ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
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„Dépasser les frontières : projet après projet"

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Recyclage optimal des agrégats de béton bitumineux dans les chaussées à faible trafic

Optimales Recycling von Ausbauasphalt auf verkehrsschwachen Straßen

01/11/2016 - 31/12/2020

FINAL ANNUAL MEETING

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Summary

- Materials characterisation (RAP & aggregates)

  A. FEESER (Cerema)

- Materials characterisation (bitumen) & Behaviour (MPO & CBR tests)

  H. HERB (HsKA)

- Mechanical behaviour (GSC & ITS tests)

  A. FEESER (Cerema)

- Mechanical behaviour (Repeated Load Triaxial tests)

  L. GAILLARD (INSA)

- Medium Scale Testing

  C. RAAB (Empa)

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PART I

Materials characterisation (Aggregates & RAP)

Arnaud Feeser, Cerema

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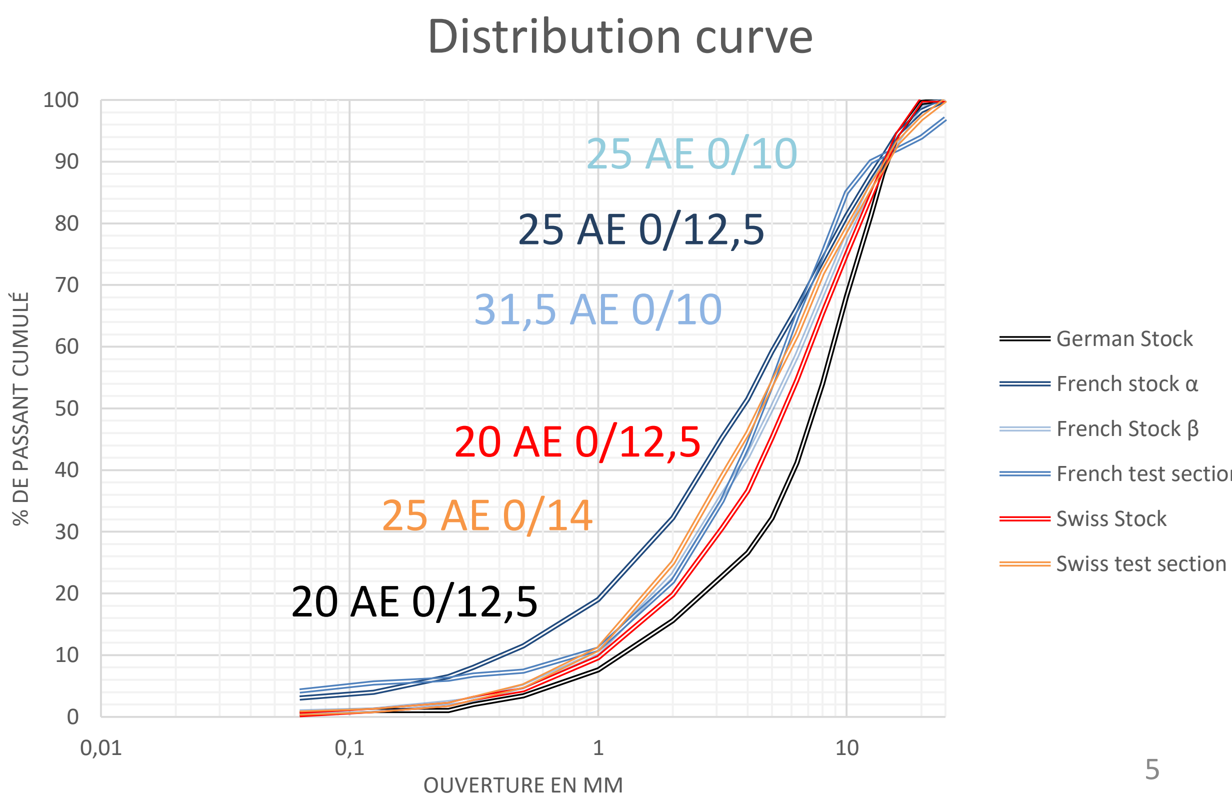
Materials description

- Two French stocks made up of : α (with PAH) and β (without PAH) :
  - Stock α (Lingenheld) with :
    - 298 mg/kg of PAH constituted in 2017 ;
    - Codification EN 13108-8 : 25 AE 0/10
  - Stock β (Lingenheld) with :
    - 8 mg/kg of PAH constituted in 2018 ;
    - Codification EN 13108-8 : 25 AE 0/12,5
- A German stock (20 AE 0/12.5)
- A Swiss stock (20 AE 0/12,5)
- The materials of the Swiss in situ test section (25 AE 0/14)
- The materials of the French in situ test section (31,5 AE 0/10)

Characteristics of RAP

Granulometric curve of German, Swiss and French materials, obtained on asphalt aggregates



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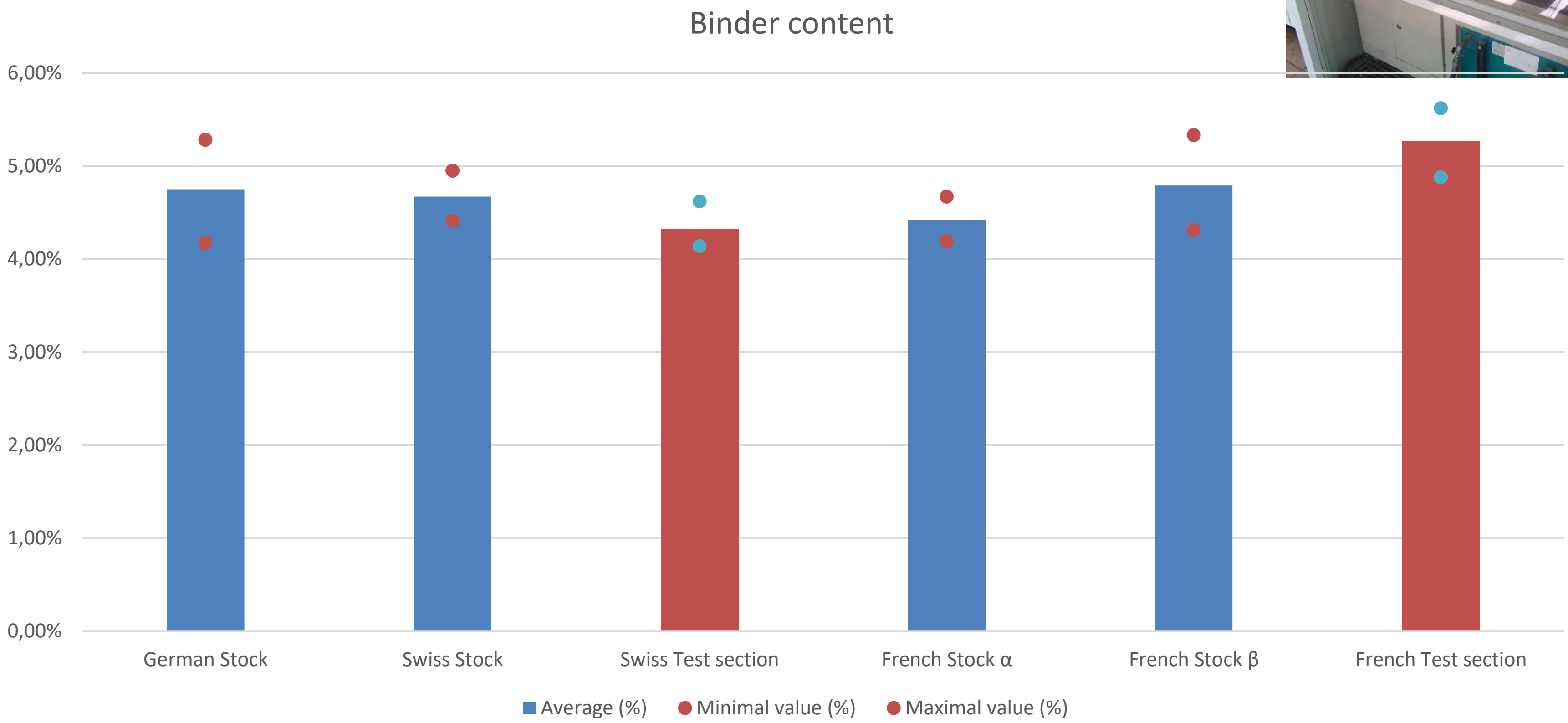
Characteristics of RAP

Results of binder content / Classification



Codification TL2 *to TL1… (Range min-max < 2 %)*

Cerema

Characteristics of RAP

Maximum Density of RAP (EN 12697-5)

	German Stock	Swiss Stock	French Stock β	French Stock α
Average (Mg/m3)	2,479	2,510	2,467	2,481
Range Δ	46 kg / m3	4 kg/m3	9 kg/m3	11 kg/m3
	< 50 kg/m3			
Estimated density of aggregates	2,662 Mg/m3	2,699 Mg/m3	2,656 Mg/m3	2,653 Mg/m3

Characteristics of RAP

Foreign elements (EN 12697-42)

Category	Maximal value of foreign elements
F_1	material contents of group 1 < 1% and material contents of group 2 < 0.1%
F_5	material contents of group 1 < 5% and material contents of group 2 < 0.1%
F_{dec}	Content and nature of foreign materials declared

German Stock, Swiss stock, Swiss Test section & French Test section : no foreign elements detected in the stock

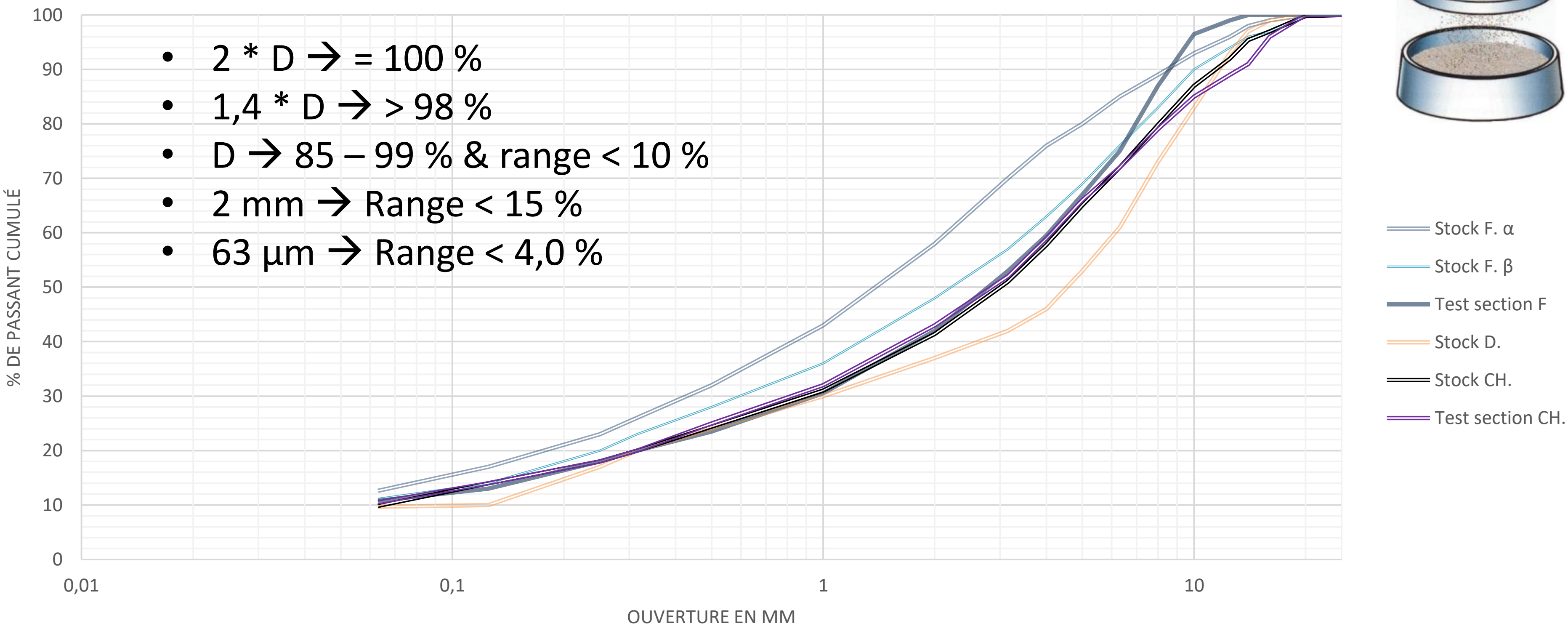
French Stock β : Presence of metal parts (0,2 %)

