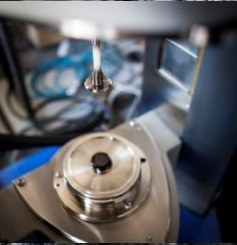




Czech experience with asphalt mixtures containing elevated content of RAP – from experiments to real practice

JAN VALENTIN

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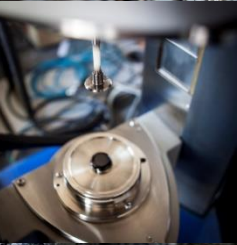
Development of hot asphalt recycling in CZ

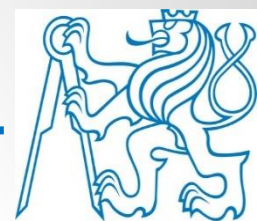
ACHIEVEMENTS:

- ➔ national technical standard for harmonized and non-harmonized asphalt mixtures with set limits and specifications for RAP usage
- ➔ national technical standard for RAP treatment and RAP quality assessments
- ➔ public decree on site-won asphalt and when to treat it as by-product or end-of-waste product

CHALLENGES:

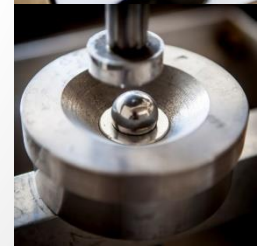
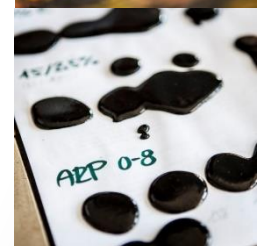
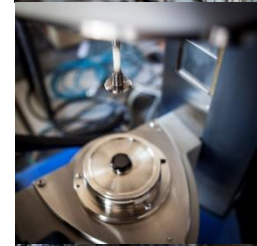
- ➔ necessary investments in mixing plants
- ➔ further development in understanding recycling agents, mainly their long-term effect
- ➔ continuous building trust in recycling being not bad – especially in case of public road administrators

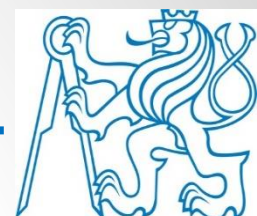




Some facts about the asphalt mix production in CZ

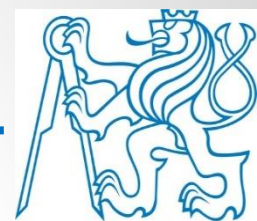
- ➔ number of asphalt mixing plants: 110 (approx. 12-14 equipped with parallel drum)
- ➔ hot mix asphalt production: 6,6 mil tonnes (2023); 6,9 mil. tonnes (2021); 6,5 mil. tonnes (2020); 7,1 mil. tonnes (2017)
- ➔ Low-temperature asphalt mix production: 30-40 thousand tonnes (2020)
- ➔ quantity of asphalt pavement material milled: 1 100-1 200 thousand tonnes per year
- ➔ quantity of reused RAP in asphalt mixtures: 400 thousand tonnes per year





Companies have sometimes strange strategies – parallel drum mixing plants around Prague



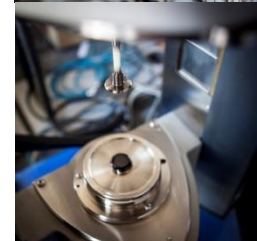


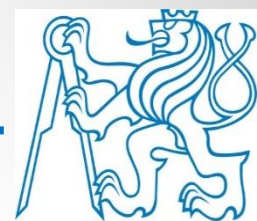
ČSN EN 13 108-1:2008

Wearing course		Binder course		Base course	
Obrusné vrstvy		Ložní vrstvy		Podkladní vrstvy	
Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)
ACO 8	25	ACL 16 S	30/15 ¹⁾²⁾	ACP 16 S	50 ¹⁾
ACO 8 CH	25	ACL 16 +	30 ¹⁾	ACP 16 +	60
ACO 11 S	–	ACL 16	40	ACP 22 S	50 ¹⁾
ACO 11 +	–	ACL 22 S	30/15 ¹⁾²⁾	ACP 22 +	60
ACO 11	25	ACL 22 +	30 ¹⁾		
ACO 16 S	–	ACL 22	40		
ACO 16 +	–				
ACO 16	25				

ČSN 73 6121:2019

Obrusné vrstvy		Ložní vrstvy		Podkladní vrstvy	
Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)
ACO 8	25	ACL 16 S	30/15 ¹⁾	ACP 16 S	50
ACO 8 CH	25	ACL 16 +	30	ACP 16 +	60
ACO 11 S	15	ACL 16	40	ACP 22 S	50
ACO 11 +	15	ACL 22 S	30/15 ¹⁾	ACP 22 +	60
ACO 11	25	ACL 22 +	30		
ACO 16 S	15	ACL 22	40		
ACO 16 +	15				
ACO 16	25				



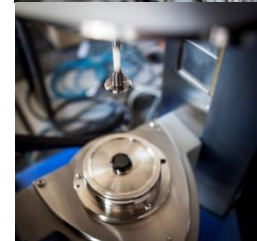


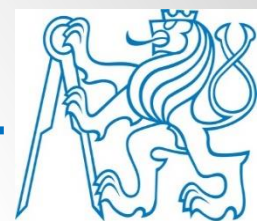
ČSN 73 6121:2023 – mixtures with paving grades

Obrusné vrstvy		Ložní vrstvy		Podkladní vrstvy	
Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)
ACO 8	35	ACL 16 +	50	ACP 16 S	60
ACO 8 CH	35	ACL 16		ACP 16 +	
ACO 11 +	30	ACL 22 +		ACP 22 S	
ACO 11	35	ACL 22		ACP 22 +	
ACO 16 +	30				
ACO 16	35				

R-materiál lze přidávat bez jeho další úpravy do asfaltových směsí v množství max. 15 %.

- ^a Pro směsi s nemodifikovaným asfaltem platí: Při dávkování R-materiálu nad 15 % do asfaltových směsí se silničním asfaltem (za studena maximálně 25 %, za horka viz tato tabulka), je nutno vypočítat potřebné množství dávkování asfaltu měkčí gradace nebo rejuvenátoru tak, aby bylo dosaženo penetrace a bodu měknutí výsledné deklarované gradace pojiva podle tabulky E.1. Zároveň musí být splněny požadavky na penetraci a bod měknutí zpětně získaného pojiva po výrobě podle tabulky 3 ČSN 73 6141:2020 (horní mez bodu měknutí není nutno dodržet u R-materiálu s modifikovaným asfaltovým pojivem). Při množství R-materiálu nad 25 % je zapotřebí, aby byla obalovna vybavena zařízením pro jeho předeřtání. Množství a druh asfaltu měkčí gradace nebo dávkovaného rejuvenátoru se uvádí ve zkoušce typu (TT). Přidávání R-materiálu metodou po částech za studena (použití variátoru) lze za výše uvedených podmínek použít pouze pro výrobu asfaltových směsí pro podkladní vrstvy.





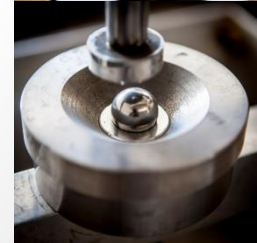
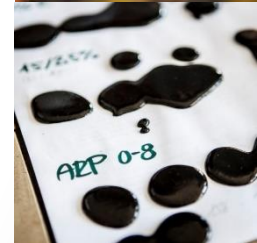
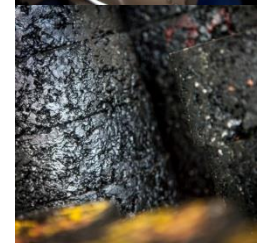
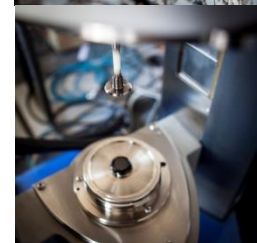
ČSN 73 6121:2023 – mixtures with PMBs

Obrusné vrstvy		Ložní vrstvy		Podkladní vrstvy	
Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)	Druh směsi	R-materiál (%)
ACO 11 +	30	ACL 16 S	40	ACP 16 S	50
ACO 16 +		ACL 16 +			
		ACL 22 S		ACP 22 S	
		ACL 22 +			

R-materiál lze přidávat bez jeho další úpravy do asfaltových směsí v množství maximálně 15 %.

