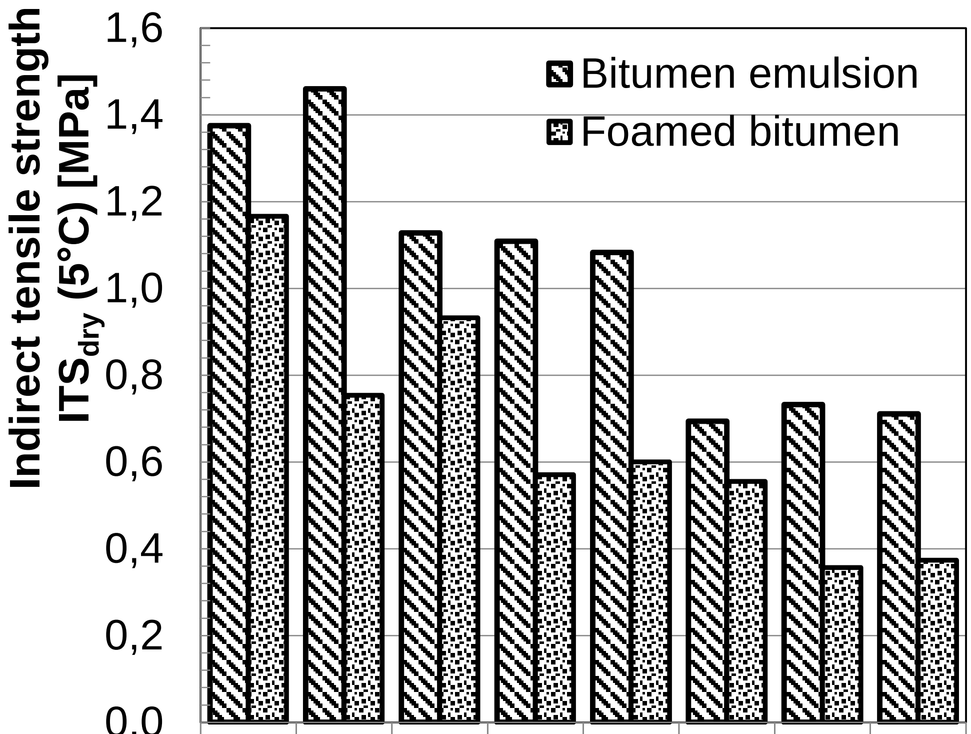
Results: Indirect tensile strength ITS_{dry} after 28 days of curing (5 °C)