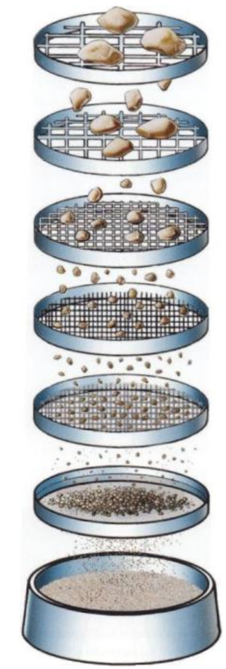
→ **Codification F1**

Characteristics of aggregates

Distribution Curve : EN 12697-2

- 2 * D → = 100 %
- 1,4 * D → > 98 %
- D → 85 – 99 % & range < 10 %
- 2 mm → Range < 15 %
- 63 µm → Range < 4,0 %





→ **Codification** G2 to **G1**

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Characteristics of aggregates

Resistance to fragmentation : LA (EN 1097-2)

	German Stock	Swiss Stock	French Stock β	French Stock α	
Granularity 4/6,3	18,5	16,9	18,5	-	→ 18
Granularity 6,3/10	18,2	17,0	17,8	17,5	→ 18
Granularity 10/14	17,0	16,4	17,4	16,5	→ 17

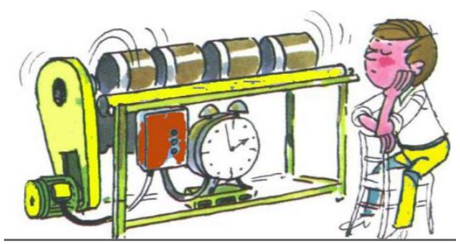
→ **Codification R1 (LA < 25)**

Cerema

Characteristics of aggregates

Resistance to wear : MDE (EN 1097-1)

	German Stock	Swiss Stock	French Stock β	French Stock α	
Granularity 4/6,3	12,2	8,7	11,7	-	→ 11
Granularity 6,3/10	9,2	7,7	8,6	9,1	→ 9
Granularity 10/14	7,9	7,6	8,1	9,9	→ 8



→ **Codification R1**

Characteristics of aggregates

Angularity : Ang (EN 933-5)

		German Stock	French Stock	Swiss Stock
Granularity 4/8	Crushed or broken / Totally rounded	86 % / 6 %	74 % / 9 %	83 % / 8 %
	Category	**Ang3 - $C_{50/10}$**	**Ang3 - $C_{50/10}$**	**Ang3 - $C_{50/10}$**
Granularity 8/14	Crushed or broken / Totally rounded	90 % / 2 %	86 % / 3 %	78 % / 7 %
	Category	**Ang2 - $C_{90/3}$**	**Ang3 - $C_{50/10}$**	**Ang3 - $C_{50/10}$**

Codification R3 (< Ang 1)

Characteristics of aggregates

Flakiness Index (EN 933-3)

	German Stock	Swiss Stock	French Stock β	French Stock α
FI (%)	8,1 %	11,9 %	8,8 %	9,9 %

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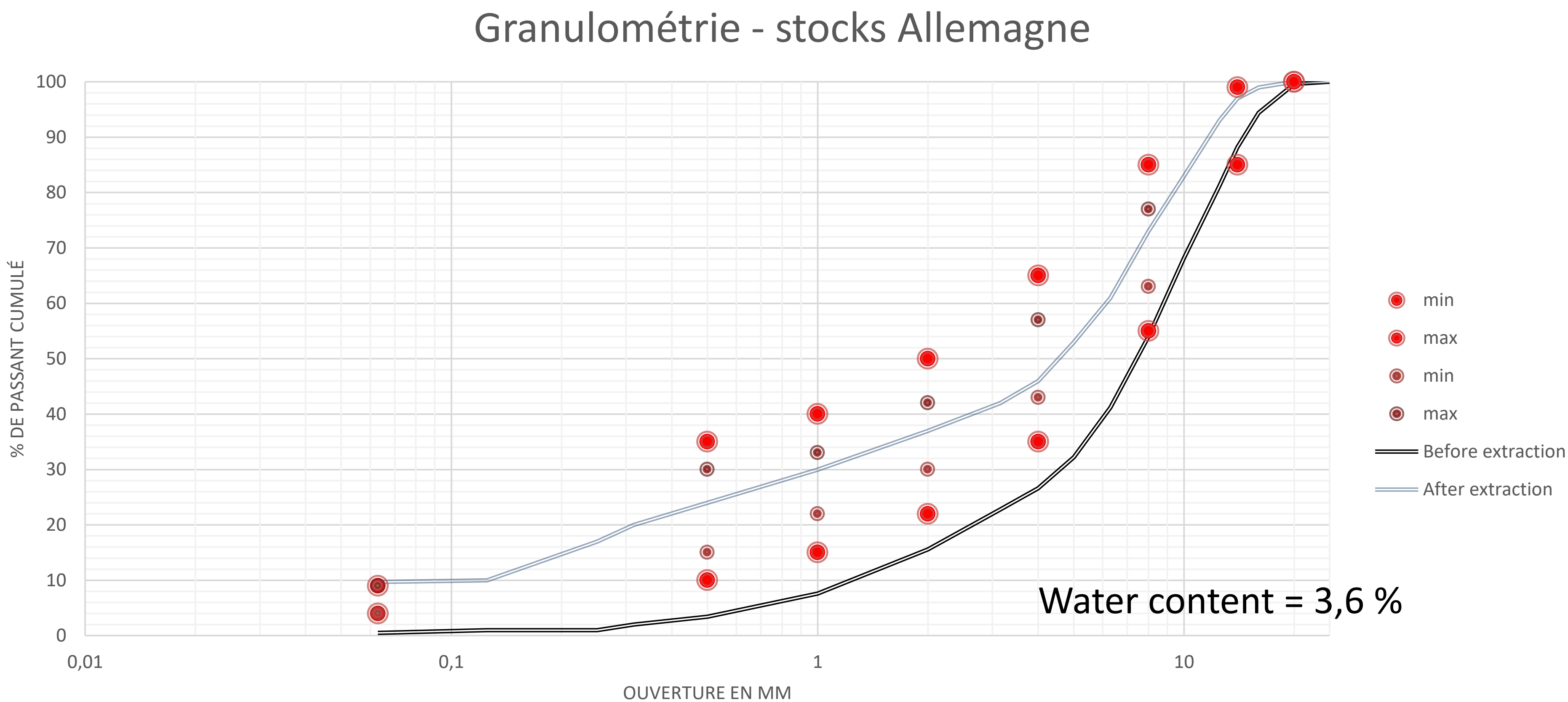
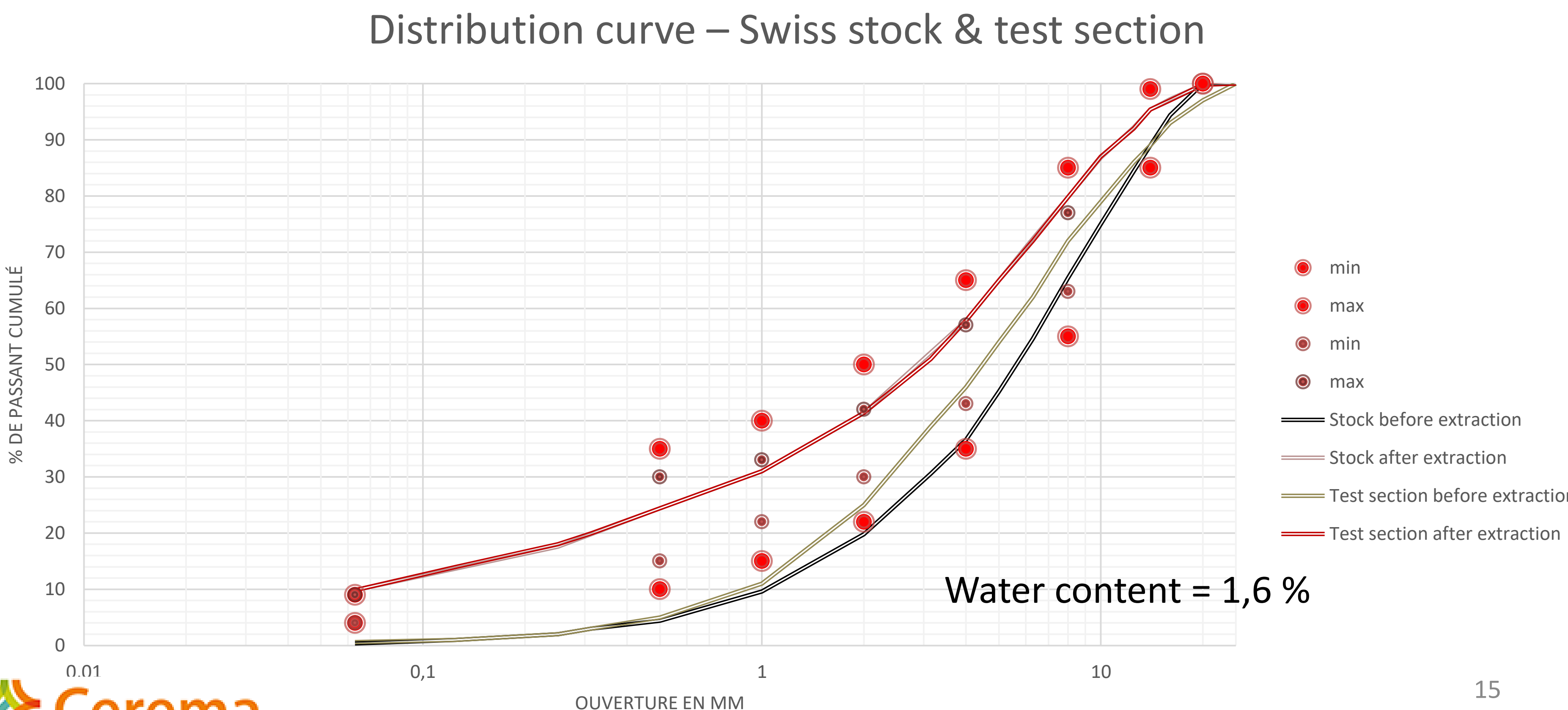
Characteristics of materials