- ^a Pro směsi s modifikovaným asfaltem platí: Při dávkování R-materiálu > 15 % do asfaltových směsí s PMB je nutno přidávat PMB RC podle normy ČSN 65 7222-1 (dávkování R-materiálu za studena maximálně do 25 % hm., dávkování za horka viz meze uvedené v této tabulce) v takovém množství, aby výsledné hodnoty penetrace, bodu měknutí a vratné duktility směsi nově přidávaného pojiva a pojiva vyextrahovaného z R-materiálu (směs pojiv je namíchána v odpovídajícím poměru) splnily požadavky penetrace, bodu měknutí a vratné duktility výsledného pojiva deklarovaného podle tabulky 1 normy ČSN 65 7222-1:2017. Zároveň musí být splněny požadavky na penetraci, bod měknutí a vratnou duktilitu zpětně získaného pojiva po výrobě podle tabulky 4 ČSN 73 6141:2020. Při množství R-materiálu nad 25 % je zapotřebí, aby byla obalovna vybavena zařízením pro jeho predehřátí.

NOTE: in HMAC or SMA for binder courses 30 % RAP can be used.

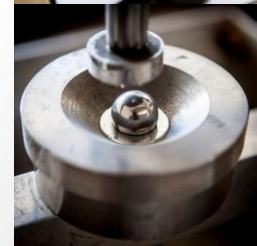
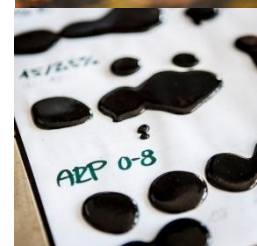
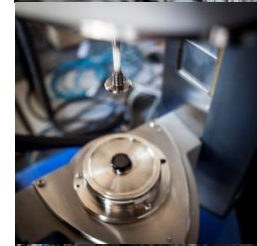




How to treat RAP for asphalt mixtures?

ČSN 73 6141: Requirements for the use of RAP in asphalt mixtures

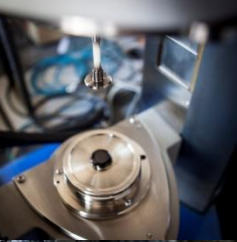
- ➔ standard valid since the 2nd half of 2019
- ➔ related to and complementary with the conditions set out in EN 13108-8 ed. 2 defining Czech national requirements;
- ➔ specifies requirements for the procedures for:
 - obtaining,
 - treatment,
 - homogenisation,
 - storage,
 - testing and control of RAP.

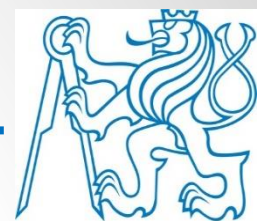




How to treat RAP for asphalt mixtures?

- ➔ asphalt mixtures containing RAP subject to the same requirements in terms of empirical, mechanical and functional characteristics as asphalt mixtures without RAP;
- ➔ to demonstrate the effectiveness of methods of treating aged bituminous binder, when RAP is dosed into the asphalt mixture in quantities >15 %, additional tests are obligatory on the recovered binder from the final mixture as part of the asphalt mix type testing and control testing:
 - (a) penetration test according to EN 1426
 - (b) softening point by the ring and ball method according to EN 1427
- ➔ testing frequencies:
 - min. 1 test per 4 000 tones of mix produced at RAP content 15-30 %
 - min. 1 test per 2 000 tones of mix produced at RAP content >30 %





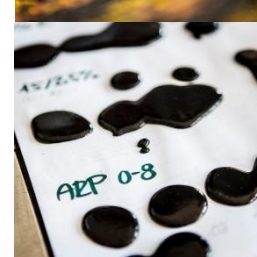
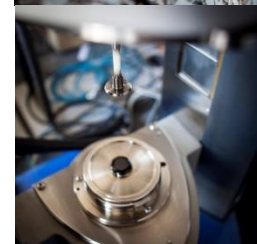
How to treat RAP for asphalt mixtures?

Requirements for recovered binder from asphalt mix in case of paving grade

Binder required in the mixture	Penetration on the recovered binder (0,1 mm)	Softening point on the recovered binder (°C)
50/70	30 to 55	48 to 60
70/100	40 to 75	45 to 57

Requirements for recovered binder from asphalt mix in case of PMB

Binder required in the mixture	Penetration on the recovered binder (0,1 mm)	Softening point on the recovered binder (°C)	Elastic recovery on the recovered binder at 25 °C ČSN EN 13398 (%)
PMB 25/55-65	15 až 50	≥ 60	≥ 40
PMB 45/80-65	30 až 70	≥ 60	≥ 40





Environmental decisions about waste vs. non-waste

Czech Republic approved and published already in 2019 public decree as an implementing regulation to the Waste Act (decree No. 130/2019 Col.).

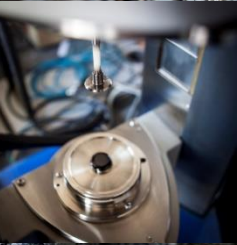
This decree was revised because of new Waste Act 541/2020 Col. and was published in October 2023 (decree No. 283/2023 Col.).

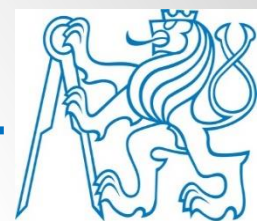
With these decrees we are quite unique in EU.

The decree sets:

- ➔ criteria which, if met, allow the site-won asphalt or macadam to be considered a by-product and not waste,
- ➔ criteria under which the site-won asphalt or macadam ceases to be waste,
- ➔ criteria for asphalt mix produced from waste reclaimed asphalt to cease to be waste.

For this reason 4 qualitative classes ZAS-T1 to ZAS-T4 are defined.

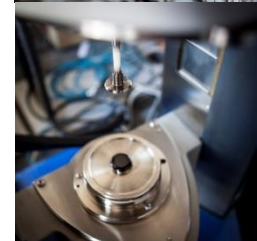




Environmental decisions about waste vs. non-waste

- ➔ the decree sets total amount of polycyclic aromatic hydrocarbons (PAHs) for qualitative classes of site-won asphalt ZAS-T1, ZAS-T2, ZAS-T3 and ZAS-T4
- ➔ in the period 2019-2023 the sum of 16 PAHs was assessed
- ➔ since October 1st 2023 only sum of 12 PAHs is assessed
- ➔ if material contains > 50 mg/kg B(a)P it is always classified as harmful material (dangerous waste)

Total concentrations of assessed parameter	Unit	Qualitative class			
		ZAS-T1	ZAS-T2	ZAS-T3	ZAS-T4
Total content of PAHs	mg/kg dry mas	≤ 12	$12 < x \leq 25$	$25 < x \leq 300$	> 300

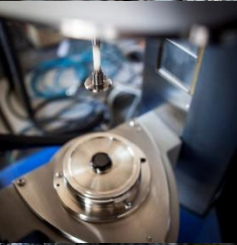


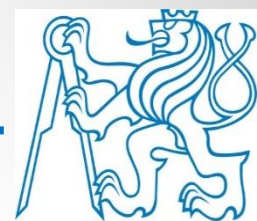


Environmental decisions about waste vs. non-waste

Lessons learnt after 3 years:

