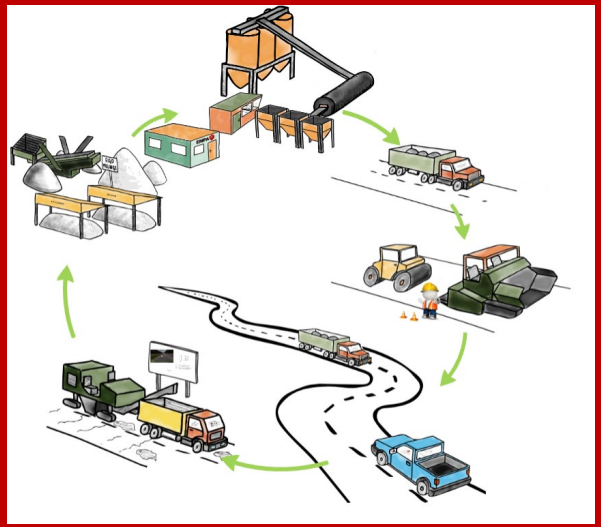
Empa
Materials Science and Technology



Hot asphalt recycling

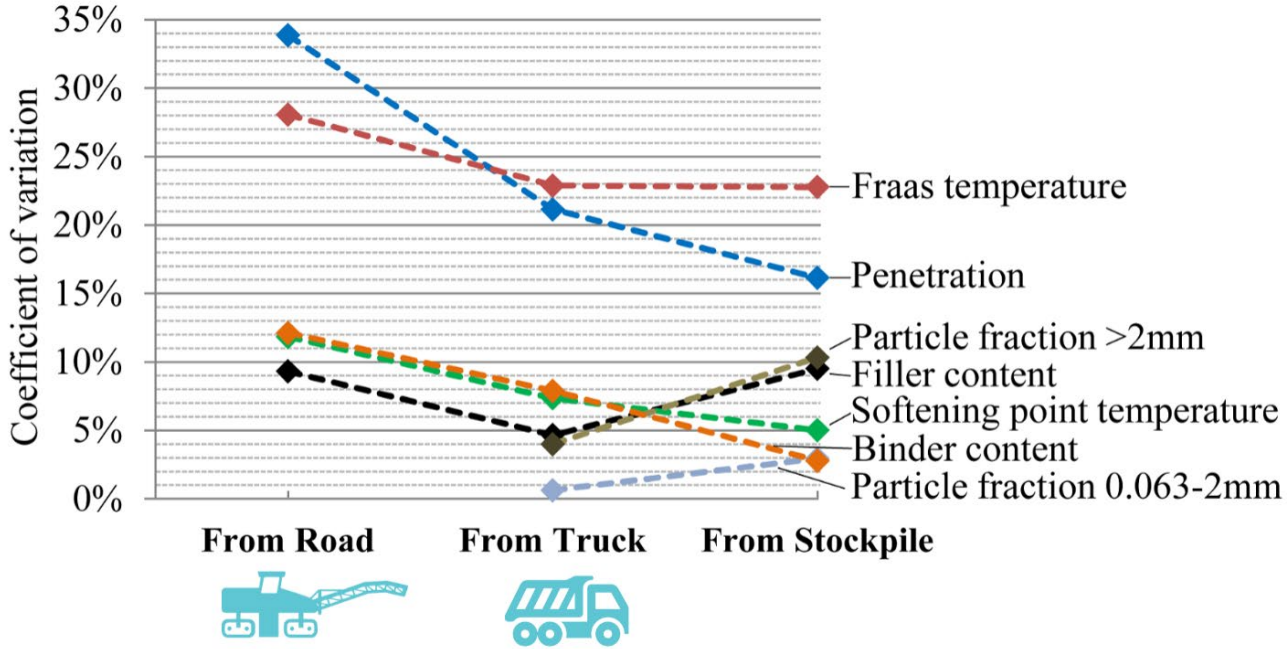
Martins Zaumanis

ART 2024, 9th of September, 2024

Reclaimed asphalt homogeneity

Paper: How to reduce reclaimed asphalt variability: A full-scale study

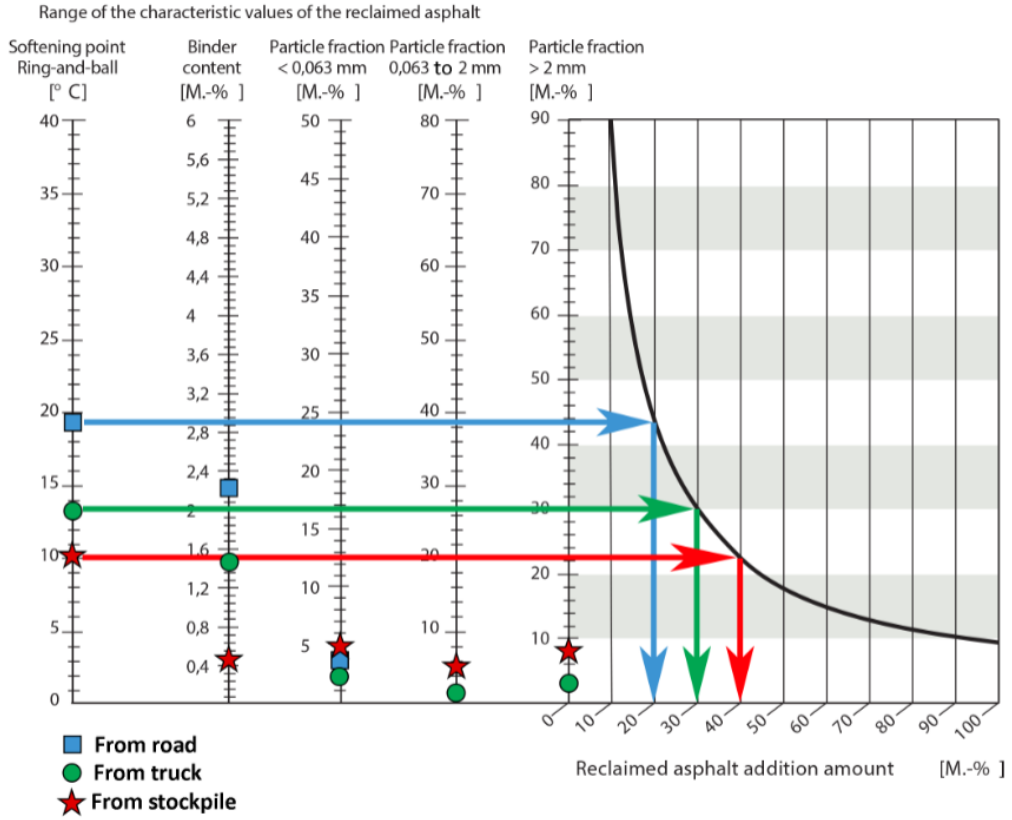
The variability of RAP can be reduced



Prezi

"How to reduce reclaimed asphalt variability: A full-scale study"