	A	B	C	D	E	F	G	H
RA	100%	75%	50%	50%	40%	-	-	-
RRC	-	-	25%	-	20%	50%	25%	-
unb.	-	25%	25%	50%	40%	50%	75%	100%

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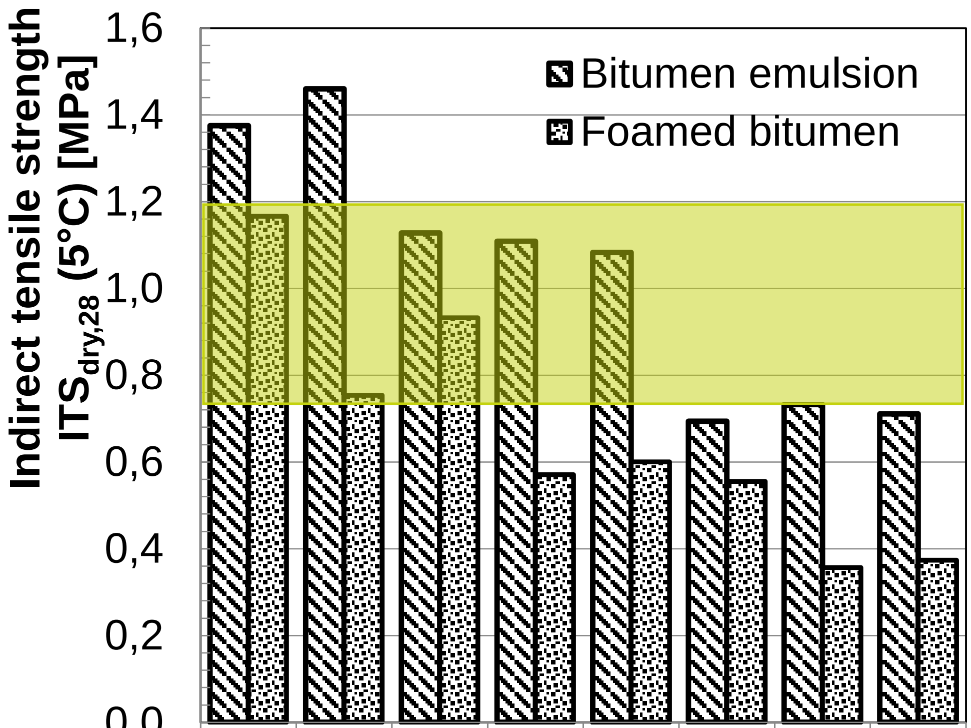
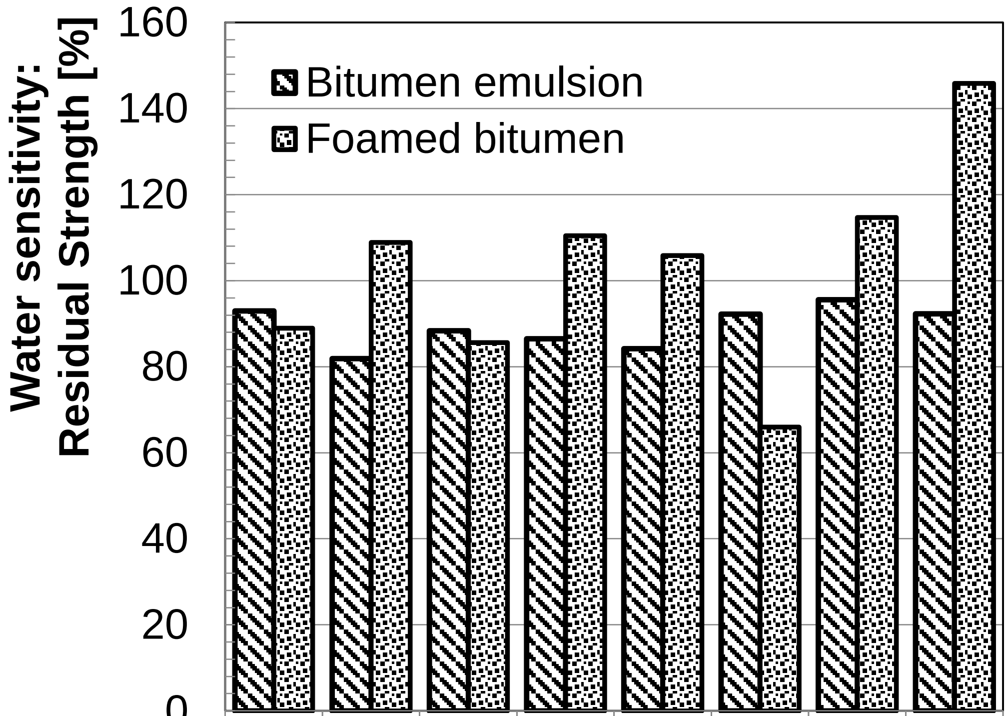
Results: Indirect tensile strength ITS_{dry} after 28 days of curing (5 °C)



Sample	A	B	C	D	E	F	G	H
RA	100%	75%	50%	50%	40%	-	-	-
RRC	-	-	25%	-	20%	50%	25%	-
unb.	-	25%	25%	50%	40%	50%	75%	100%

- German specification:
  - $ITS_{dry,28} \geq 0{,}75$ MPa
  - $ITS_{dry,28} \leq 1{,}2$ MPa
- Mixtures with bitumen emulsion show higher strength compared to mixtures with foamed bitumen
- Higher RA content results in higher strength
  - Lower void content
  - Higher flexibility
- Increase of RRC compared to unbound aggregates:
  - Same strength in emulsion mixtures
  - Higher strength in foamed bitumen mixtures

Water sensitivity: ITS_{dry}/ITS_{wet} [%] – 14 days water saturation at 20 °C



Sample	A	B	C	D	E	F	G	H
RA	100%	75%	50%	50%	40%	-	-	-
RRC	-	-	25%	-	20%	50%	25%	-
unb.	-	25%	25%	50%	40%	50%	75%	100%

- Comparison between ITS of dry cured specimen with saturate, wet-cured specimen
- Emulsion mixtures:
  - Little strength loss (~ -10 %)
  - No effect of RA or RCC content
- Foamed bitumen mixtures:
  - For most mixtures strength increase (cement hydration)
  - Strength decrease for mixtures with RRC – resulting from higher dry strengths