- ➔ at least 75-80 % of samples meet ZAS-T1 or ZAS-T2, with approximately 10-12 % falling into the ZAS-T3 category
- ➔ quite frequent assessment by the managers already during the pavement diagnostics (road management tries to minimize the „ghost" WASTE)
- ➔ much debate over analytical methods (different views of road administrators and envi labs)
- ➔ the need for regular inter-laboratory testing
- ➔ the need to address the specific area of asphalt and tar macadams





Environmental decisions about waste vs. non-waste

Number of samples in the diagnostic survey of the assessed, repaired or renewed area of a road

Type of sample	Reference area (m ²)	Min. number of samples	Min. number of sub-samples
Mixed sample	10 000	1	4

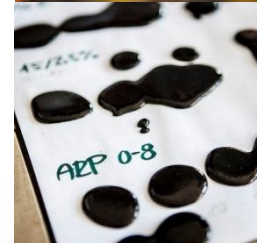
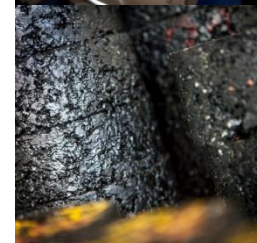
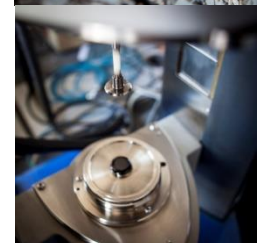
The reference area is the maximum area that can be represented by one sample.

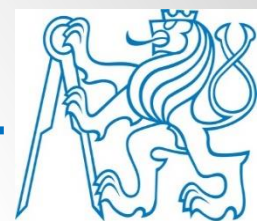
A mixed sample is formed by mixing sub-samples. A laboratory sample is taken from this sample after homogenisation and quartering, whereby a sub-sample may represent an area of no more than 2 000 m².

Number of samples for site-won asphalt (on mixing plants, stockpiles or in recycling centers)

Type of sample	Amount (t)	Min. number of samples	Min. number of sub-samples
Mixed sample	5 000	1	10

A mixed sample is formed by mixing the sub-samples. A laboratory sample is taken from this sample after homogenisation and quartering, whereby a sub-sample may represent a maximum of 500 t of site-won asphalt or reclaimed macadam.





Mixing plants

- ➔ parallel drum mixing plants – both key producer Benninghoven and Ammann
- ➔ several mixing plants with the middle drum ring (RAH50)
- ➔ 60-70% of the remaining able to proceed cold feeding 15-25% RAP

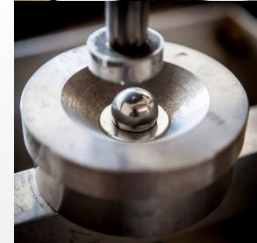
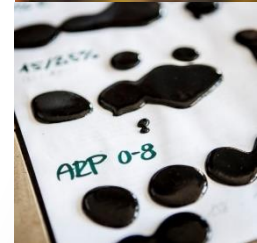
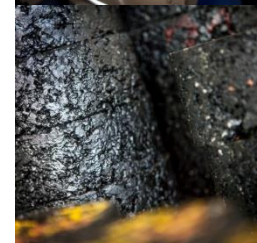
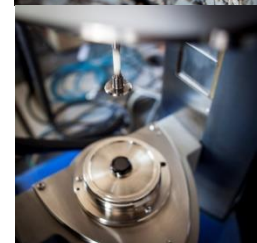
ONLY BATCH MIXING PLANTS ARE USED IN CZ

Dosing recycling agent

- ➔ majority prefers dosing to the mixer
- ➔ several dose rejuvenator after parallel drum
- ➔ dosing on conveyor belt before parallel drum was tested on few but mix producer do not like it

BUT

- ➔ there is still 50:50 between recycling agent and softer binder (usually 70/100)
- ➔ last two years more and more popular use of PMB RC (25/55 and 45/80)

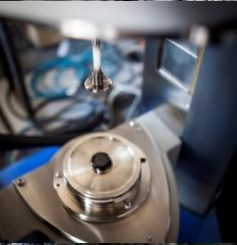




Pavement recycling – trial section (2016)

County (rural) road – combination of RAP and WMA approach

- ➔ 40-60 % RA either in surface course or binder course
- ➔ one rejuvenator (REOB based)
- ➔ 8 solutions for WMA (waxes, foam, silanes, combination rejuvenator and wax)
- ➔ assessment of additives and combinations on the functional behaviour of asphalt mixtures

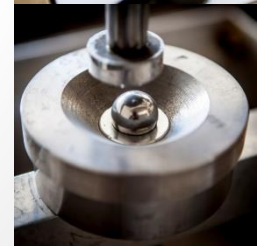
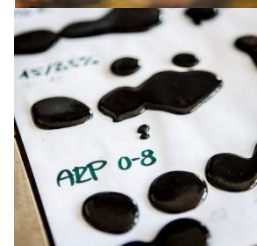
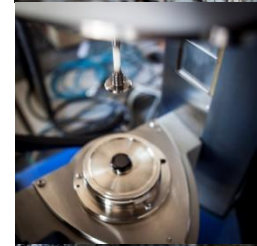


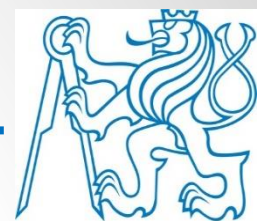


Pavement recycling – trial section (2019)

Trunk road (I/61 close to Prague) – combination of RAP and PMBs

- ➔ 30-50 % RA either in surface course or binder course
- ➔ comparison of bio-rejuvenator + traditional PMB and PMB RC
- ➔ it is expected that this road will continue to be loaded by high number of HLVs.



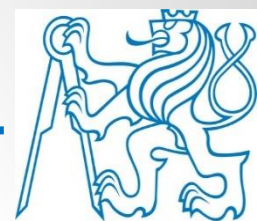


Pavement recycling – trial section (2017)