The variability of RAP can be reduced

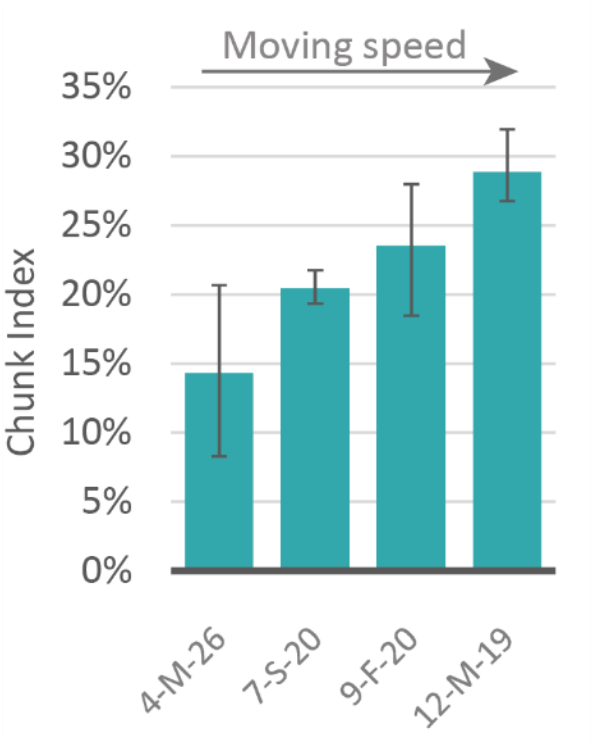


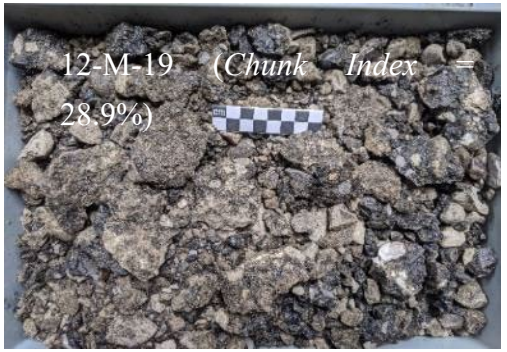
Asphalt milling

Paper: Impact of milling machine parameters on the properties of reclaimed asphalt pavement

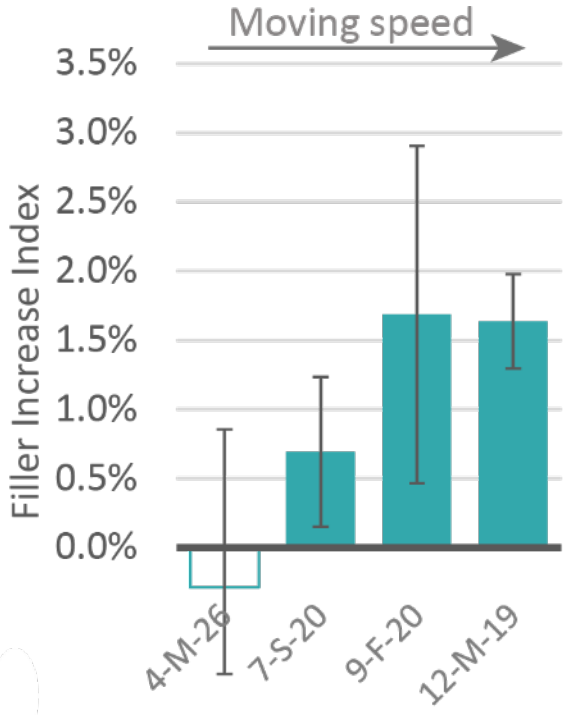
Milling parameters impact the RAP properties. But which parameters and how?

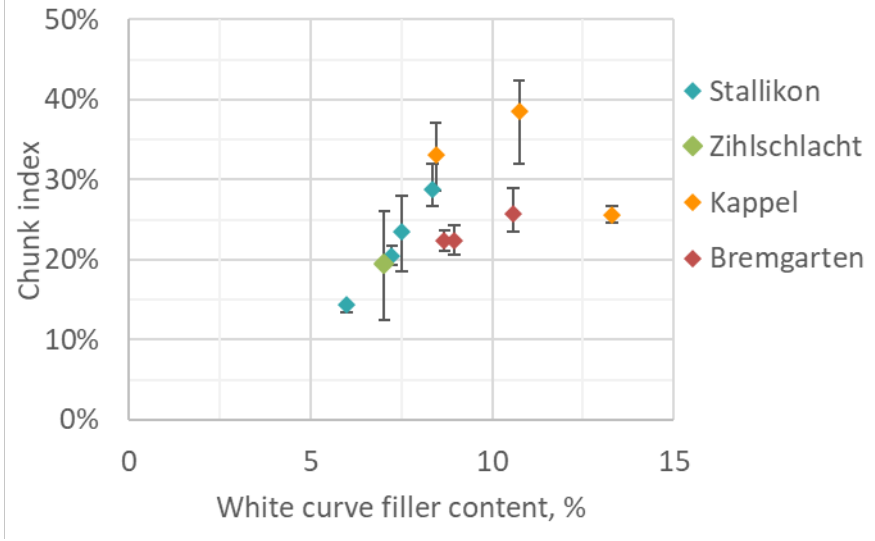
The size of RAP agglomerations increase with higher milling speed





Less filler is generated at lower milling speed





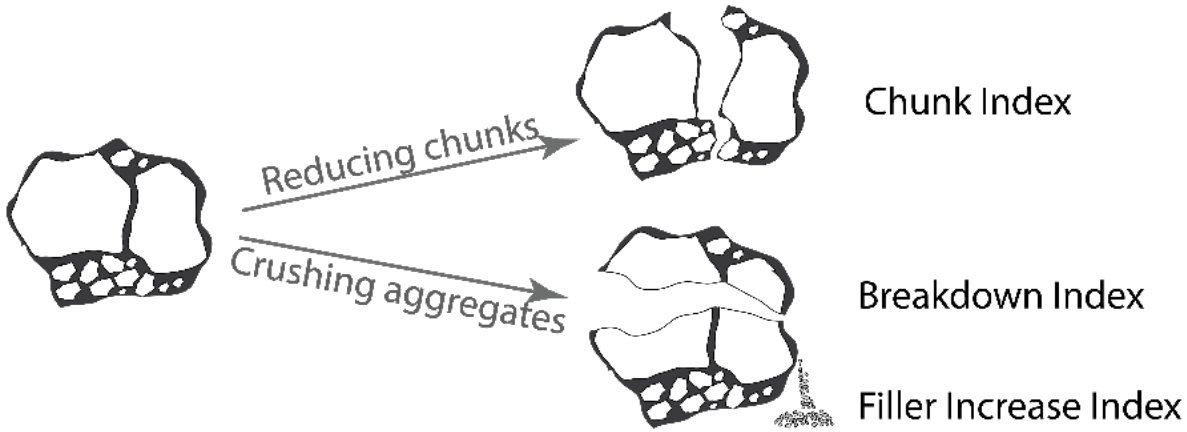
RAP processing

Paper: Three indexes to characterise crushing and screening of reclaimed asphalt pavement