- Distribution curve of german materials before / after extraction of bitumen (EN 13285)



Characteristics of materials

- Distribution curve of swiss materials before / after extraction of bitumen (EN 13285)



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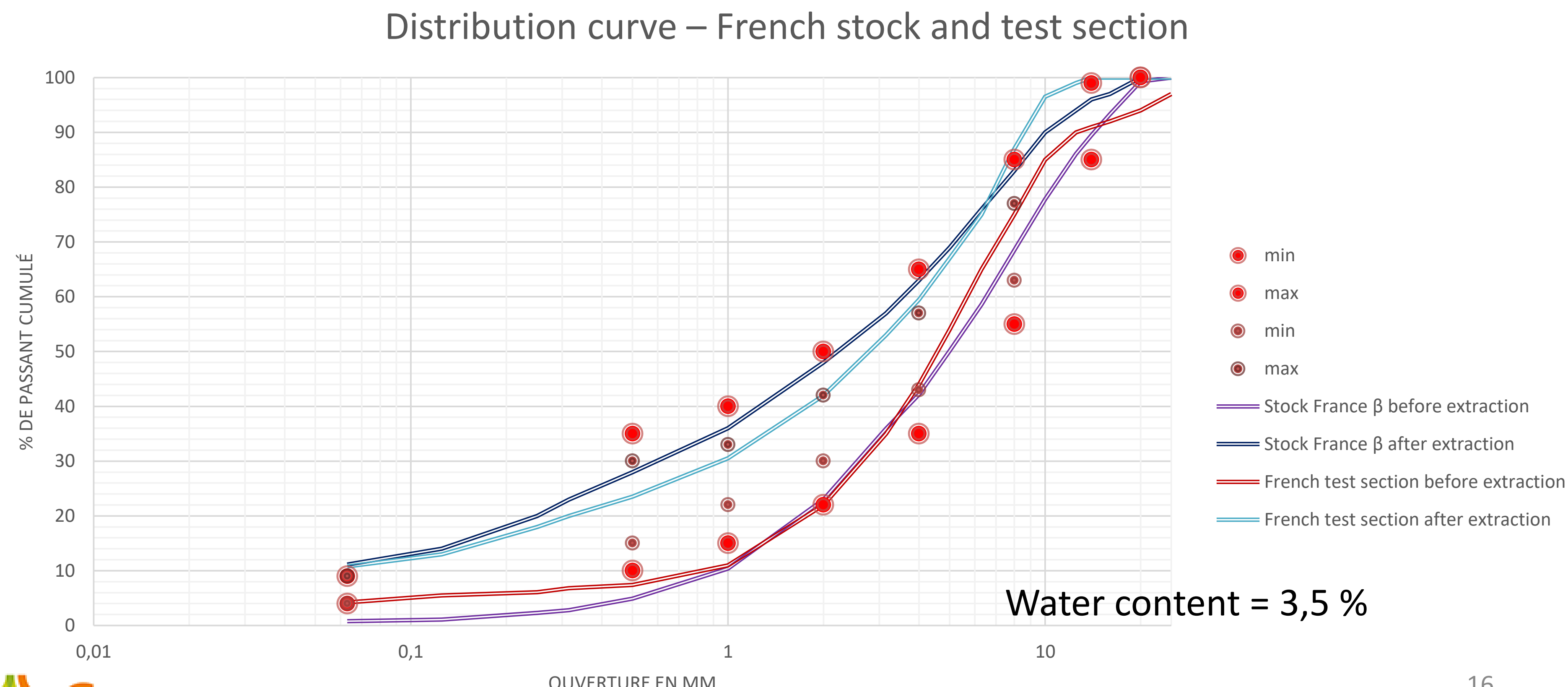
Characteristics of materials

- Distribution curve of french materials before / after extraction of bitumen (EN 13285)



Water content = 3,5 %

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Conclusions

- Relatively homogeneous materials (intrinsic characteristics)

  → silico-limestone alluviums

- Materials more or less graded depending on stocks

- Extracted aggregates rather located at the top of the UGM standard spindle (EN 13285)

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Characterization of extracted bitumen

Hartmut Herb

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

Determination and Methods:

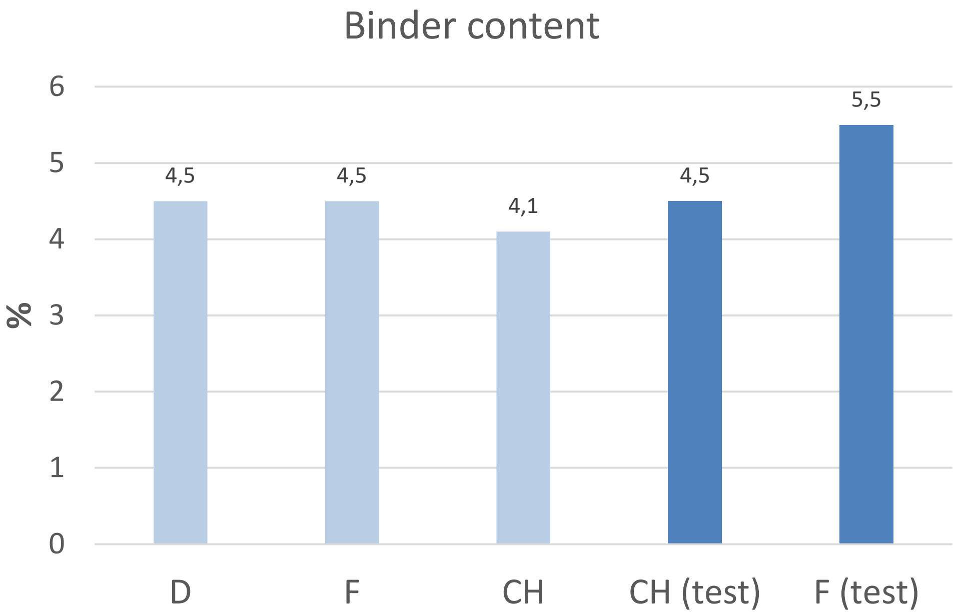
Physico-mechanical:

Binder content
Softening point
Needle-Penetration
Elastic recovery
Density
DSR
BBR

Chemical:

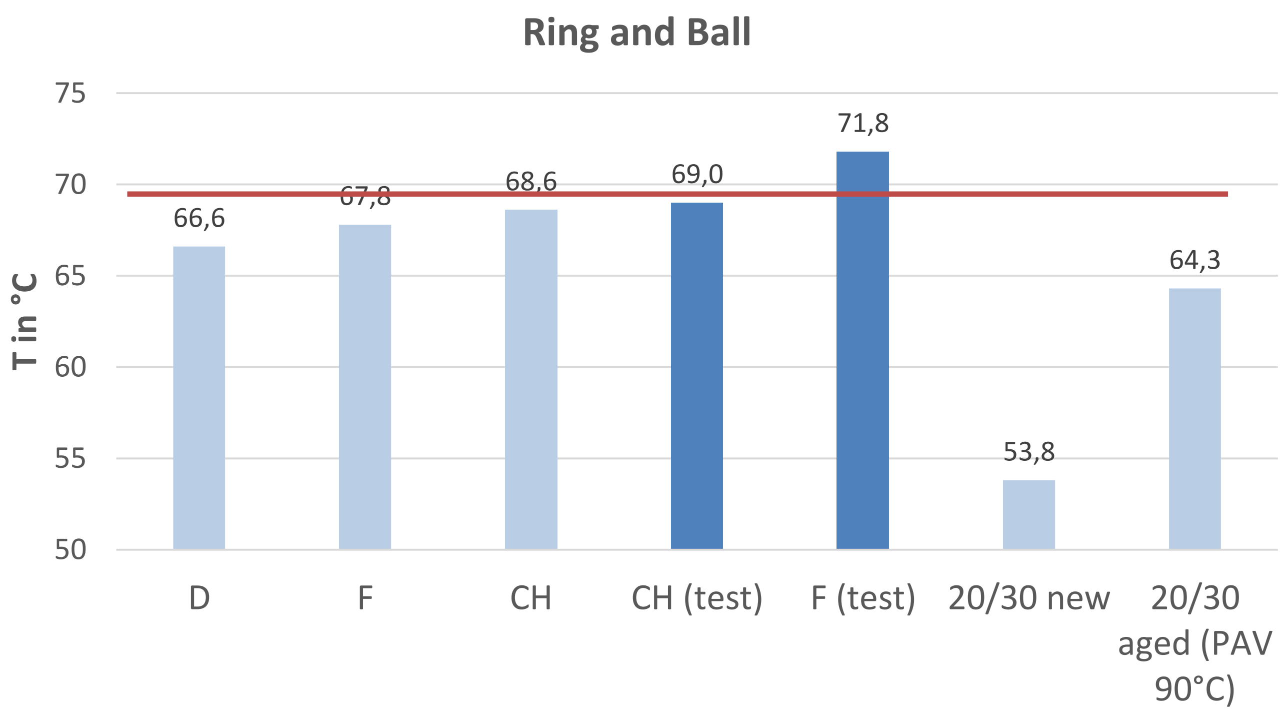
Molecular weight
Indices of Oxidation
SARA

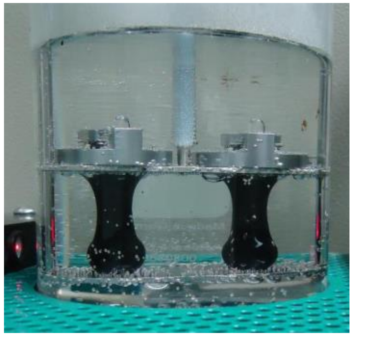
Binder content (EN 12697-3)



Ring and Ball (EN 1427)

Determination of the softening point

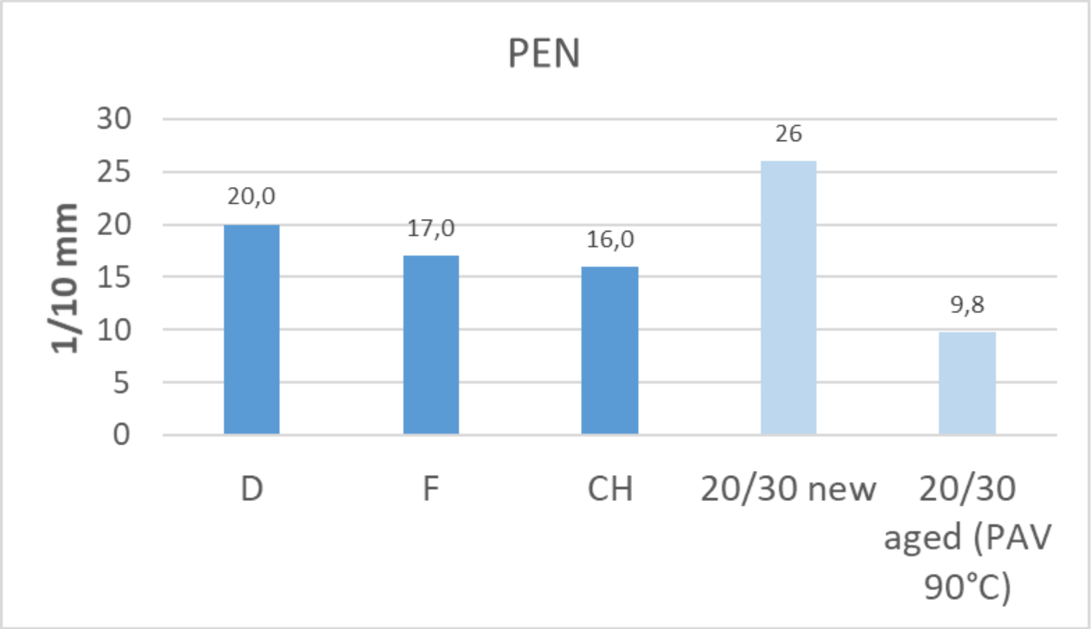




Regulation: limit 70°C (average), 77°C (maximum)