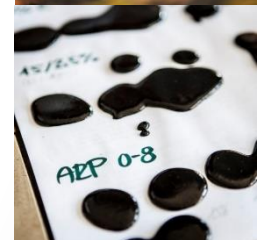
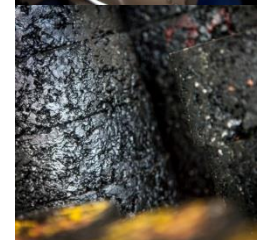
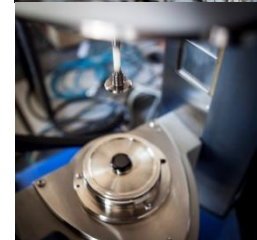
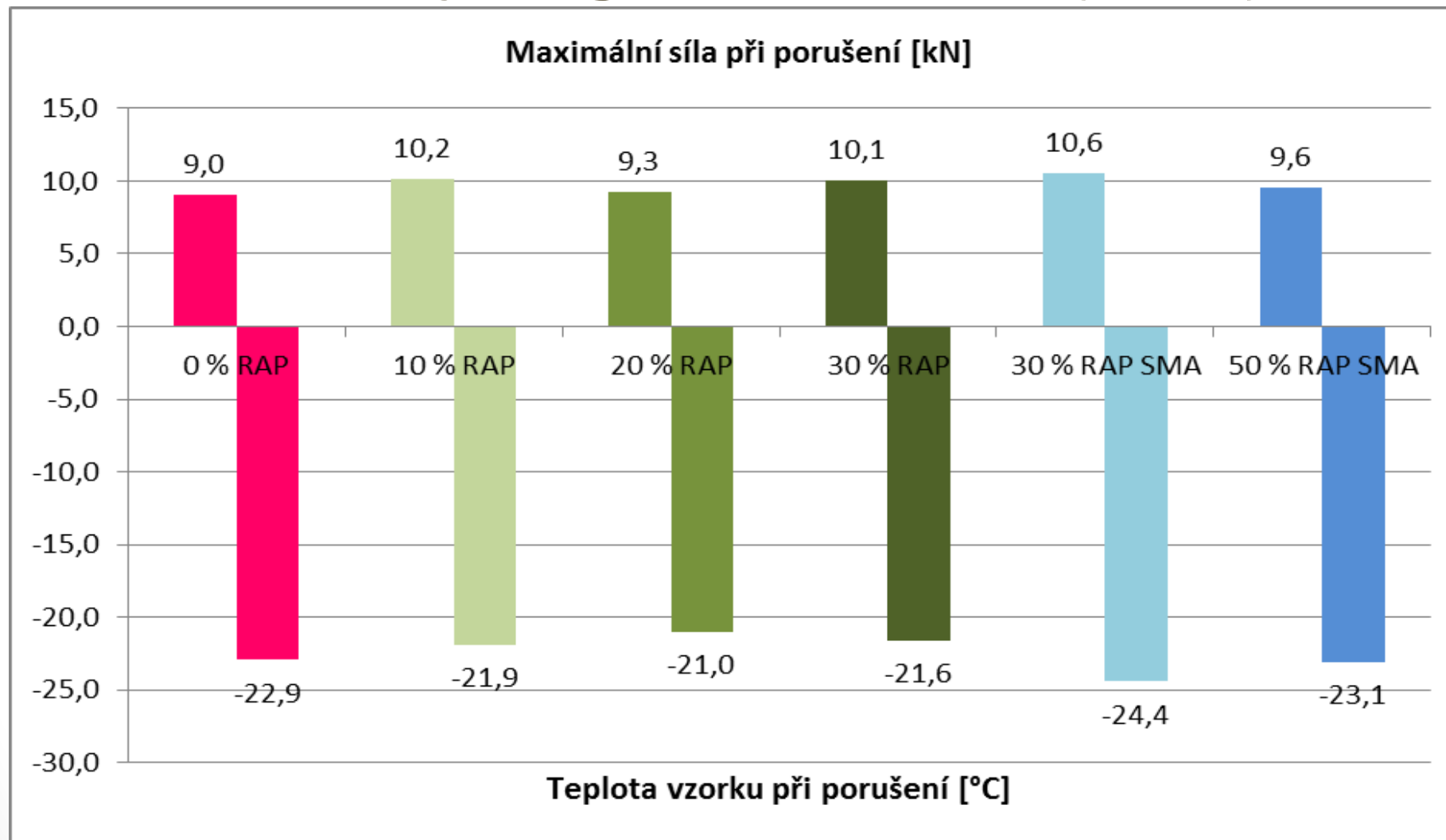
Regional road – use of RAP in SMA mixtures

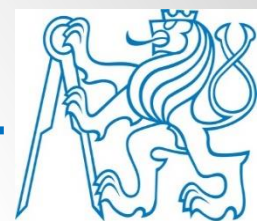
- ➔ 30-50 % RA in SMA mixture – 17 variants of mixtures tested
- ➔ use of one type of rejuvenator including rejuvenator combined with crumb rubber
- ➔ use of 5 types of fibers
- ➔ comparison of paving grade (50/70) and PMB
- ➔ verification of new types of fibres
- ➔ regional road II/227 (Rakovník – Kněžveses) with a project length of 4,8 km
- ➔ SMA based RAP and regular RAP





Pavement recycling – trial section (2017)

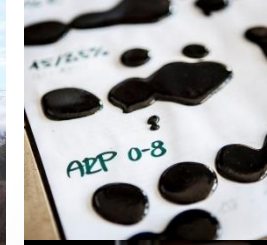
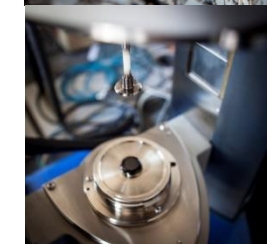
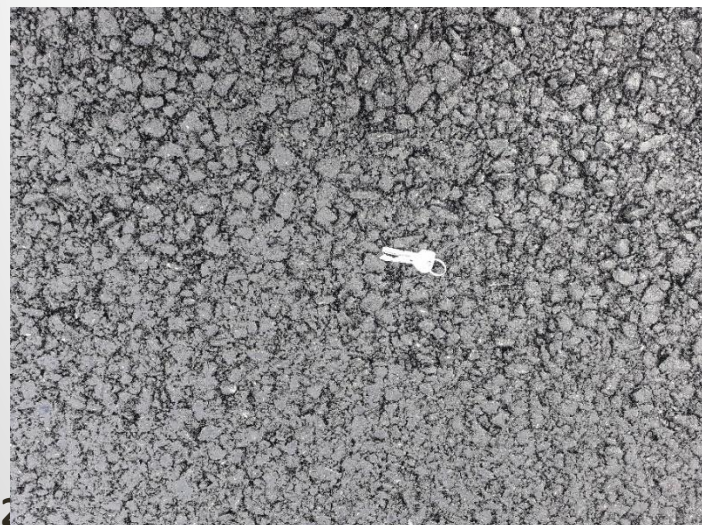


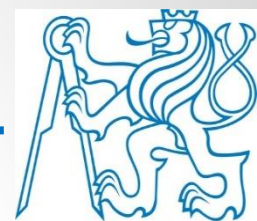


Pavement recycling – trial section (2017)

Regional road – surfacings with reduced maintenance costs

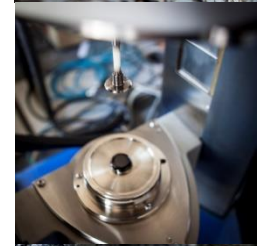
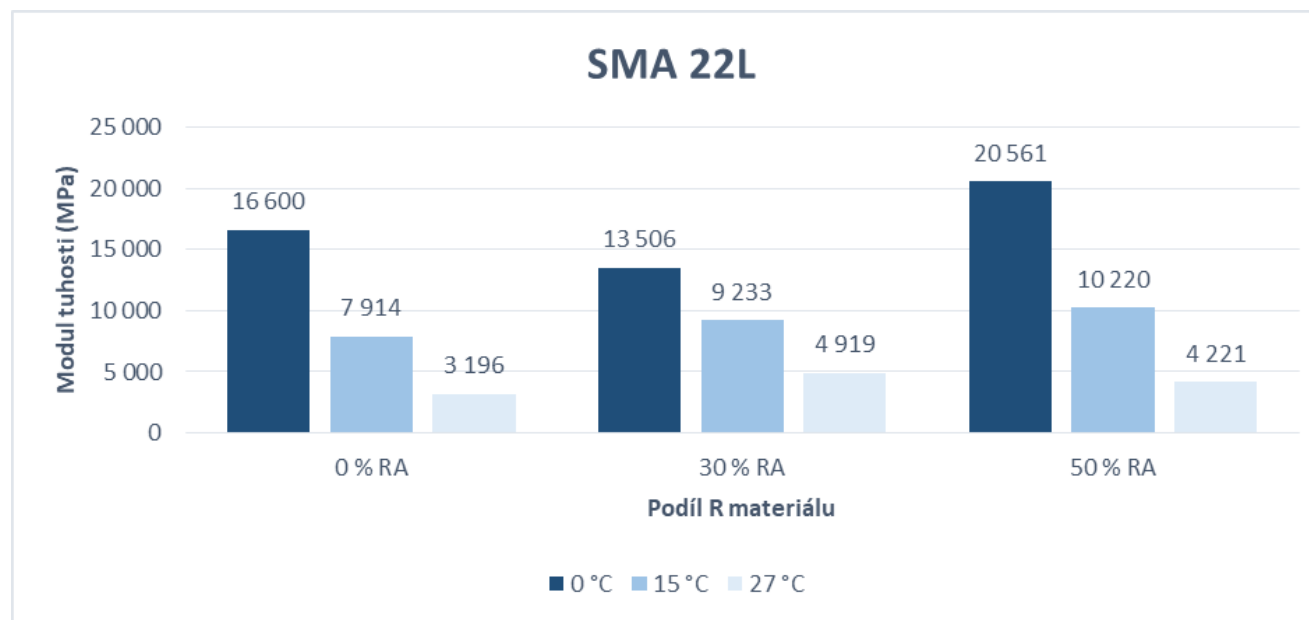
- ➔ verification of the feasibility of SMA 22L in combination with a thin wearing course
- ➔ central Bohemia regional road II/236 Kačice – Smečno with moderate HLV traffic
- ➔ 2 km long section with 100 mm binder course and 30-35 mm wearing course
- ➔ SMA 22L with 0%, 30% and 50% RAP
- ➔ wearing course BBTM 8NH and SMA 8NH (with RAP up to 30 %)
- ➔ initial mix design, control tests and subsequent monitoring by CTU in Prague.