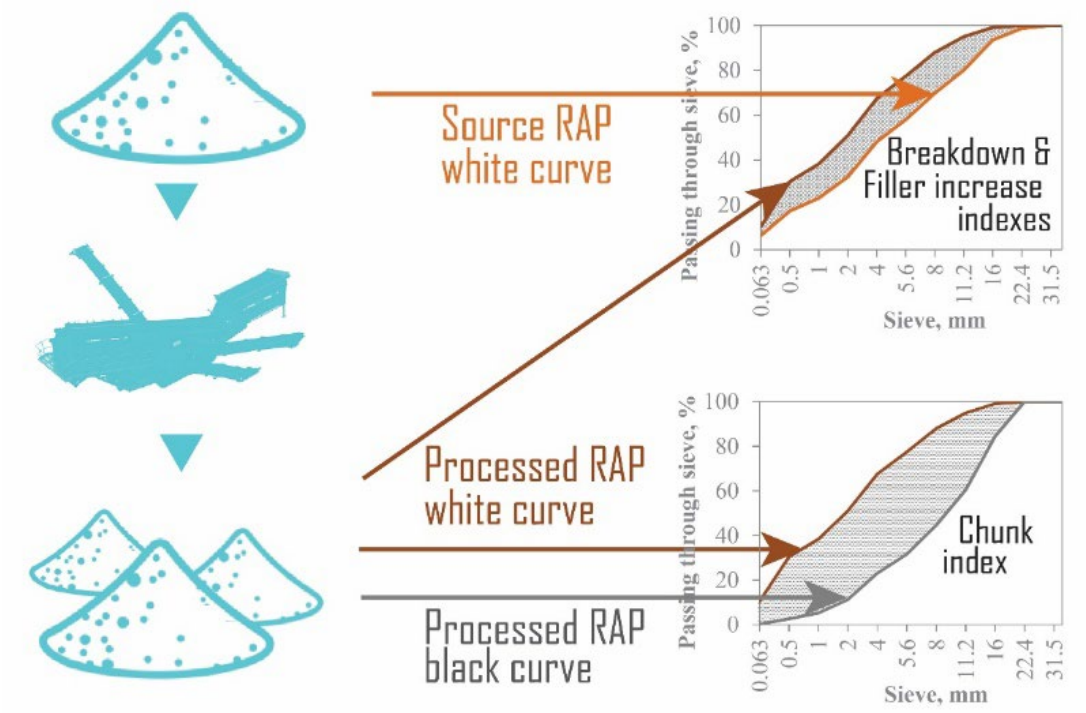
Four different crushers were used for the experiment

Three indexes that allow evaluating crushing and screening of RAP were developed:

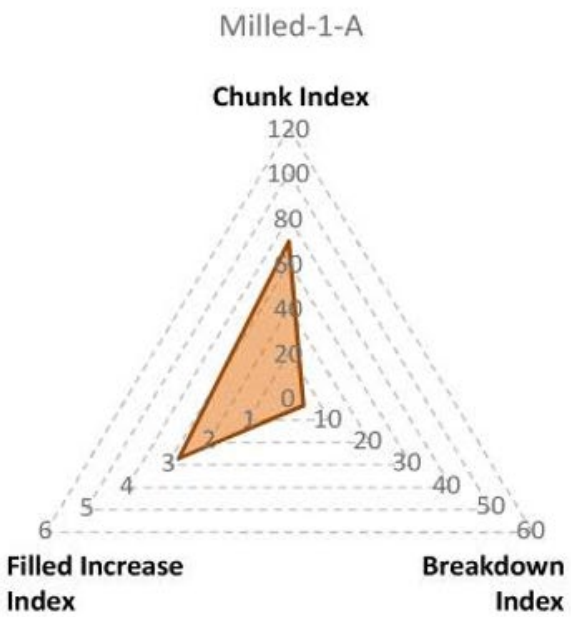
- **Chunk Index** demonstrates the size of RAP agglomerations.
- **Breakdown Index** demonstrates the reduction of RAP aggregate particle size during processing.
- **Filler Increase Index** reflects the amount of generated filler content during RAP processing.

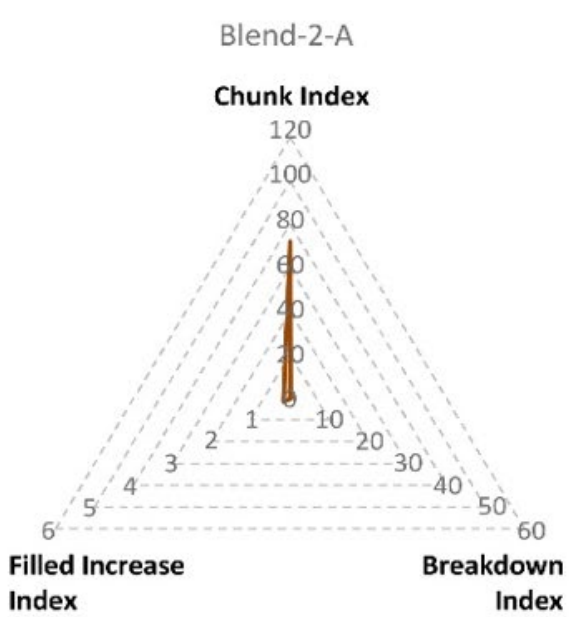


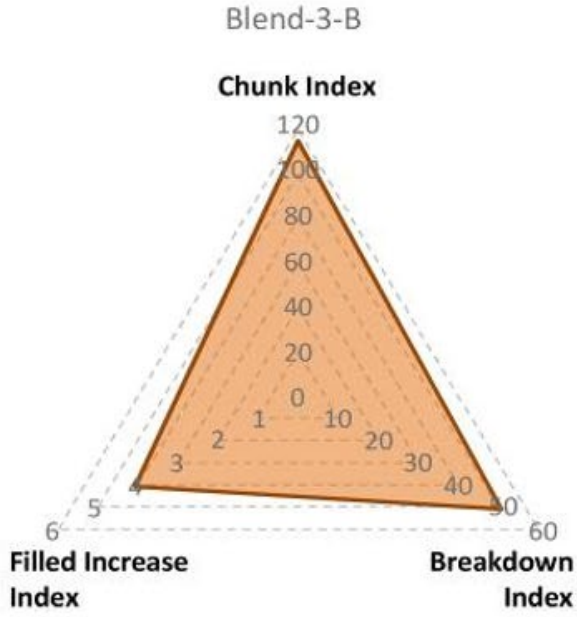
The indexes can be determined using gradation analysis of RAP before and after binder extraction.