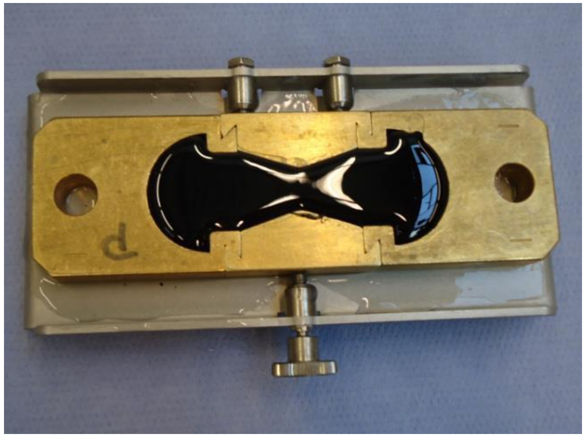
PEN (EN 1426)

Determination of needle penetration

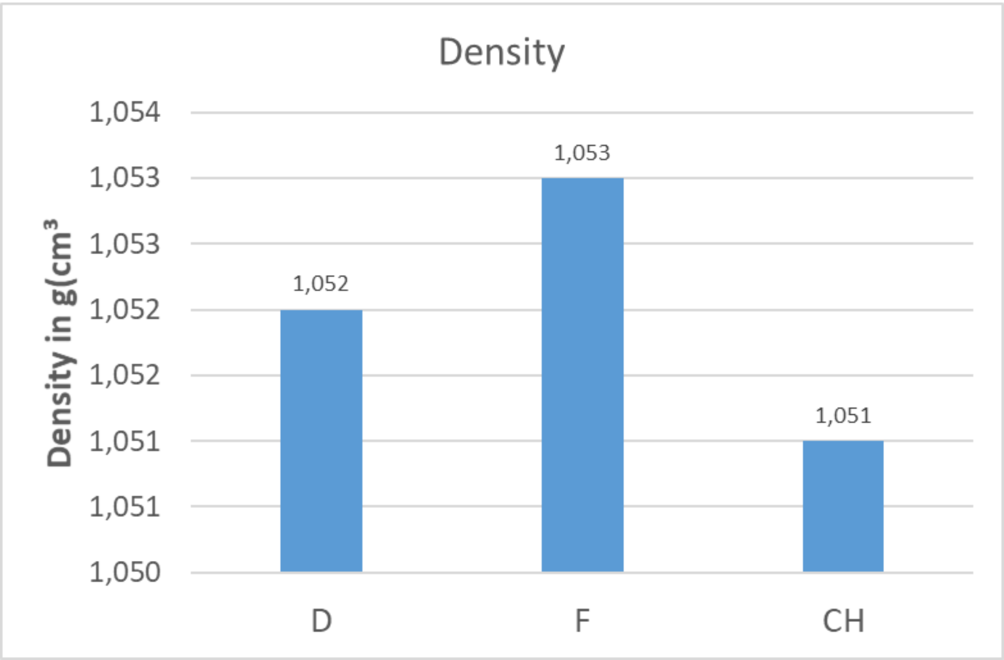


Elastic recovery test (EN 13398)

results:
no elastic recovery of each Bitumen



Density (EN 15326)



interreg Oberrhein Rhin Supérieur
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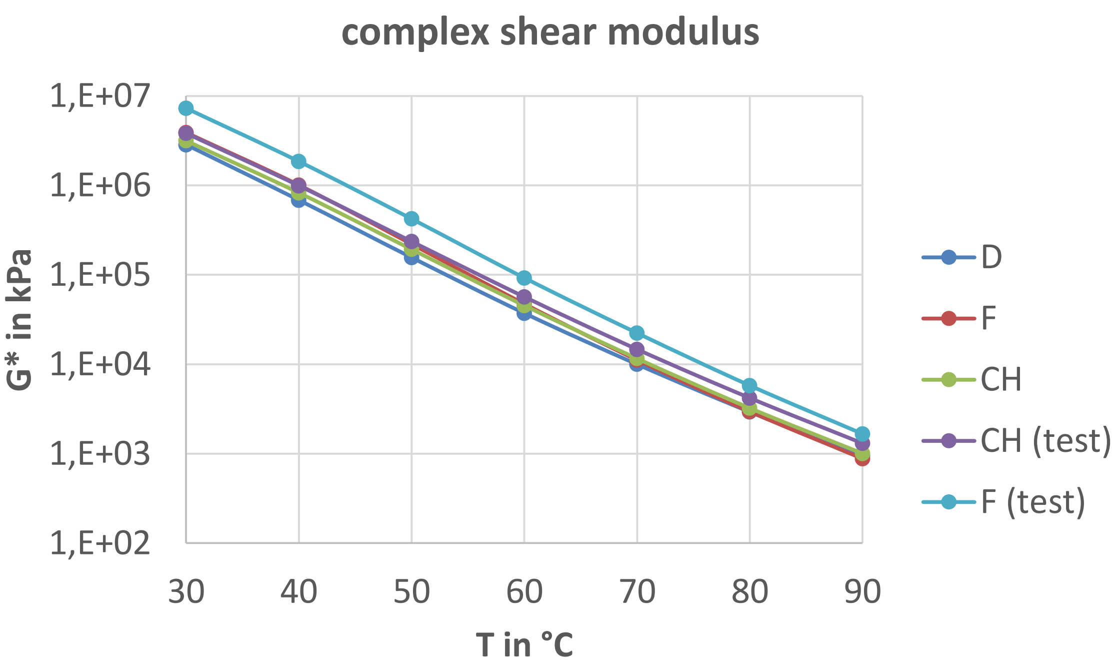
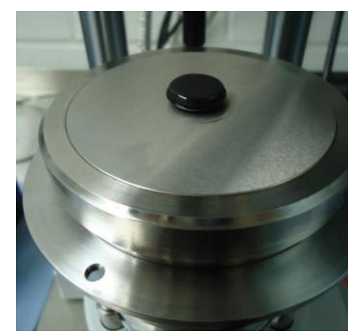
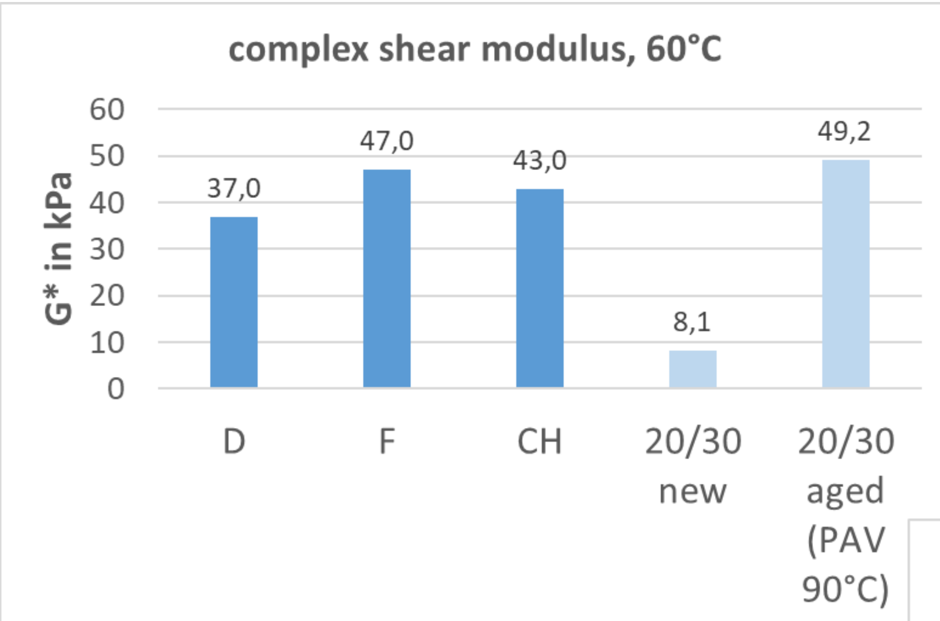
Dynamic shear rheometer (DSR, EN 14770)

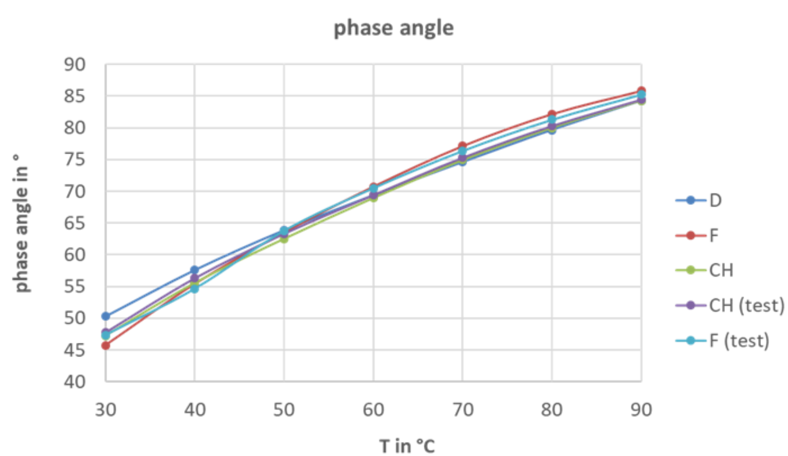
Determination of complex shear modulus

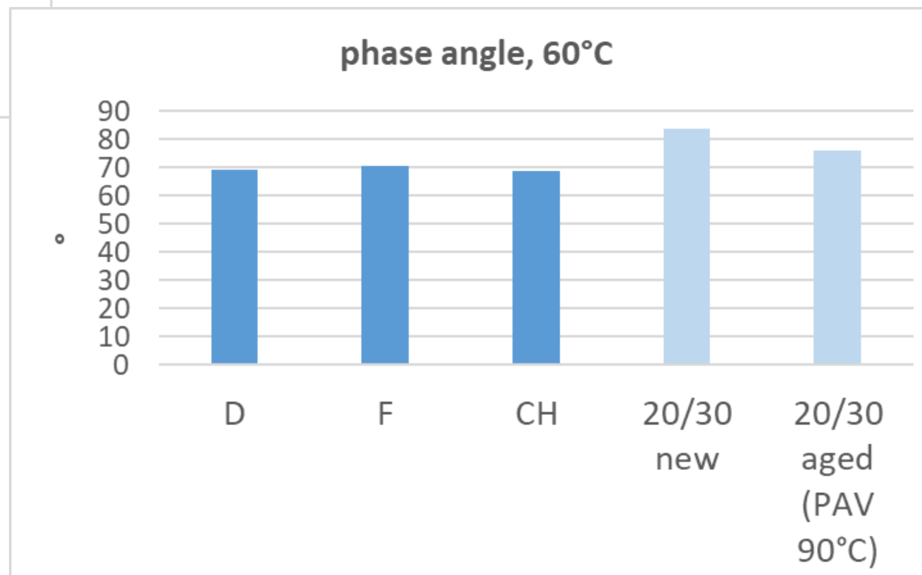
and phase angle (d=25mm, s=1mm)