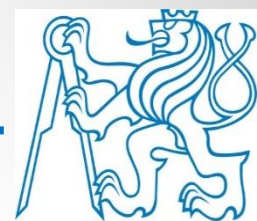




Pavement recycling – trial section (2017)

Varianta směsi SMA 22L	Odolnost proti účinkům vody	Odolnost proti trvalým deformacím		Modul tuhosti při 15°C (IT-CY)	Teplotní citlivost
	ITSR (%)	WTS _{AIR} (mm)	PRD _{AIR} (%)	S ₁₅ (MPa)	S ₀ /S ₂₇ (-)
reference dle ITT	80	0,022	2,9	10 756	4,51
0 % RA	86	0,029	3,2	7 914	5,19
30 % RA	77	0,015	2,2	9 233	2,75
50 % RA	73	0,016	1,8	10 220	4,87

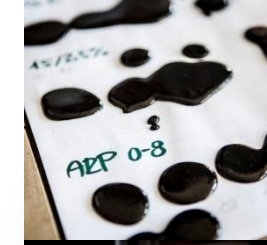
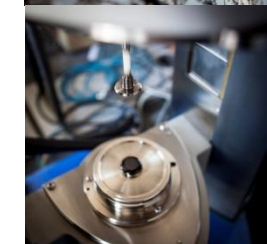
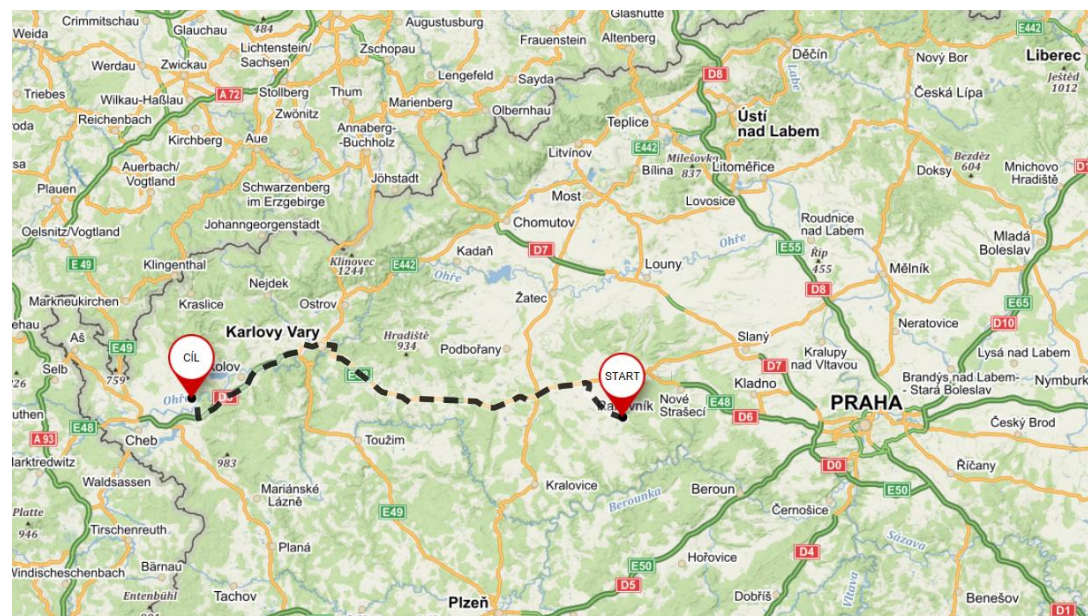




Pavement recycling – trial section (2017)

Regional road – mixtures containing RAP and hauled for longer distance

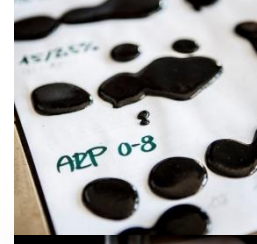
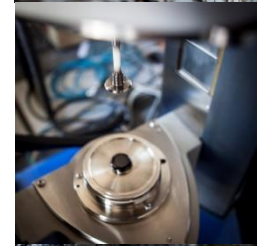
- ➔ 2nd class road (II/212) managed by the Karlovy Vary Region with a distance of 120 km from the mixing plant
- ➔ 1,5 km long section (400-500 m sub-sections) with replacement of the binder and wearing course (60 % RAP in binder course and 50 % RAP in wearing course)
- ➔ use of a rejuvenator with 4 types of synthetic waxes and foamed asphalt technology
- ➔ paving at a reduced working temperature

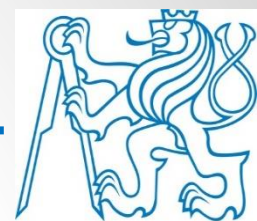




Pavement recycling – trial section (2017)