A radar chart allows comparing different RAP crushing methods and optimize the crusher parameters







Smaller area = better RAP processing

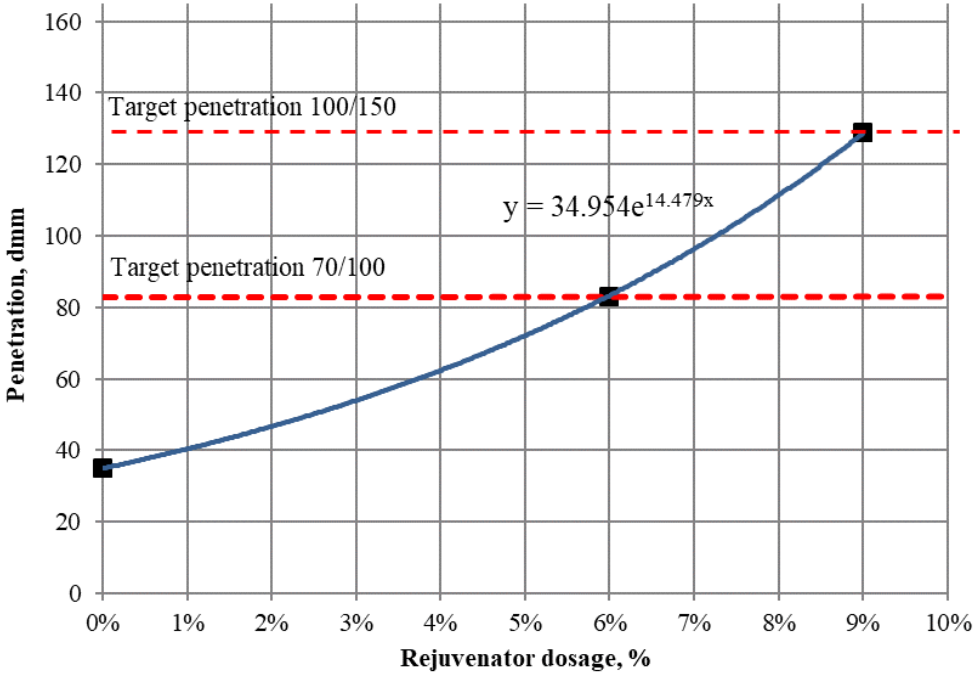
Calculator is available for download: https://doi.org/10.5281/zenodo.5500154

Rejuvenators

Papers: 100% recycled high-modulus asphalt concrete mixture design and validation using vehicle simulator

Determining optimum rejuvenator dose for asphalt recycling based on Superpave performance grade specifications

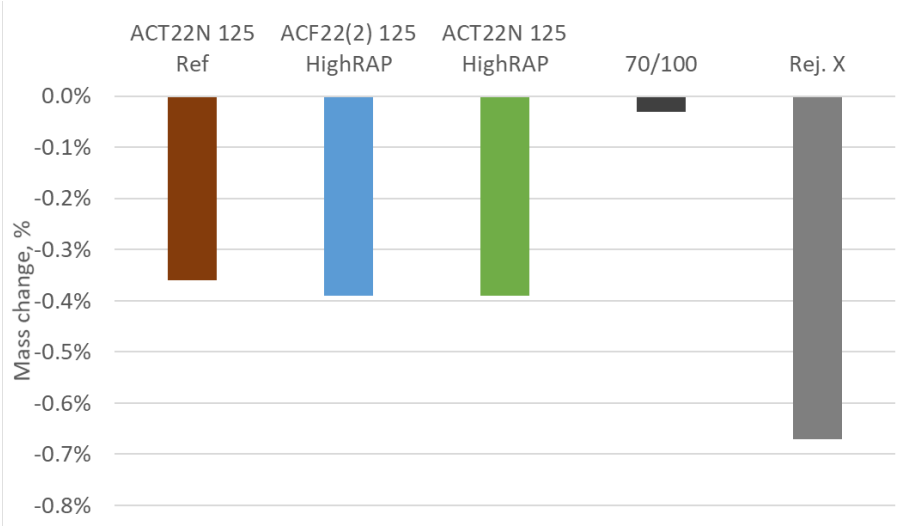
Step 1: Rejuvenator dosage to reach the penetration of target grade



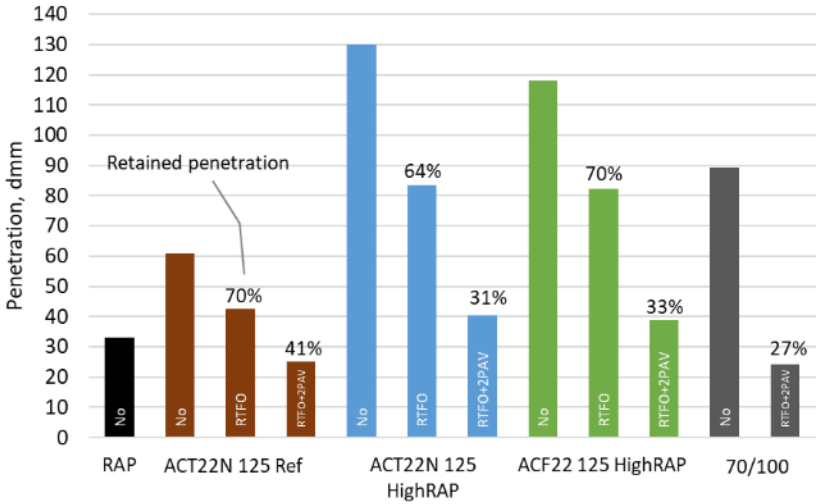
$$Dose = \frac{log_e \frac{PEN}{A}}{B}$$