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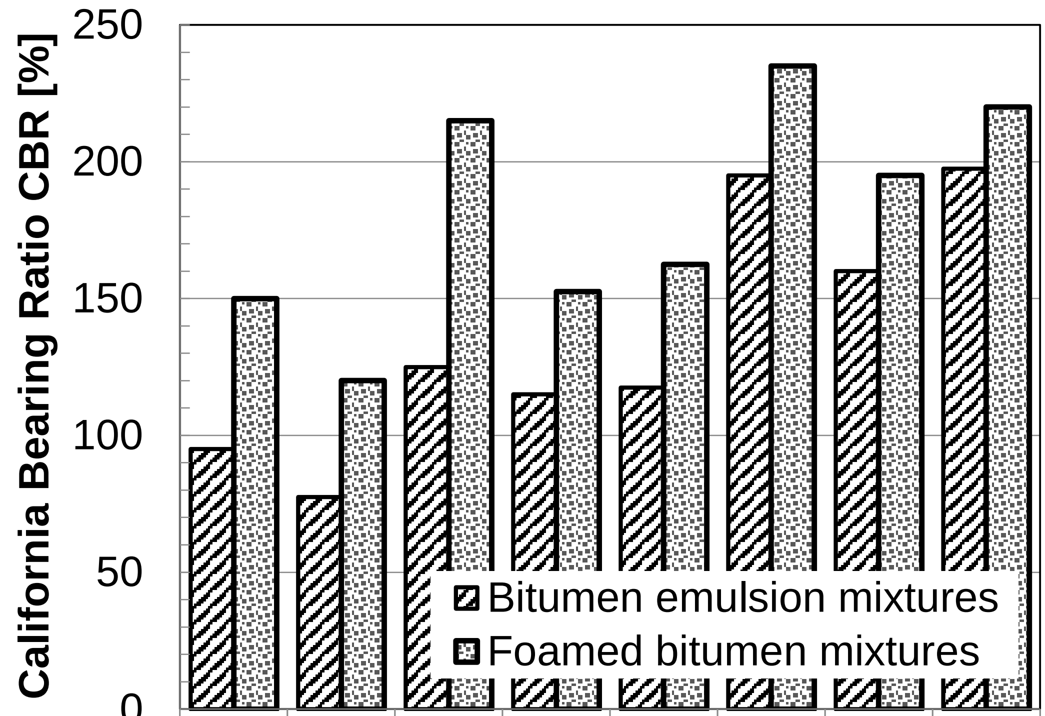
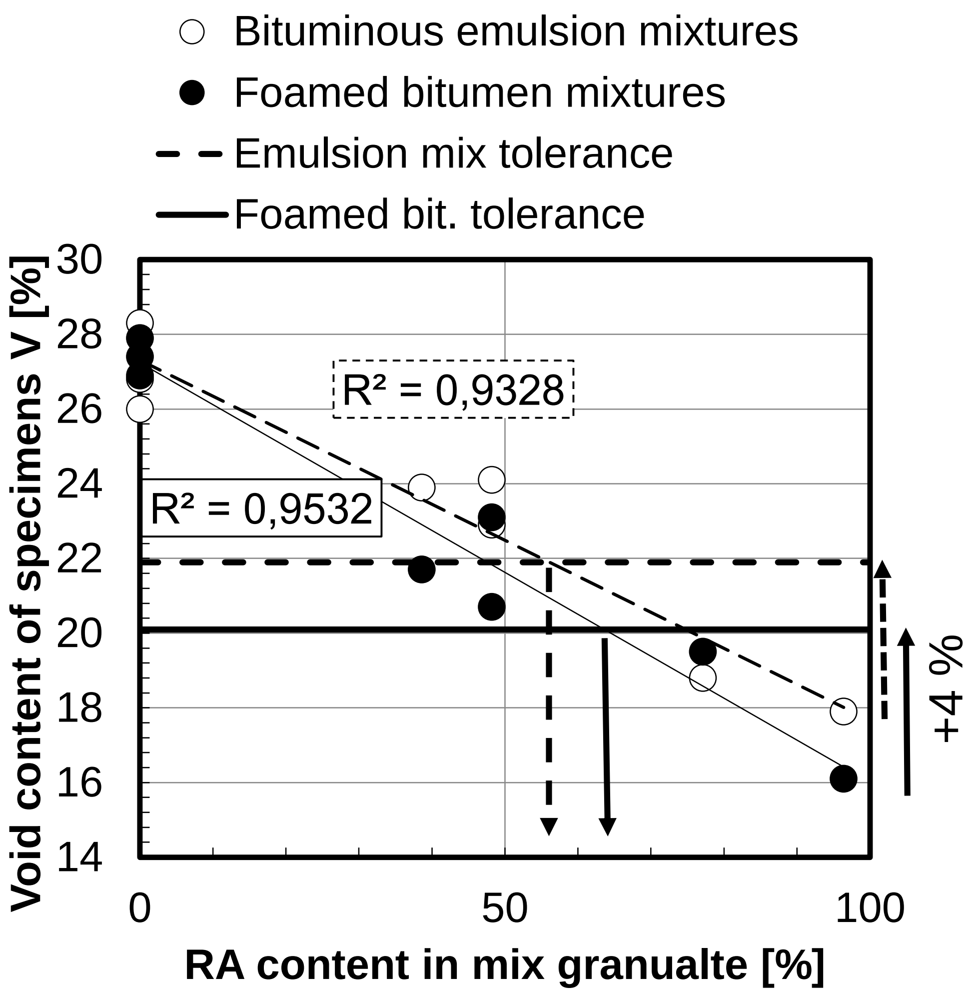
Results: California Bearing Ratio CBR_{dry} as indicator for resistance against permanent deformation (test temperature: 20 °C)