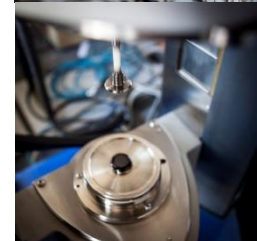
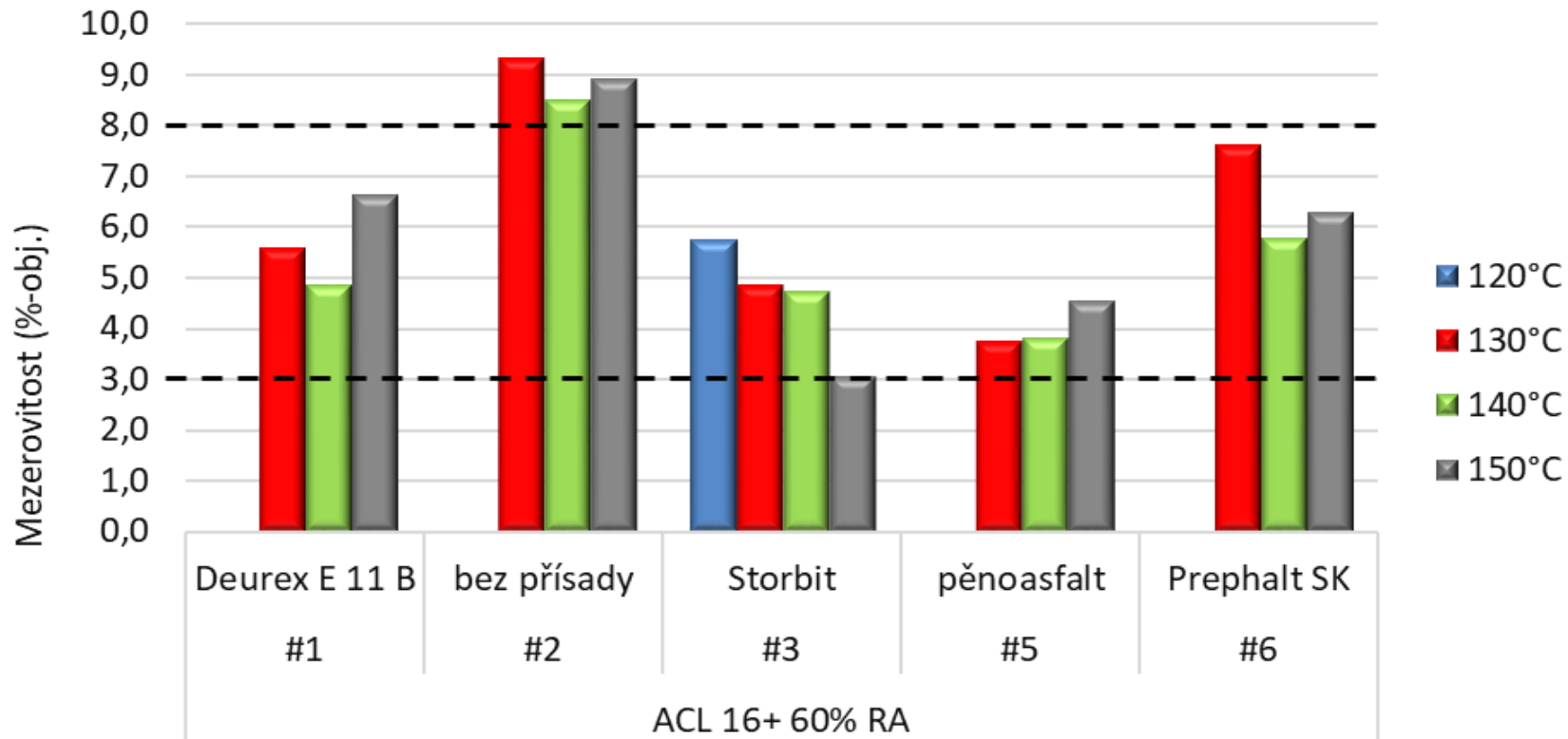
			Obsah rozpustného pojiva (%)	ITT	Rozsah obsahu rozpust. pojiva dle ČSN EN 13108-21
ACO 11+ 50% RA	#1	Deurex E 11 B	5,6	5,6 %	5,1-6,1 %
	#2	bez přísady	5,4		
	#3	Sasobit Redux	4,9		
	#4	Storbit	5,2		
	#5	zpěněný asfalt	5,2		
	#6	Prephalt SK	5,9		
ACL 16+ 60% RA	#1	Deurex E 11 B	4,8	4,4 %	3,8-5,0 %
	#2	bez přísady	4,5		
	#3	Storbit	4,9		
	#5	zpěněný asfalt	5,1		
	#6	Prephalt SK	5,0		

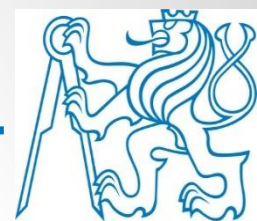




Pavement recycling – trial section (2017)

Relationship between the voids content and compaction temperature – binder course mixture

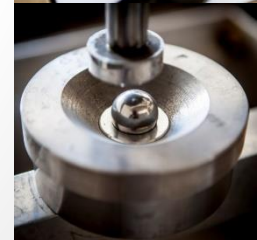
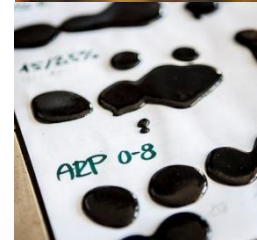
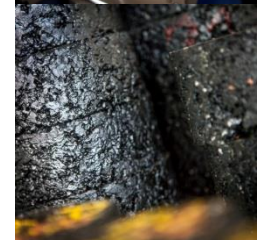
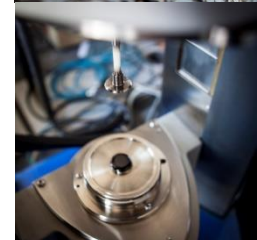


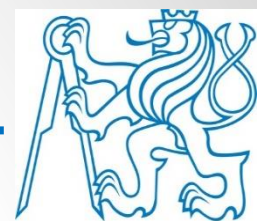


Pavement recycling – trial section (2017)

Resistance to rutting of wearing course mixture (ACO 11+ with 50% RA)

Směs	Asfaltové pojivo	Přísada	Ø hloubka koleje po 10 000 cyklech (mm)	WTS _{air} (mm)	Mez	PRD _{air} (%)	Mez
ACO #1	50/70	Deurex E 11 B	1,60	0,034	0,080	3,5	6,0%
ACO #2		bez přísady	0,79	0,020		1,7	
ACO #3		Sasobit Redux	1,12	0,019		2,5	
ACO #4		Storbit	1,18	0,021		2,6	
ACO #5		zpěněný asfalt	2,08	0,051		4,6	
ACO #6		Prephalt SK	1,13	0,024		2,5	

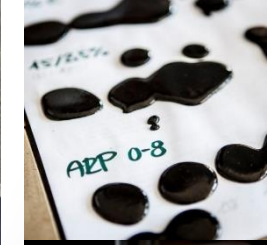
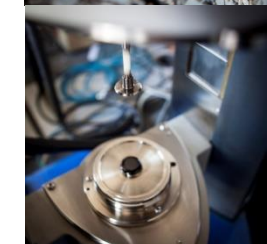


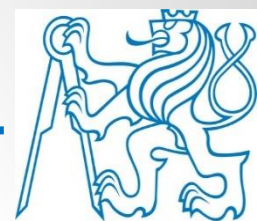


Pavement recycling – trial section (2018)

Regional road – use of RAP combined with rejuvenator vs. soft binder

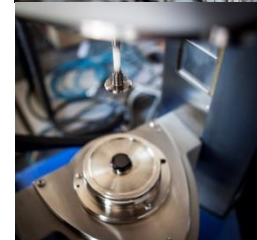
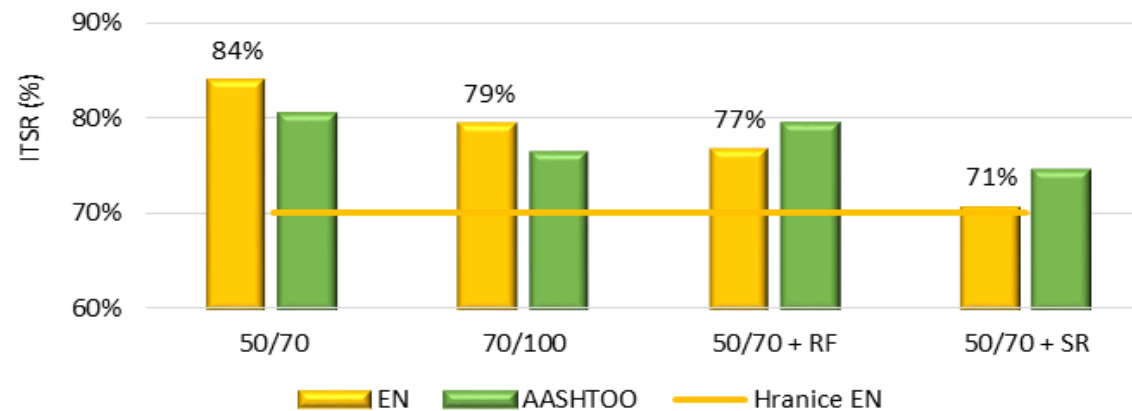
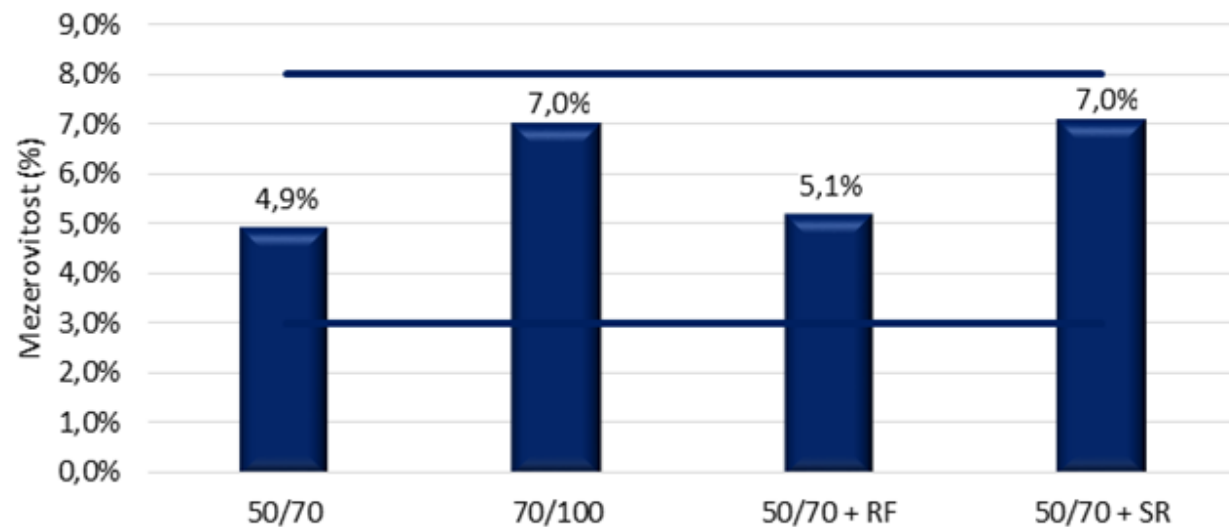
- ➔ trial section in Central Bohemian region on a road where cold recycling was followed by asphalt layers containing RAP (for CR Wirtgen large prototype recycler used)
- ➔ 20 % RAP in wearing course and 40 % RAP in binder course
- ➔ comparison of two rejuvenators and soft paving grade bitumen 70/100
- ➔ longer hauling distance (2hrs from mixing plant)