Step 2: Determine aging resistance

1) Mass change after RTFO aging

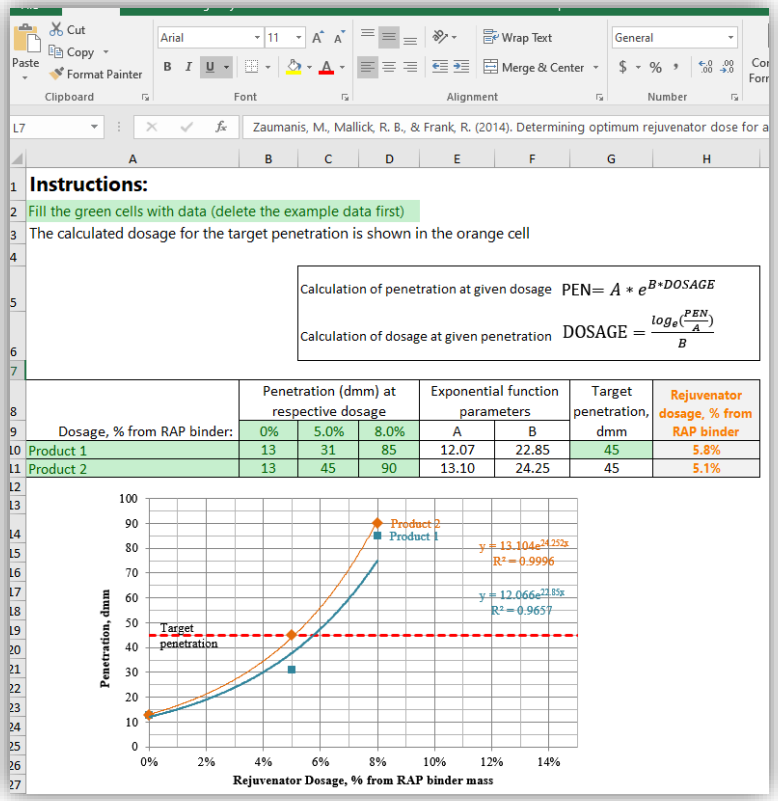


2) Penetration after RTFO + 2PAV



Calculator for determining dosage:

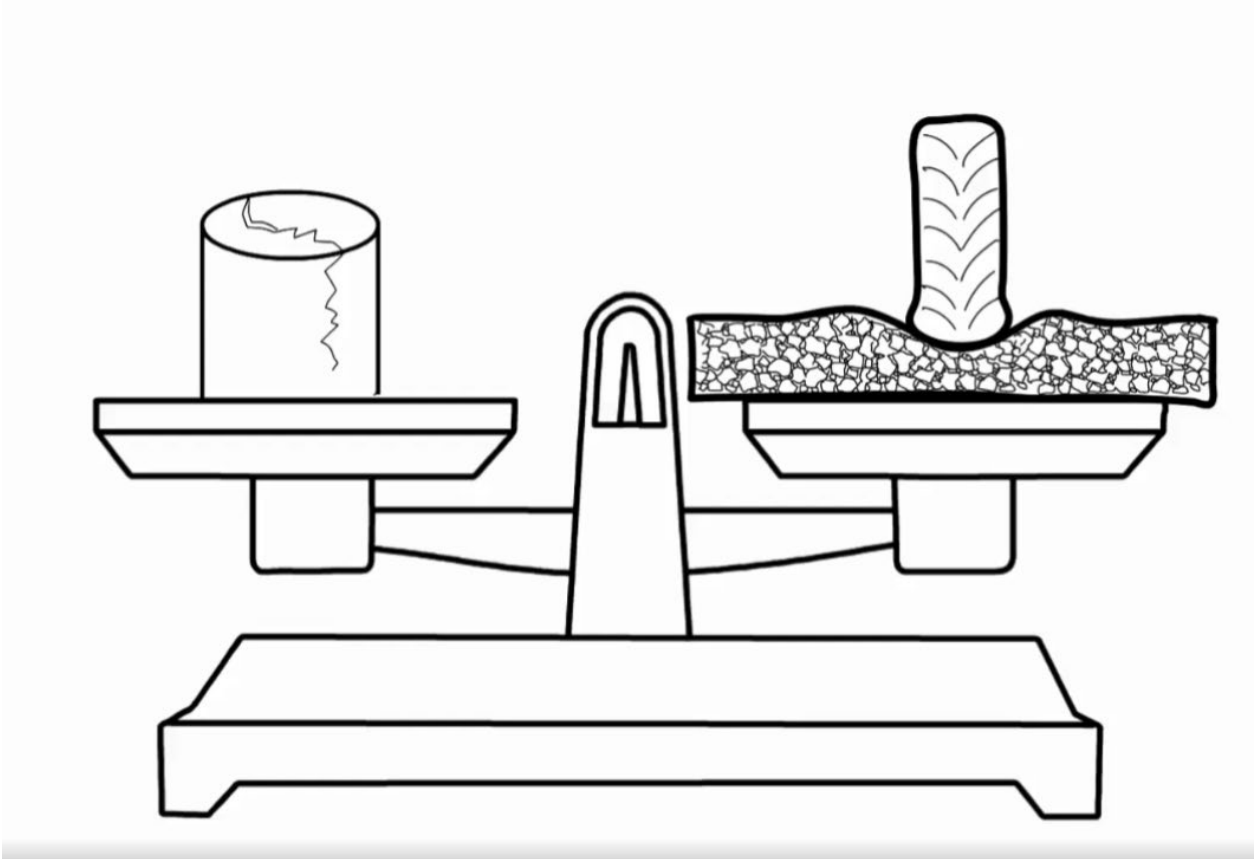
https://doi.org/10.5281/zenodo.7441805



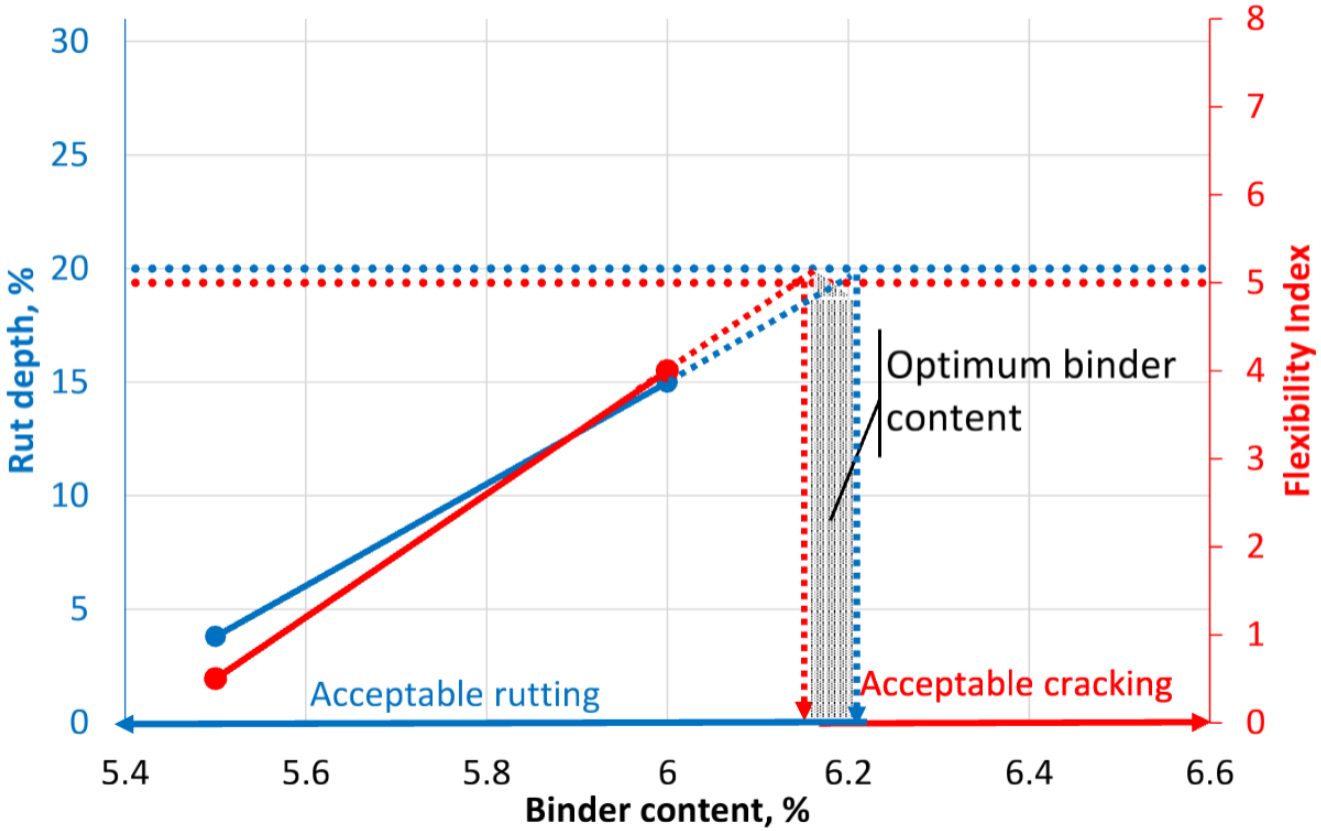
Balanced mix design

Papers: Performance-based design of 100% recycled hot-mix asphalt and validation using traffic load simulator

The test methods for balanced mix design should be carefully selected



Optimization of binder content



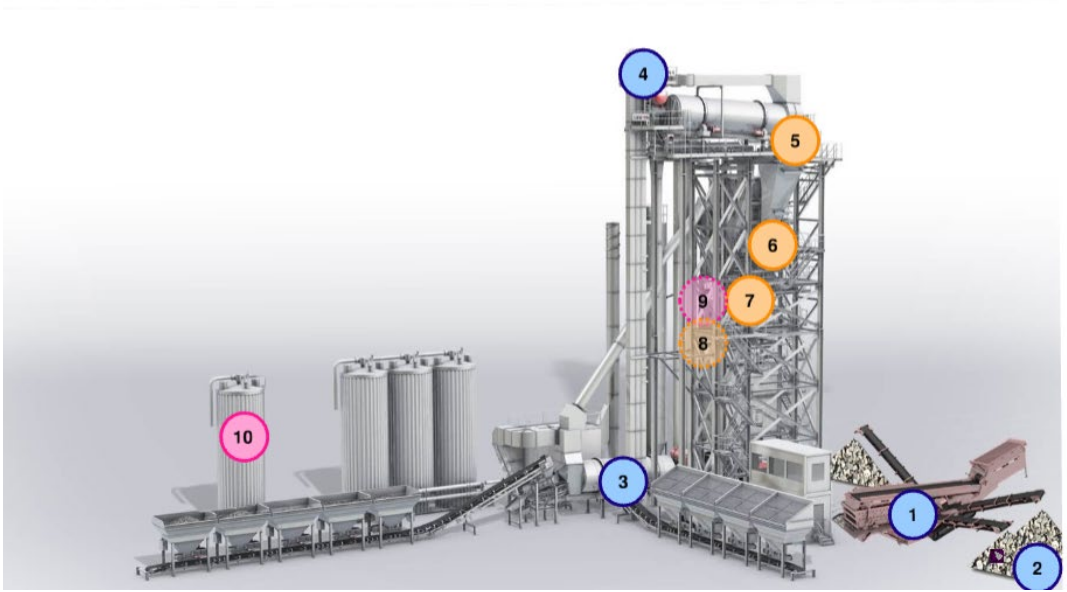
Rejuvenator addition in asphalt plant

Papers: Determining optimum rejuvenator addition location in asphalt production plant

Effect of rejuvenator addition location in plant on mechanical and chemical properties of RAP binder

A rejuvenator can be added in different locations

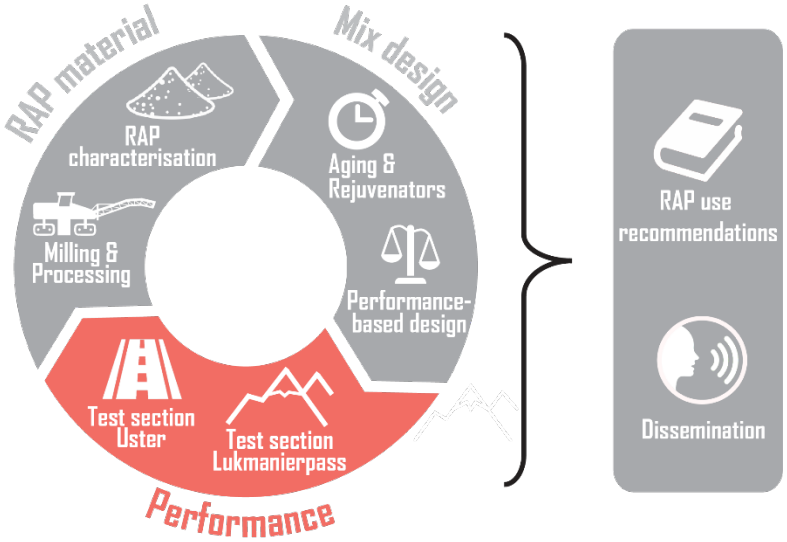
"Effect of rejuvenator addition location in plant on mechanical and chemical properties of RAP binder"