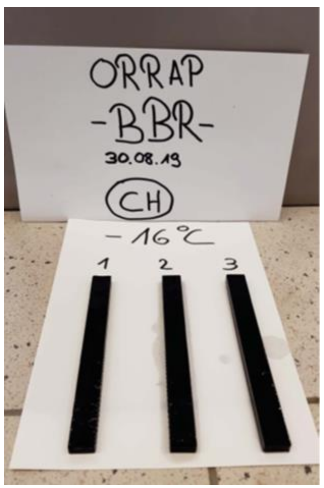

complex shear modulus, 60°C
G* in kPa
60
50
40
30
20
10
0
37,0
47,0
43,0
8,1
49,2
D
F
CH
20/30 new
20/30 aged (PAV 90°C)

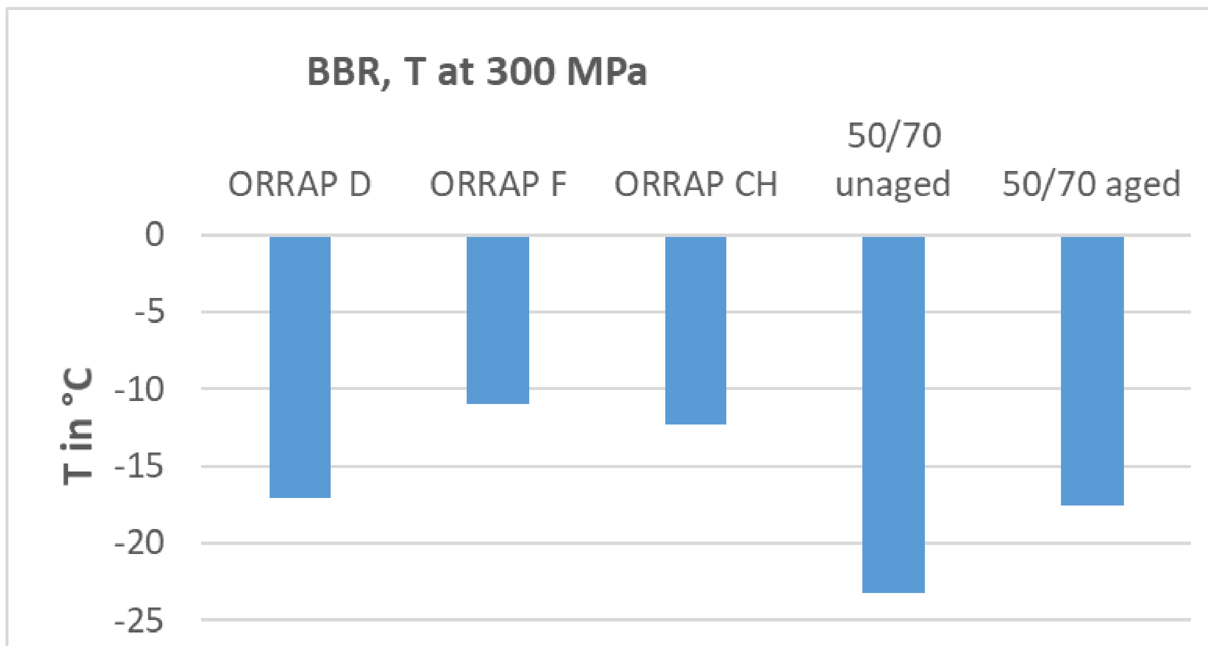

phase angle
phase angle in °
90
85
80
75
70
65
60
55
50
45
40
30
40
50
60
70
80
90
T in °C
D
F
CH
CH (test)
F (test)


phase angle, 60°C
°
90
80
70
60
50
40
30
20
10
0
D
F
CH
20/30 new
20/30 aged (PAV 90°C)

Low temperature performance

by Bending Beam Rheometer, BBR





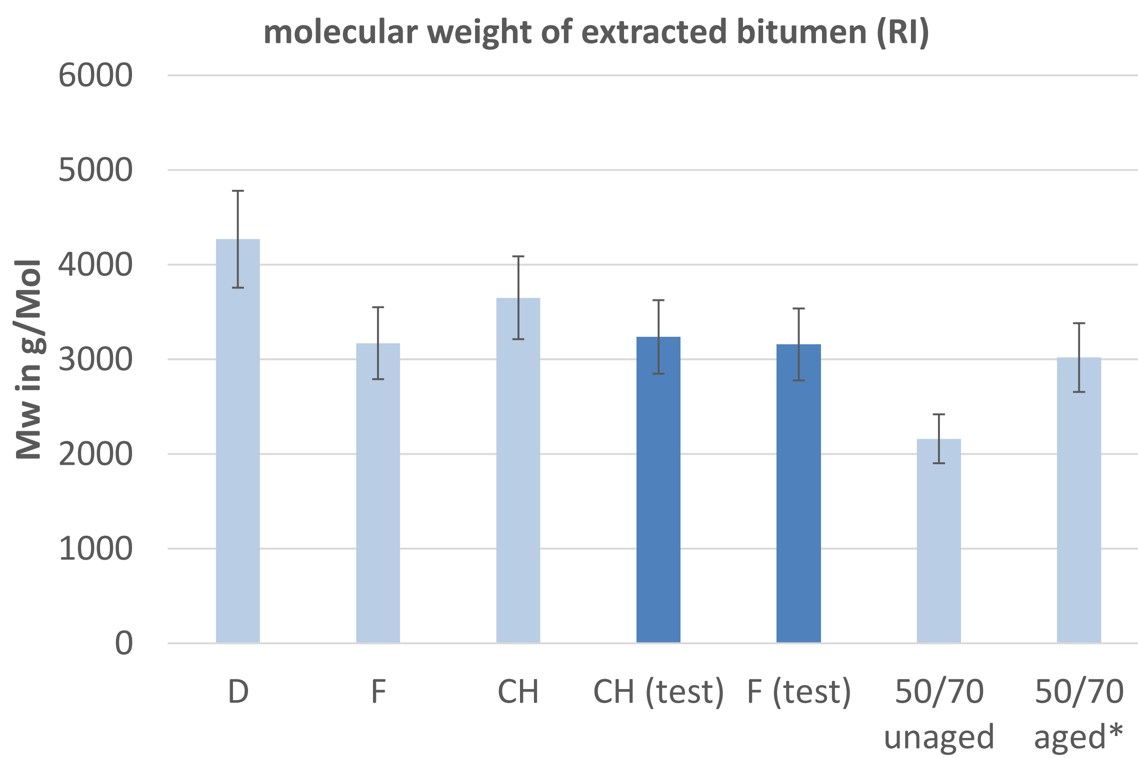
Molecular weight

by gel permeation chromatography, GPC

Method of liquid chromatography

separation of compounds by hydrodynamic volume, i.e. by size and shape in a porous system

solid phase: SDV
solvent: THF
detector: RI
calibration: polystyrene



SARA-analysis

Two step method:
precipitation of **Asphaltenes** (iso-octane insolubles)
and liquid-chromatographic separation of **Maltenes**

information:
quantitative separation of bitumen in

Saturates
Aromatics (mono-, di-, poly-)
Resins
} **Maltenes**

Asphaltenes

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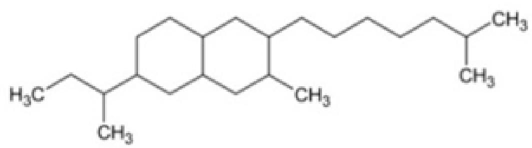
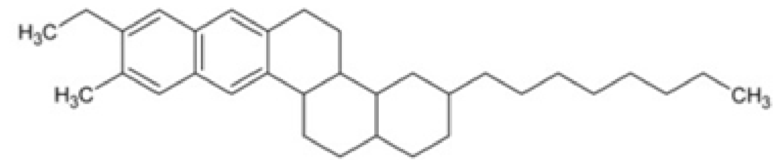
Schematic structures of SARA-compounds

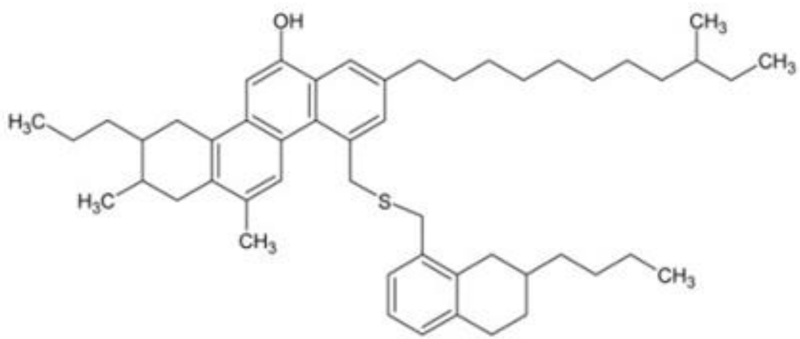
Saturates



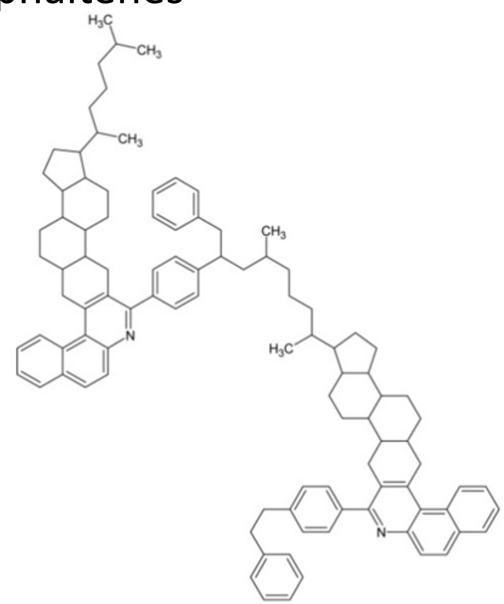
Aromatics



Resins



Asphaltenes



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procedure of Maltene separation (Sebor et al.)