Sample	A	B	C	D	E	F	G	H
RA	100%	75%	50%	50%	40%	-	-	-
RRC	-	-	25%	-	20%	50%	25%	-
Unb.	-	25%	25%	50%	40%	50%	75%	100%

- Increase RA content results in lower CBR-ratio (higher deformation)
  - RA bitumen is still „active“ in cold recycled mixtures
  - RA flexibility results in deformation
- Foamed bitumen mixtures indicate higher CBR (lower deformation) compared to emulsion mixtures
  - Lower shear deformation between mix aggregates
  - Better aggregate interlock

Discussions on limits regarding non-homogeneities of pavement structures: Void content requirements



- German specification for in-situ control tests:
  - Tolerance for void content compared to mix design: +4%
- Required RA content in actual mix granulate (on site):
  - Bitumen emulsion: 55 %
  - Foamed bitumen: 65 %

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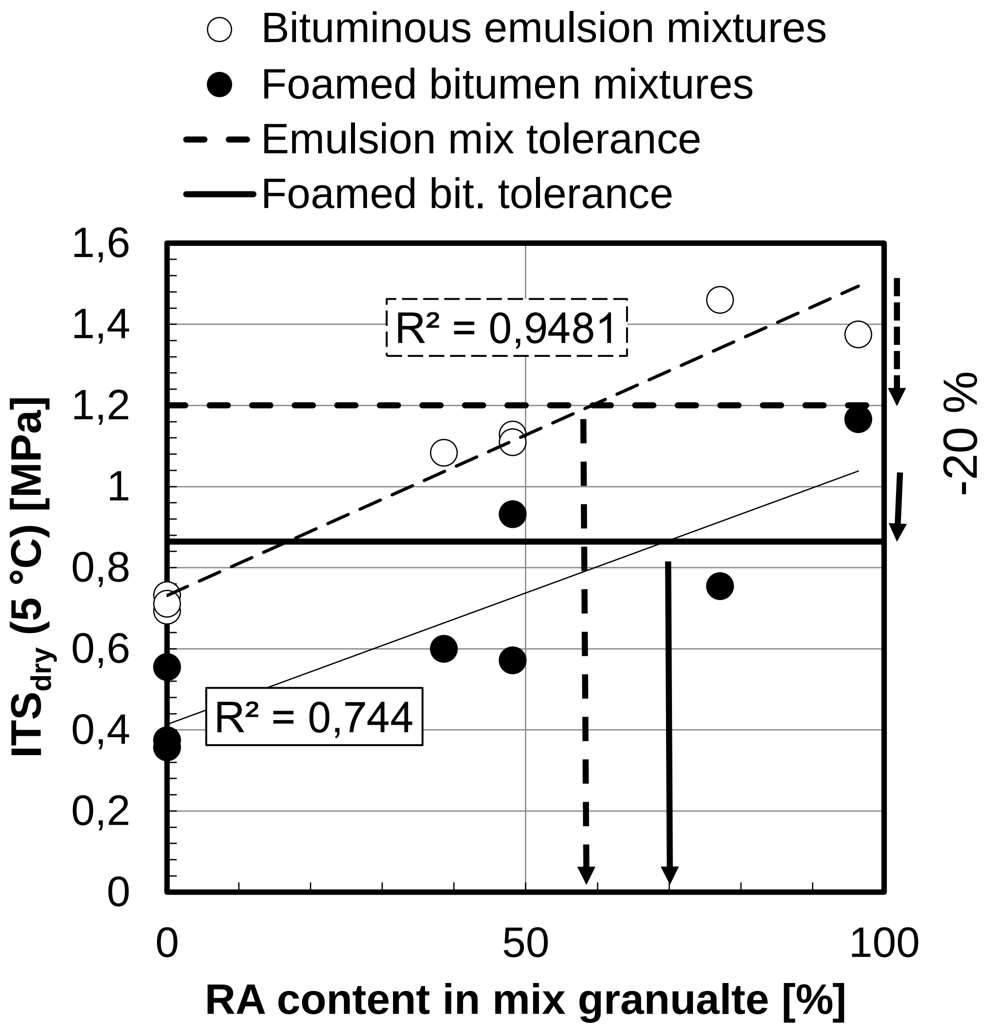
Discussions on limits regarding non-homogeneities of pavement structures: ITS requirements