A rejuvenator can be added in different locations

Addition location	Environment		Operation		Quality			
	Operational health and safety hazards	Environmental impacts	Ease of plant integration	Flexibility of rej. dosage	Precise rej. dosage	Homogeneous rej. distribution	Long rej. contact with RA	Rej. effectiveness/ mix performance
Rejuvenator added upstream of RA dryer drum								
1. RA crusher outlet belt	✗	✗	—	—	✗	—	—	—
2. RA storage	✗	✗	—	—	✗	✗	—	—
3. RA conveyor belt	↗	↑	↗	↑	↗	↑	↑	↑
4. RA drum inlet		✗	—	—	—	—	—	—
Rejuvenator added downstream of RA drayer drum								
5. RA drier drum outlet chute	↑	↑	↗	↑	↗	↗	↗	—
6. RAH scale	—	—	—	—	—	✗	—	—
7. RAH chute	—	—	—	—	—	✗	—	—
8. Mixer	↑	↑	↑	↑	↑	↑	↗	↗
Rejuvenator added in virgin bitumen								
9. Bitumen line/scale	—	—	—	—	—	—	✗	—
10. Ready-mix with bitumen	—	—	—	—	—	—	✗	—

Legend:			
↑	no risk	easiest	highest performance
↗	minimal risk	simple	good performance
→	acceptable	acceptable	acceptable performance
✗	unacceptable	not possible	unacceptable performance
—	not evaluated	not evaluated	not evaluated



Paper: To be published

Test section: Uster

Study	Tasks	Activities during HighRAP project
Test section in Uster	Evaluate full-scale production and paving of high RAP mixtures for high traffic roads.	• Construction of a test section in Uster to validate the performance of polymer-modified mixtures with high RAP content.

Video from construction

(https://youtu.be/MvyCwyrMNOs)

The produced mixtures were thoroughly characterized using mixture and binder tests

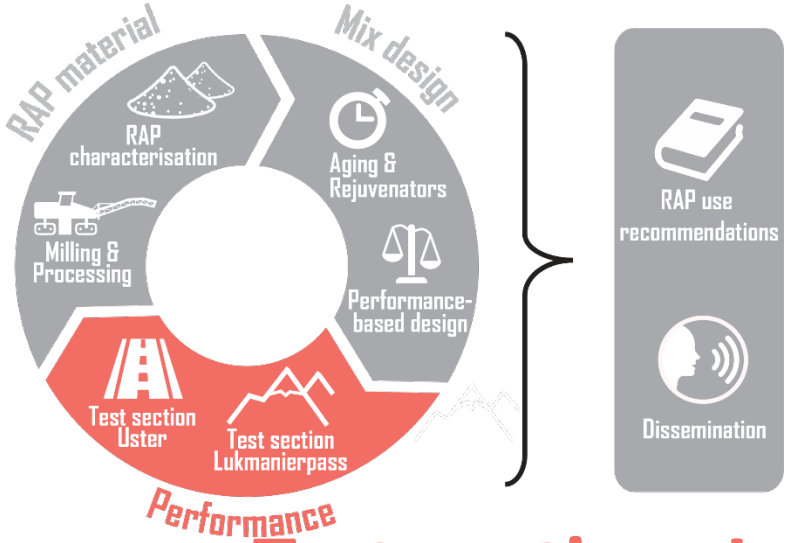
Summary

	Mixture	Binder grade	RAP content	Crack propagation resistance		Rutting resistance			Stiffness	Fatigure Resistance		Noise
				SCB	G-R	CC	FR	MSC	ITT	ITT	MMLS3	Texture
AC 8 H (Uster)	AC 8 H HighRAP	45/80-80	30%	→	→	↗	↗	→	→	→	-	→
	AC 8 H reference	45/80-80	0%	●	●	●	●	●	●	●	-	●
AC B 22 H (Uster)	ACB 22 H HighRAP	45/80-65	60%	→	↗	↓	↘	↘	↘	↘	↓	-
	AC B 22 H reference	45/80-80	30%	●	●	●	●	●	●	●	●	-
AC B 22 S(Uster)	AC T 22 S HighRAP 65%	50/70	65%	↘	↗	↑	-	↘	↗	→	-	-
	AC T 22 S HighRAP 75%	50/70	75%	↓	↓	↑	-	↗	↑	↓	-	-
	AC T 22 S reference	50/70	65%	●	●	●	-	●	●	●	-	-

Legend:

- ● reference mixture result
- ↑ significantly better performance
- ↗ slightly better performance
- → similar performance
- ↘ slightly worse performance
- ↓ significantly worse performance

SCB Semi-circular bend test (mixture)
G-R Glover-Rowe test (binder)
CC Cyclic compresstion test (mixture)
FRT French Ruting Tester (mixture
MSCR Multiple stress creep recovery test (binde
ITT Indirect tensile test (mixture)
MMLS3 Model mobile load simulator (mixture)
Texture Laser scanner (pavement)