Column material:

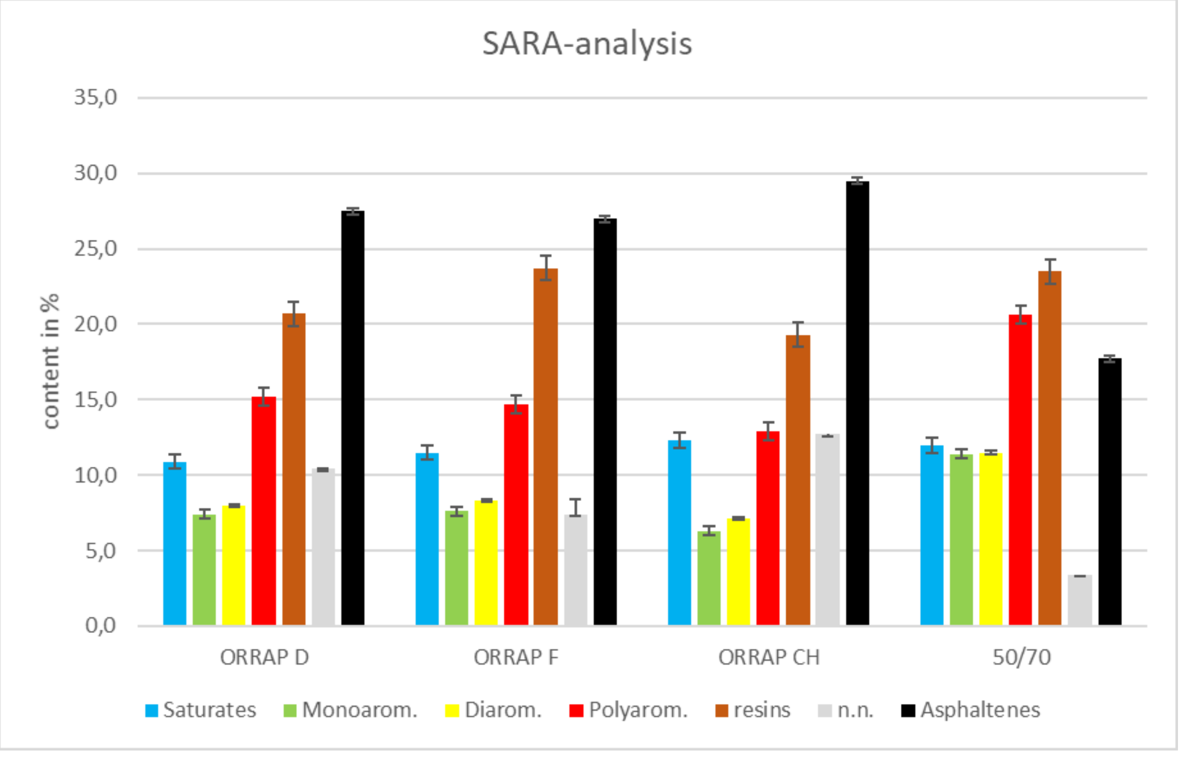
alumina/silicagel

Solvents:

Saturates:	Iso-octane	
Mono-aromatics:	Iso-octane/Toluene 19:1	
Di-aromatics:	Iso-octane/Toluene 17:1	increasing polarity
Poly-aromatics:	Toluene	
Resins:	Methanol/Diethylether/Toluene 3:1:1	

Evaluation:

Determination of mass after solvent evaporation and drying


SARA-analysis
content in %
35,0
30,0
25,0
20,0
15,0
10,0
5,0
0,0
ORRAP D
ORRAP F
ORRAP CH
50/70
Saturates
Monoarom.
Diarom.
Polyarom.
resins
n.n.
Asphaltenes

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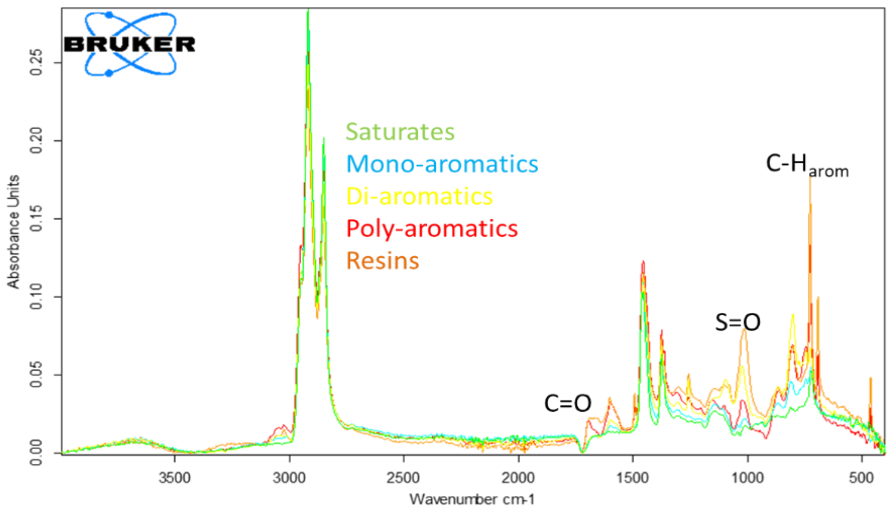
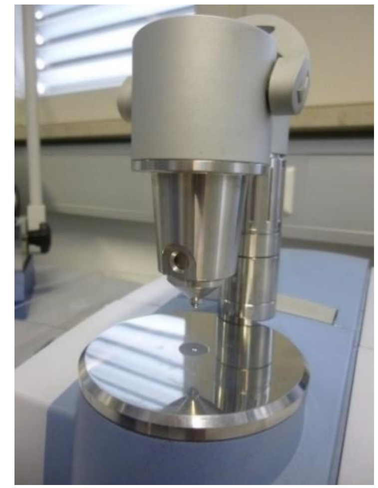
Oxidation state

by FTIR-ATR-technique



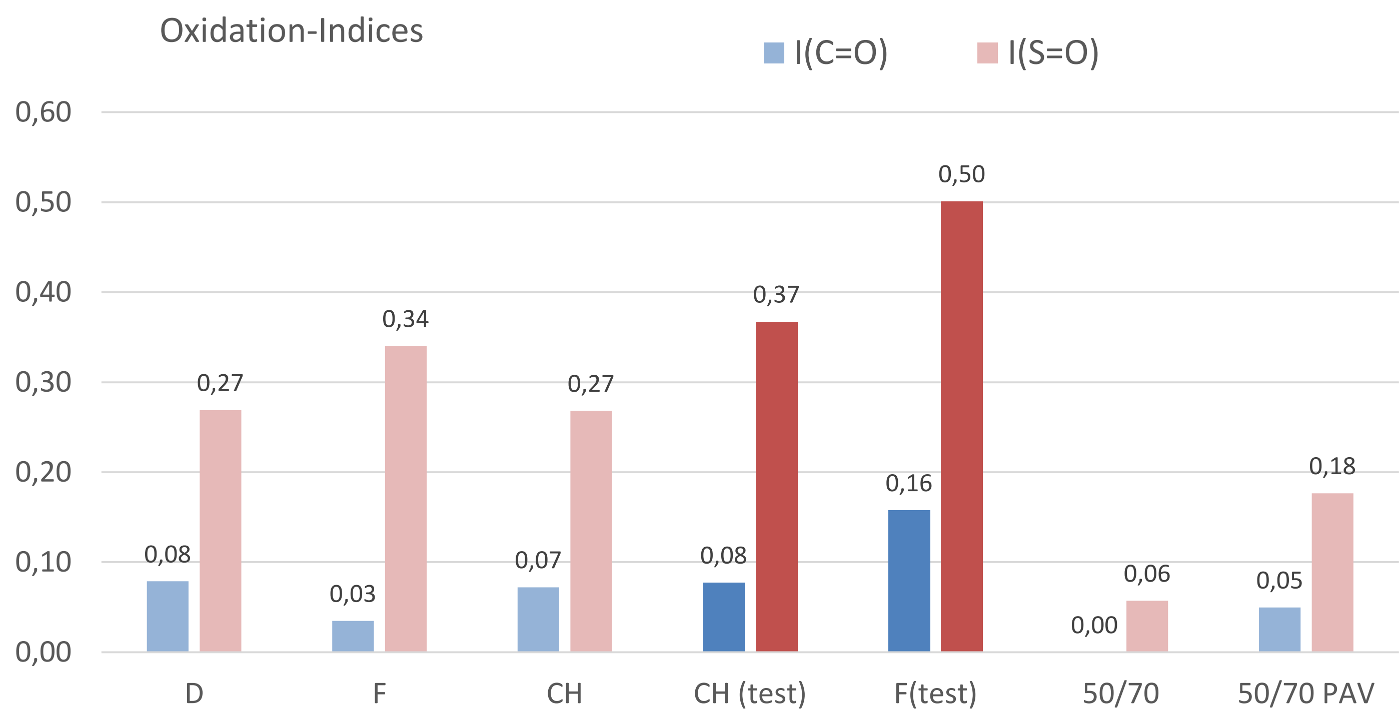


Quantification by Carbonyl- and Sulfoxid-Indices

$$I_{CO} = \frac{Area\ of\ the\ C=O\ peak\ around\ 1700\ cm^{-1}}{Area\ of\ the\ CH\ peak\ around\ 1455\ cm^{-1} + Area\ of\ the\ CH\ peak\ around\ 1376\ cm^{-1}}$$

$$I_{SO} = \frac{Area\ of\ the\ S=O\ peak\ around\ 1030\ cm^{-1}}{Area\ of\ the\ CH\ peak\ around\ 1455\ cm^{-1} + Area\ of\ the\ CH\ peak\ around\ 1376\ cm^{-1}}$$