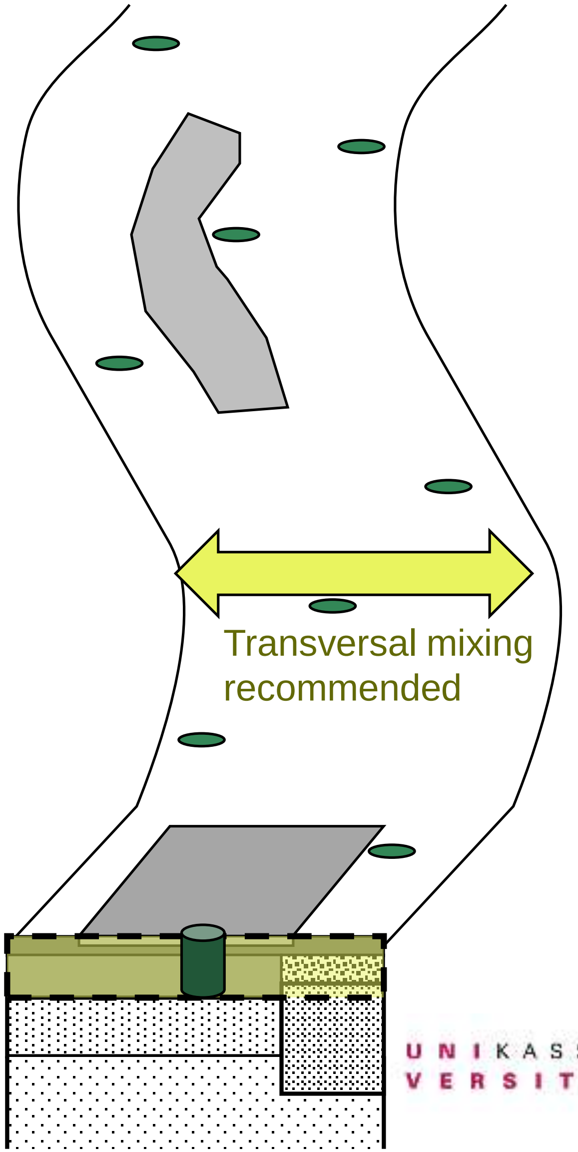
- German specification for in-situ control tests:
  - Tolerance for ITS compared to mix design: -20 % (+ 30 %)
- Required RA content in actual mix granulate (on site):
  - Bitumen emulsion: 55 %
  - Foamed bitumen: 70 %

Conclusions regarding allowed tolerances on structural variability

- Conclusions valid for following cold recylcing mix properties
  - CBSM (foamed bitumen and bitumen emulsion)
  - Residual bitumen content: 4 %
  - Cement content: 2 %
  - Same grading of mix granulate
- RA content in mix granulate is predominating property
- Limit of allowed RA-content in mix granulate
  - Bitumen emulsion mix: RA ≥ 55 %
  - Foamed bitumen mix: RA ≥ 70 %
- Bitumen within RA is significantly “active” within cold recycling mixtures

Recommendations

- Assess pavement structure prior to recycling works thoroughly:
  - Assess structural history (locals)
  - Coring for assessment of structure along the road with varying transversal positions
- Ensure best homogenisation of mix granulate:
  - transversal mixing will reduce effects of varying structural properties
- Apply In-plant (cold) recycling
  - In case of highly varying structural properties
  - In case of high quality requirements (traffic loading)



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Hvala na pažnji

Thank you very much for your attention