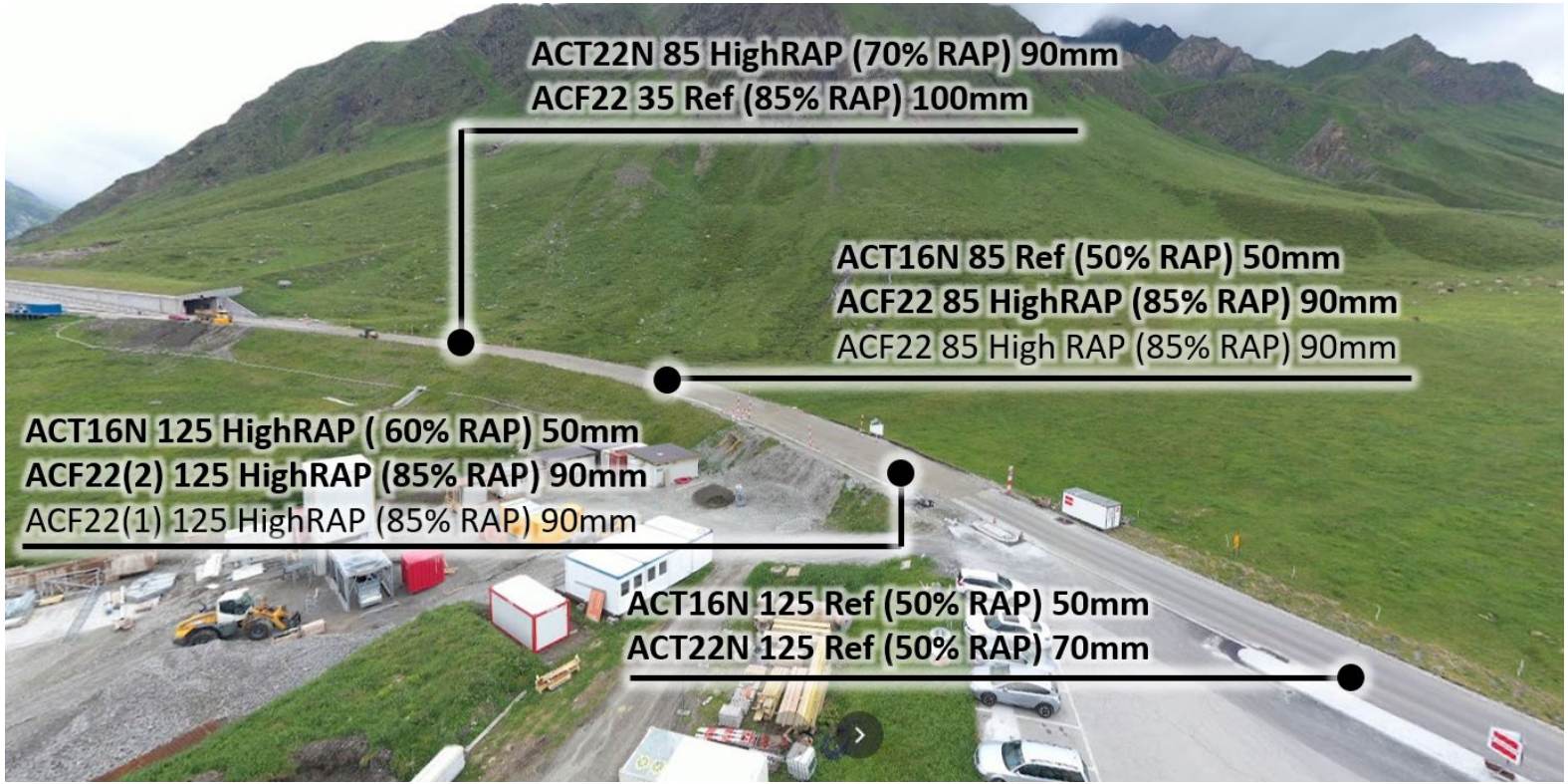


Paper: Asphalt recycling in polymer modified pavement: A test section and recommendations

Test section: Lukmanierpass

Study	Tasks	Activities during HighRAP project
Test section in Lukmanierpass	Evaluate full-scale production and paving of high RAP mixtures for high altitude roads.	• Construction of a test section in Lukmanierpass to validate the performance of foundation and base course mixtures with high RAP content.

Mix types


ACT22N 85 HighRAP (70% RAP) 90mm
ACF22 35 Ref (85% RAP) 100mm
ACT16N 85 Ref (50% RAP) 50mm
ACF22 85 HighRAP (85% RAP) 90mm
ACF22 85 High RAP (85% RAP) 90mm
ACT16N 125 HighRAP (60% RAP) 50mm
ACF22(2) 125 HighRAP (85% RAP) 90mm
ACF22(1) 125 HighRAP (85% RAP) 90mm
ACT16N 125 Ref (50% RAP) 50mm
ACT22N 125 Ref (50% RAP) 70mm


AC T 16 85 Ref
ACF22 85 HighRAP


ACF22 125 (1) HighRAP


Sample collection

s, Empa

The produced mixtures were thoroughly characterized using mixture and binder tests

Summary

	Mixture	Binder grade	RAP content	Crack propagation resistance		Rutting resistance		Thermal Cracking resistance	Stiffness	Fatigure Resistance	
				SCB	G-R	CC	BTSV	TSRST	ITT	ITT	MMLS
ACT 16 N (Lukmanierpass)	ACT16N 125 HighRAP	100/150	60%	→	→	→	→	→	↗	↗	-
	ACT16N 125 Reference	100/150	50%	●	●	●	●	●	●	●	-
	ACT16N 85 Reference	70/100	50%	↗	→	↘	→	→	↗	↗	-
ACT 22 N (Lukm)	ACT22N 85 HighRAP	70/100	70%	→	→	→	→	→	↑	↗	-
	ACT22N 125 Reference	100/150	50%	●	●	●	●	●	●	●	-
ACF 22 (Lukmanierpass)	ACF22 85 HighRAP	70/100	85%	↗	↗	↑	↘	↑	↗	↘	↗
	ACF22(2) 125 HighRAP	100/150	85%	↗	↗	→	↓	↑	→	→	→
	ACF22(1) 125 HighRAP	100/150	85%	↑	↗	→	↓	-	-	-	-
	ACF22 35 Reference	20/50	85%	●	●	●	●	●	●	●	●

Legend:

- ● reference mixture result
- ↑ significantly better performance
- ↗ slightly better performance
- → similar performance
- ↘ slightly worse performance
- ↓ significantly worse performance

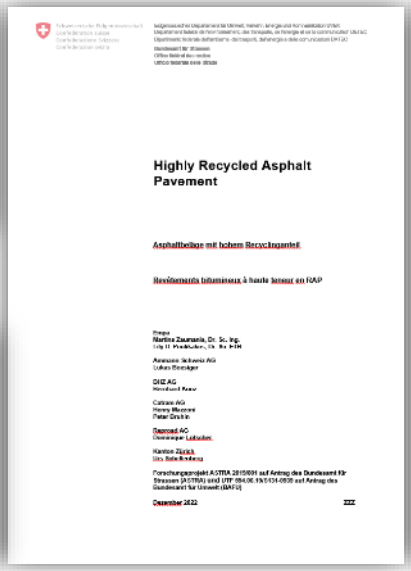
SCB Semi-circular bend test (mixture)
G-R Glover-Rowe test (binder)
CC Cyclic compresstion test (mixture)
BTSV BTSV temperature (bitumen)
TSRST Thermal stress restrained specimen test (mixture)
ITT Indirect tensile test (mixture)
MMLS3 Model mobile load simulator (mixture)

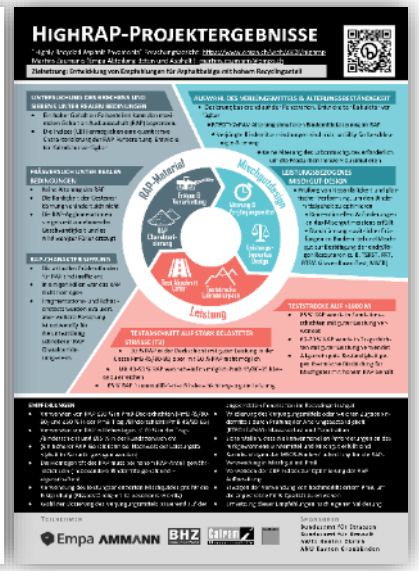
Results of the HighRAP-Project

This Presentation

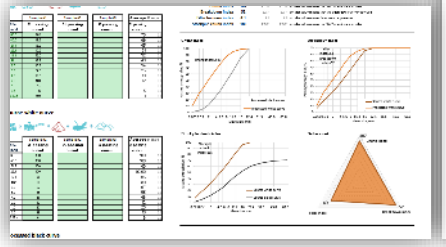
Report &
summary in DE, FR, EN

One-pager





Excel-spreadsheets



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