Extracted bitumen



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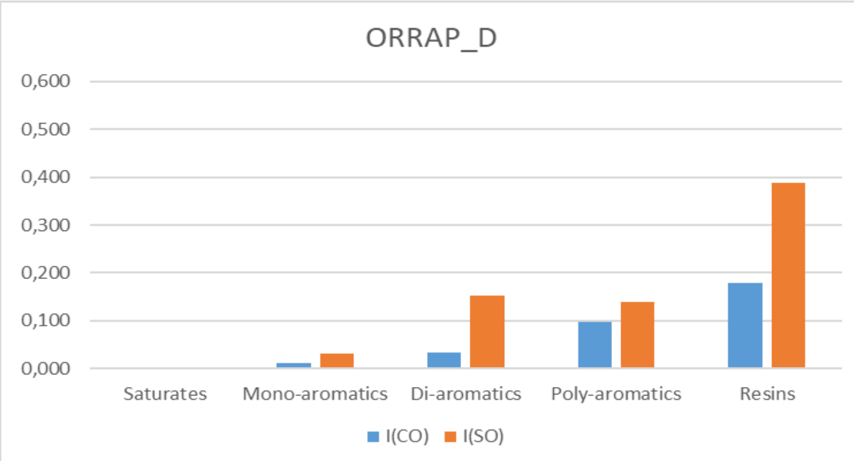
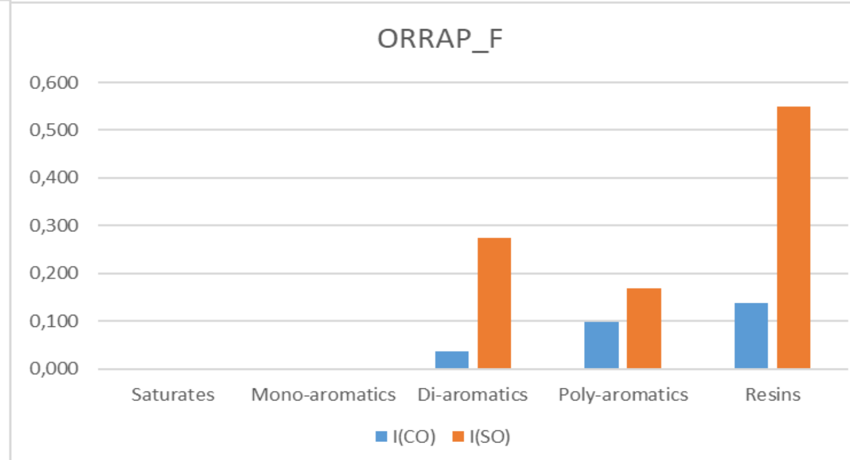
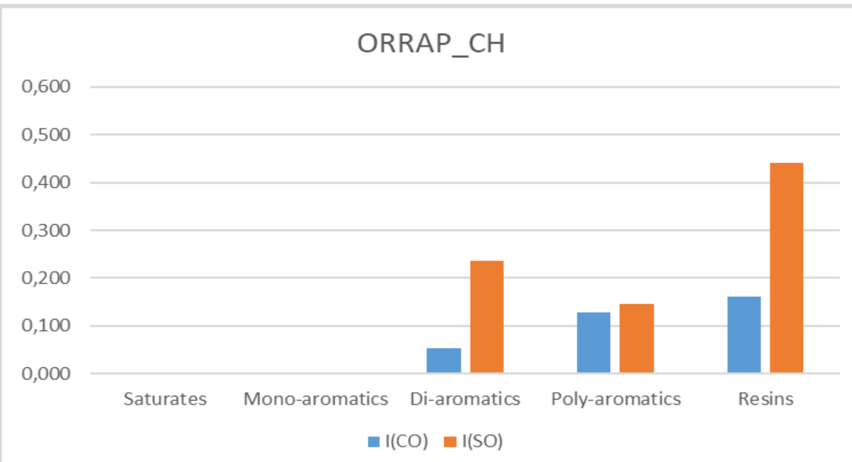
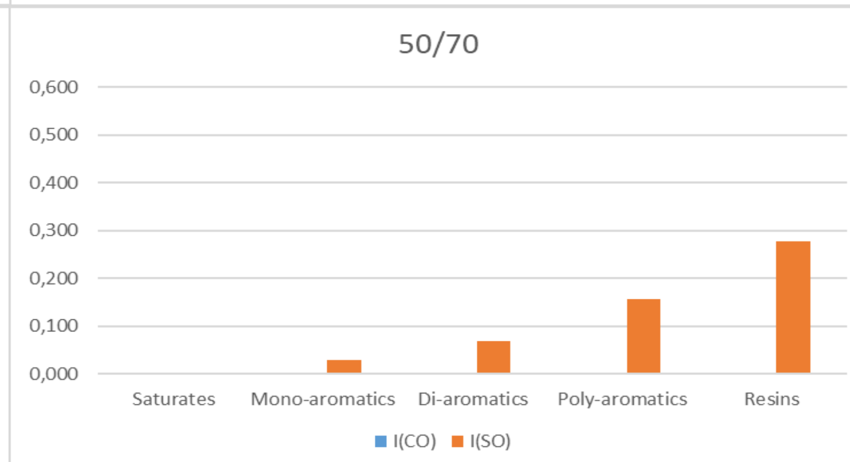
Separated Maltenes

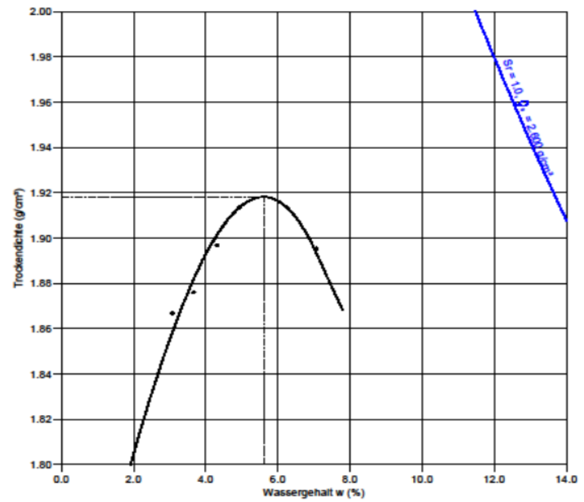








Modified Proctor Test (DIN 18127)



		D	F	CH
max. density	g/cm³	1,92	1,79	1,81
opt. moisture content	%	5,6	5,5	4,3

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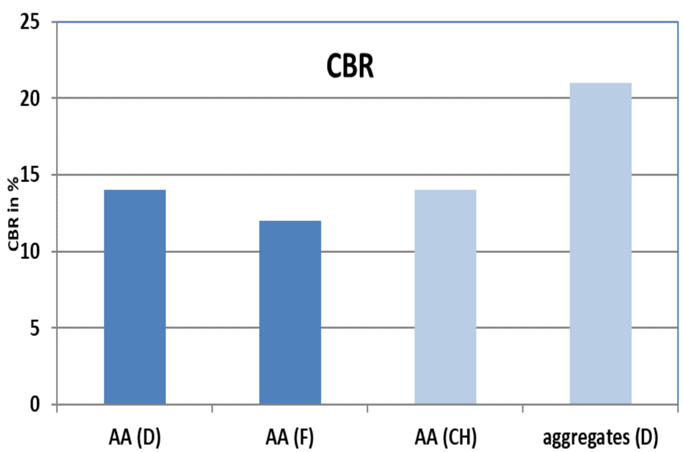
CBR (California Bearing Ratio)
(EN 13286-47)

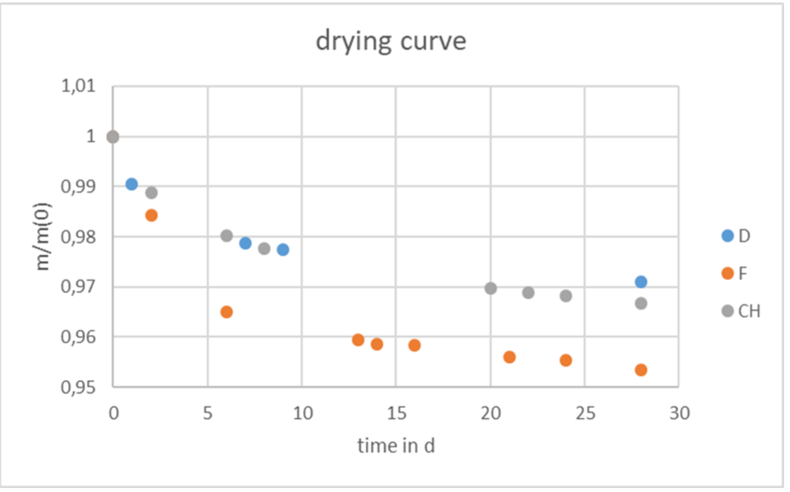
→ measuring the pressure required to penetrate soil or aggregate with a plunger

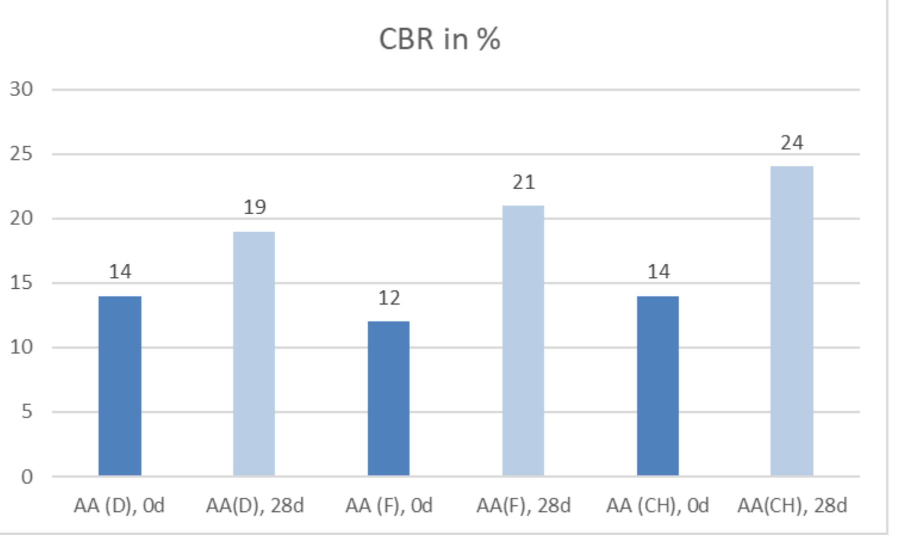
AA compacted by **modified Proctor test**

value compared to certified limestone in %



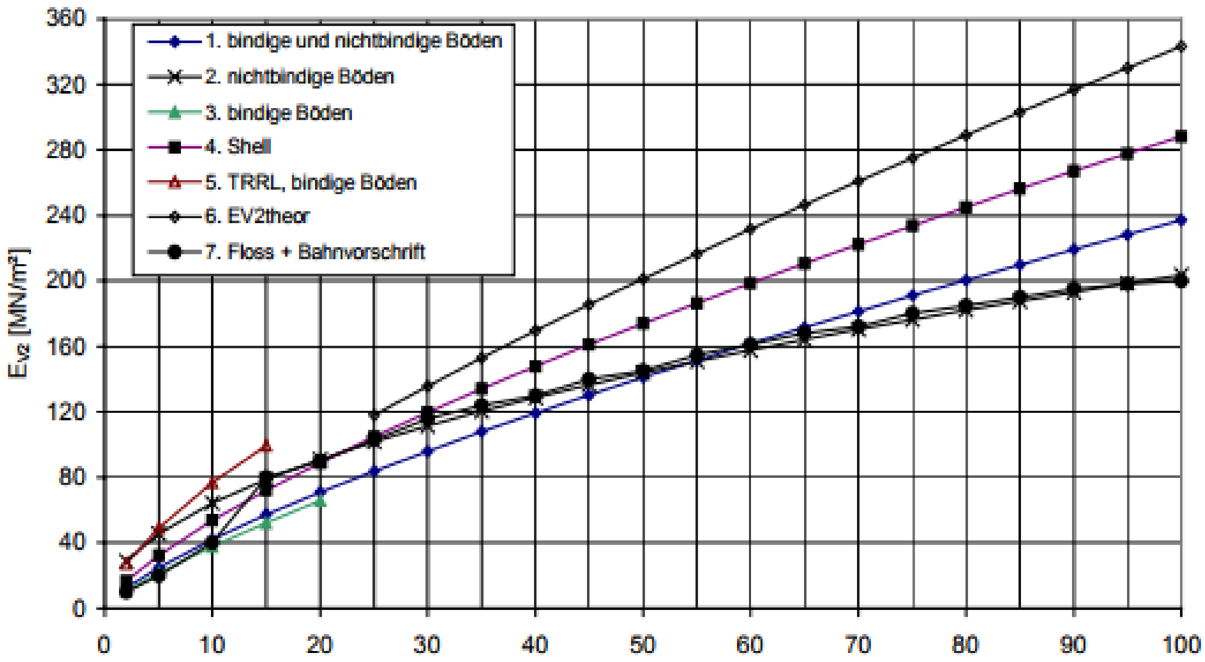
Effect of drying





→ increase after 28 d for each AA

Correlation between CBR and E_{V2}-modulus of deformation



source: https://opus4...bv.de/opus4-btu/files/104/diss_lottmann.pdf

→ max. E_{V2}-values for AA: ca. **75 N/mm²**

→ verification in situ by plate-loading test

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Optimales Recycling von Ausbauasphalt auf verkehrsschwachen Straßen

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PART III

Mechanical Behaviour (GSR & ITS tests)

Arnaud Feeser, Cerema

Mechanical behaviour

Assessment of the impact of moisture content on compactibility (PCG) – EN 12697-31