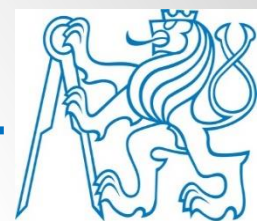




Pavement recycling – trial section (2018)

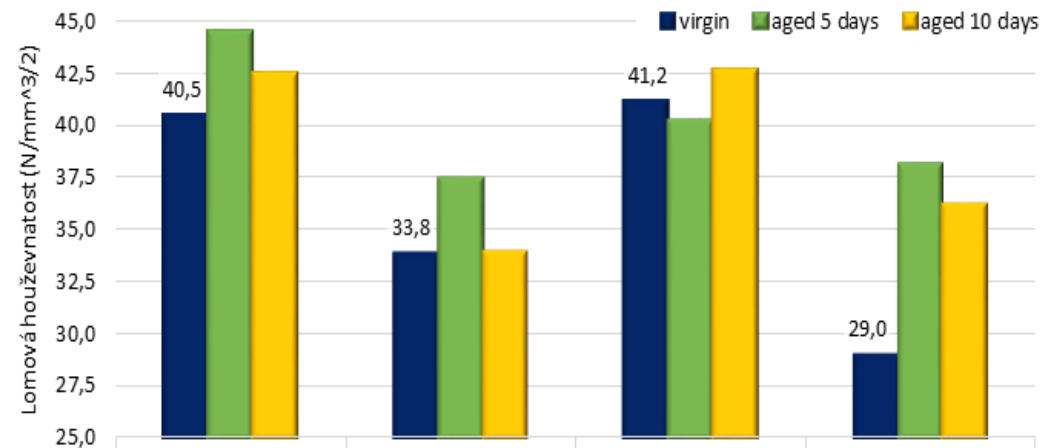
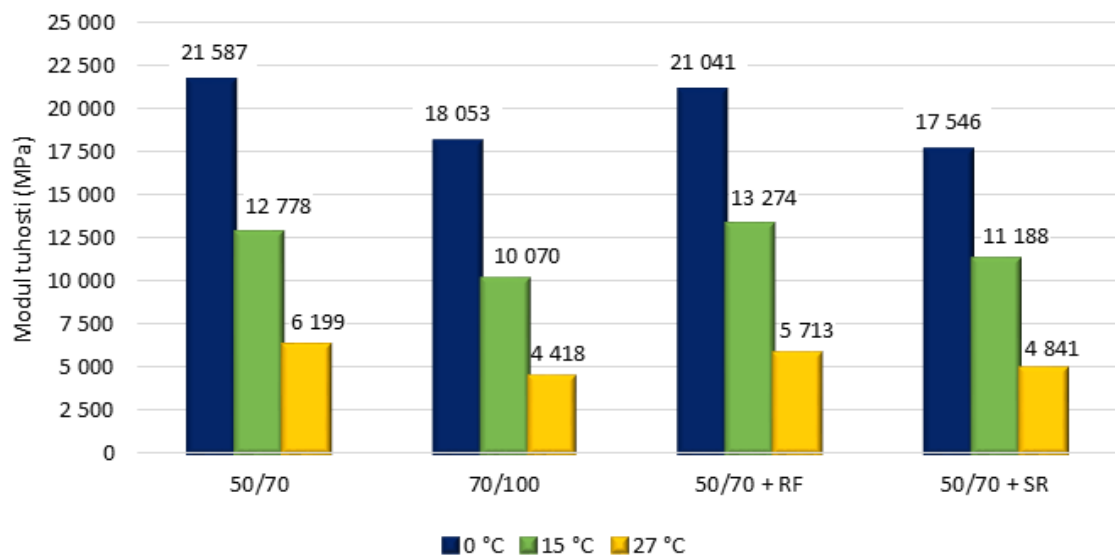
Voids content and ITSR values of AC 16 mix variants from the trial section



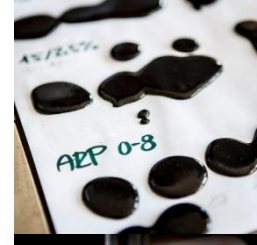
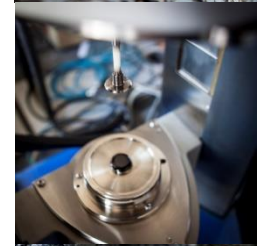


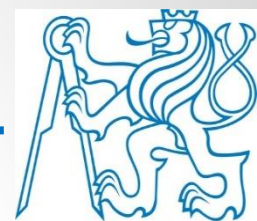
Pavement recycling – trial section (2018)

Stiffness and fracture toughness of AC 16 mix variants from the trial section



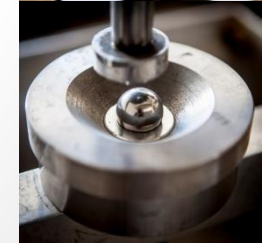
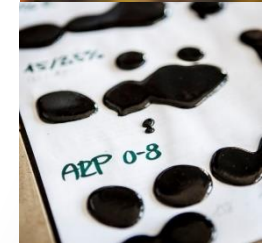
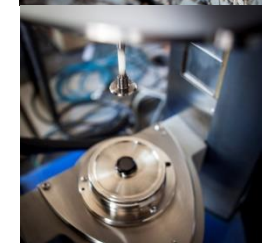
Index stárnutí:	50/70	70/100	50/70 + RF	50/70 + SR
aged 5 days	1,10	1,11	0,98	1,31
aged 10 days	1,05	1,00	1,04	1,25

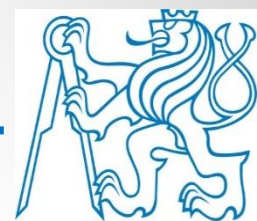




Exploring asphalt mixtures with 80 to 100 % RAP

- ➔ ACsurf 16 with 80% RA produced and paved in 2020
- ➔ County road of traffic loading class V-VI (access to a production plant)
- ➔ monitoring for 3 years (roadway with no apparent defects)
- ➔ bitumen recovery and analysis: PEN 43 dmm, RuK 57,7°C

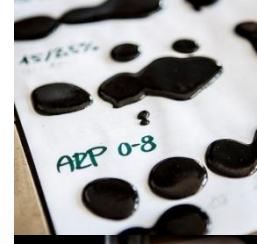
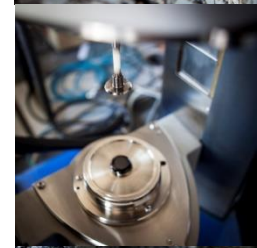


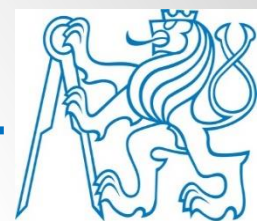


Exploring asphalt mixtures with 80 to 100 % RAP

- ➔ ACbase 16S with 100% RA in two variants (different stiffness of the resulting binder)
- ➔ RAP 32 RA 0/16
- ➔ comparison with a conventional asphalt mix of the same type (without RA)

		Experimental	Experimental	Konvenční	Requirements	
Mix		1. ACP 16 F	2. ACP 16 F	ACP 16 S	ACP 16R	ACP 16+
Production		Lab	Lab	Obalovna	ČSN 73 6148	ČSN 73 6121 TP170
Obsah R-materiálu 32 RA 0/16	%	100	100	0	100	max 60
Stiffness	EN 12697-26	MPa	13 929	9 614	10 749	min 7 500
Fatigue	EN 12697-24	$10^{-6}(\mu\text{m}/\text{m})$	106			min 100
Air voids	EN 12697-8	%	6,3		5,1	4,0-7,0

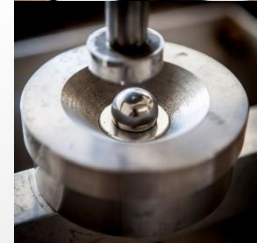
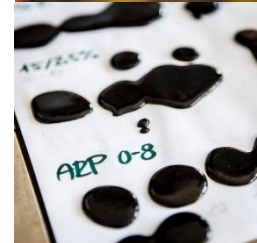
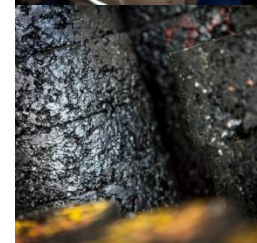
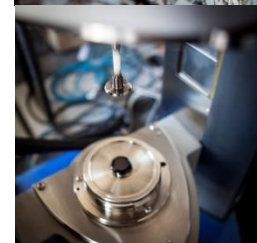




Other superior solutions with elevated RAP mixtures

- ➔ motorway D4 (SMA 11S with 30% RA and ACbin 22S with 40% RA)
- ➔ motorway D5 (ACP 22S with 50% RA and ACbin 22S with 40% RA)
- ➔ motorway D6 (HMAC 22 with 30% RA)

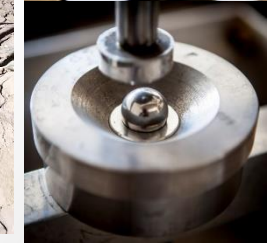
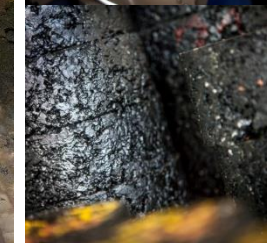
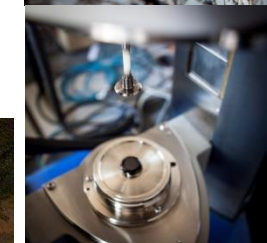
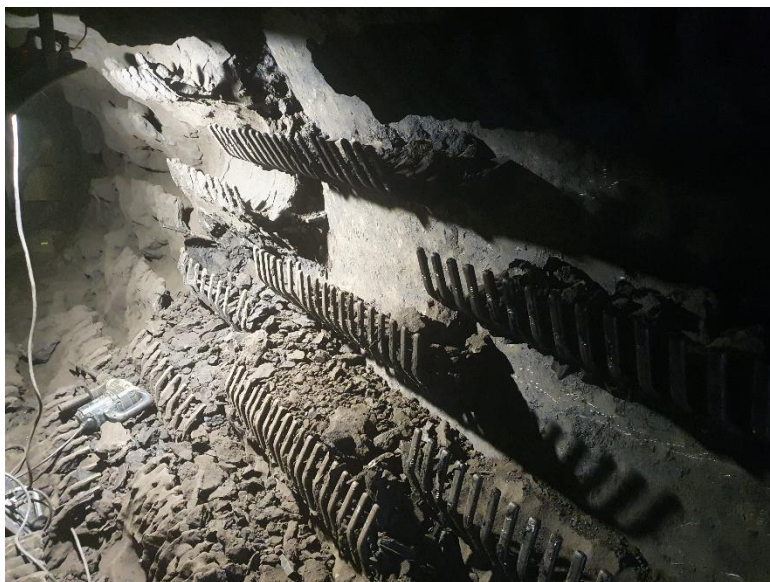
Asphalt mix	ACsurf 11 S		ACbin 22 S		ACsurf 11 +	
	Production	Requirements	Production	Requirements	Production	Requirements
Bitumen	PMB 25/55-65 RC		PMB 25/55-65 RC		PMB 45/80-65 RC	
RA content	30%		40%		30%	
Fibers	FlexForce		FlexForce		FlexForce	
Binder content	5,4	5,4	4,3	4,1	5,7	5,7
Voids content	3,9	2,5-4	4,9	4-6	3,9	2,5-4
ITSR	86	80		80	85	80
Rutting (50°C) PRD	2,2	<5	1,7	<3	-	-
Rutting (50°C) WTS	0,019	<0,07	0,018	<0,05	-	-
Rutting (60°C) PRD	-	-	-	-	2,2	<5
Rutting (60°C) WTS	-	-	-	-	0,015	<0,07
Stiffness IT-CY @15°C	7 800	NR	12 400	NR	8 600	NR
	Military airport Prague - Kbely (runway)				Airport Prague	





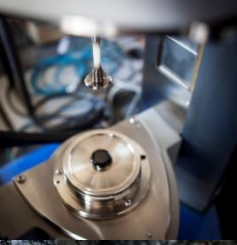
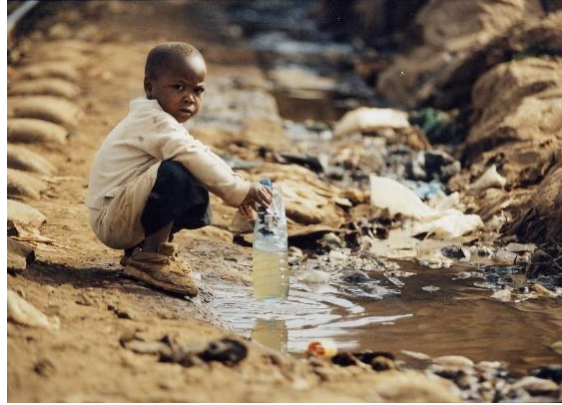
What troubles do we know?

- ➔ RAP availability
- ➔ too many rejuvenators and no common rules what shall be declared – we just believe
- ➔ elevated production of back filler
- ➔ clogging in the parallel or double coated drum
- ➔ RAP from superior pavements always the best ??
- ➔ selective milling – when does it make really sense ??





LET'S HAVE POSITIVE MOTIVATION 😊

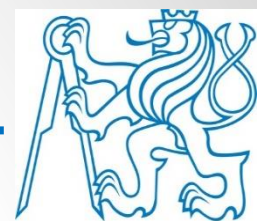


Was der Mensch für sich und seine Umwelt tut, ist rein seine freiheitliche Entscheidung.

Die Konsequenzen dann aber auch.

Er kann also herumkaspern, sich schlau machen und endlos wachsen oder aber seinen Verstand gebrauchen und die Dinge einfach besser machen...





Danke für's Zuhören.

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