- Protocol
  - 300 gyrations
  - 4 water contents (4 to 7 %)
  - French stock α

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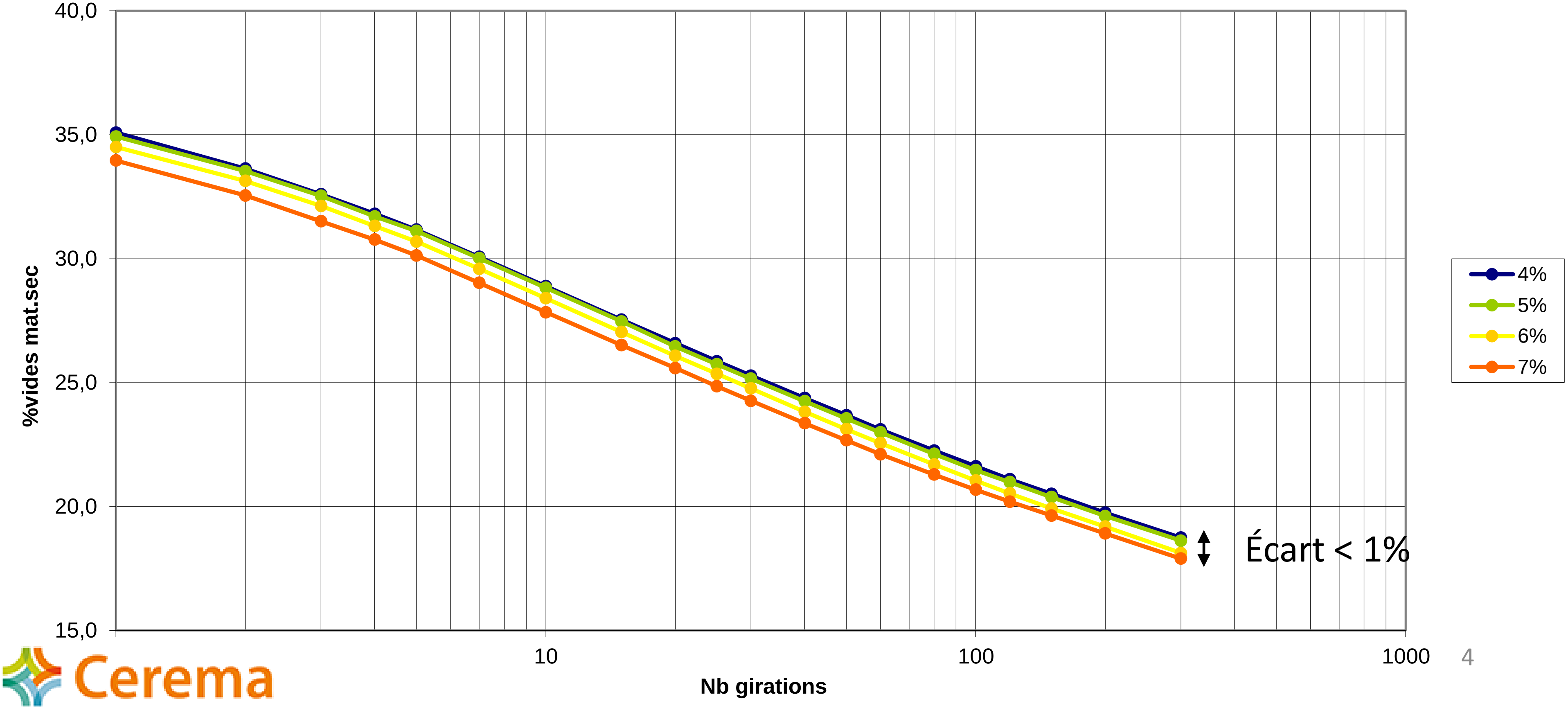
Mechanical behaviour

Assessment of the impact of moisture content on compactibility (PCG) – EN 12697-31



Cerema

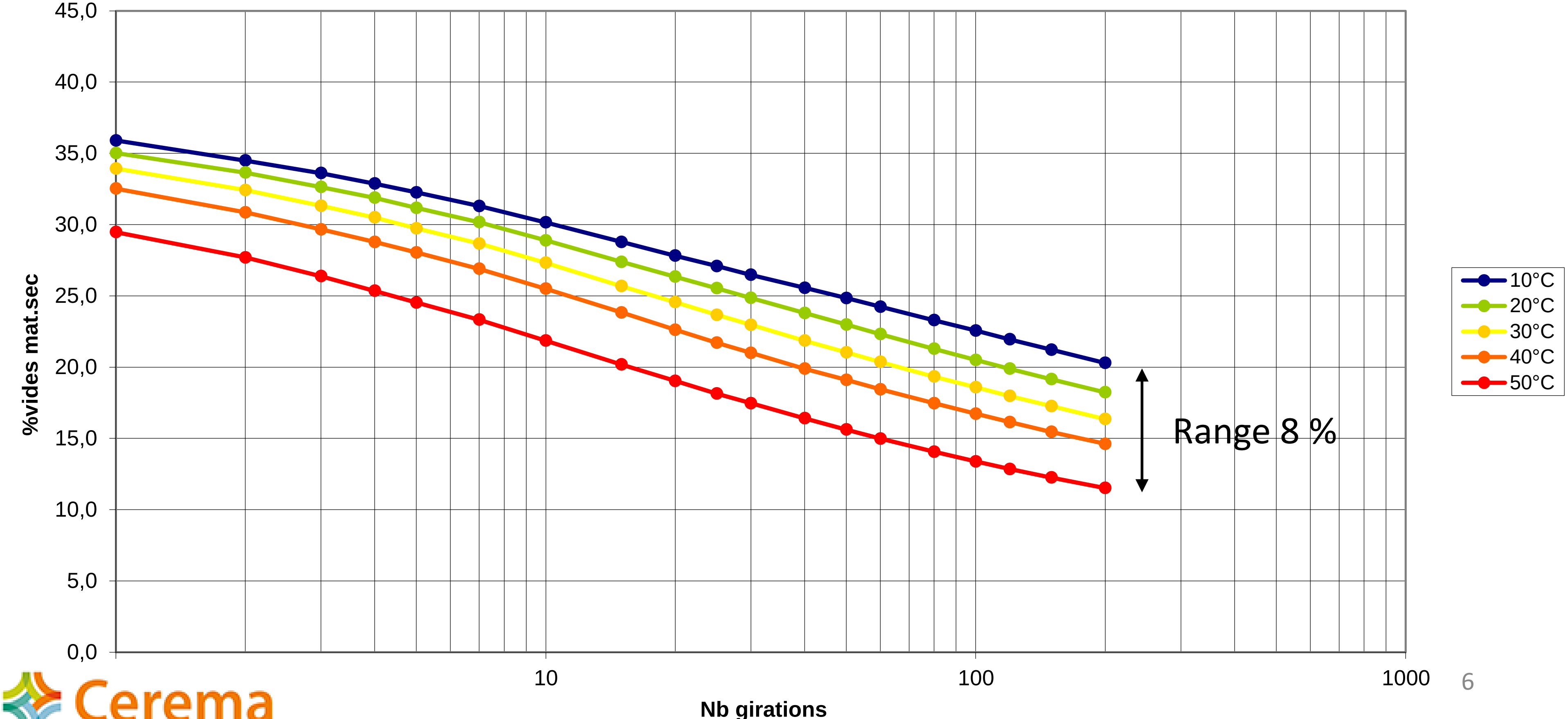
Mechanical behaviour

Assessment of the impact of temperature on compactibility (PCG) – EN 12697-31

- Protocol
  - 200 gyrations
  - 5 temperatures (10 to 50 °C)
  - German and French β stocks
  - Compaction to MPO water content

Mechanical behaviour

Assessment of the impact of temperature on compactibility (PCG) – Example for France β Stock



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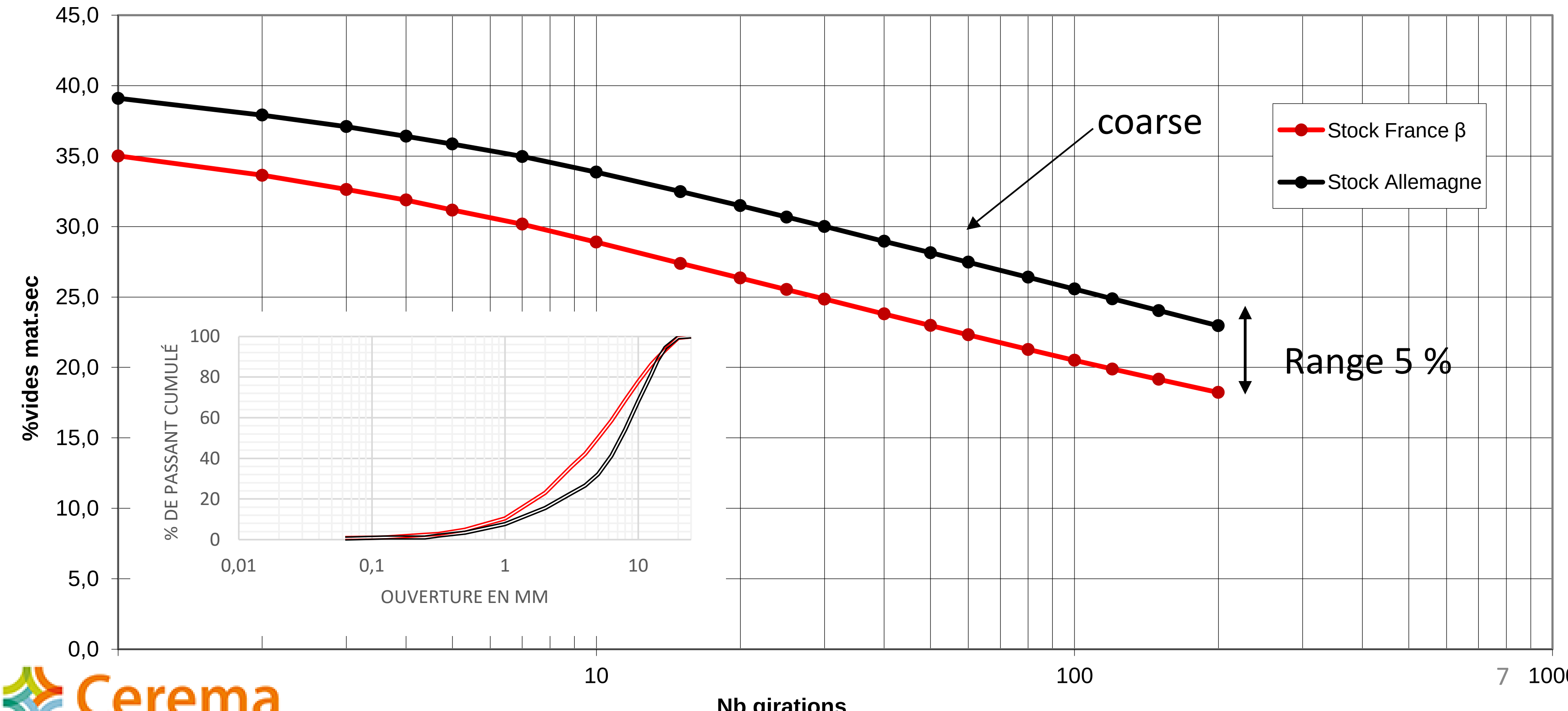
Mechanical behaviour

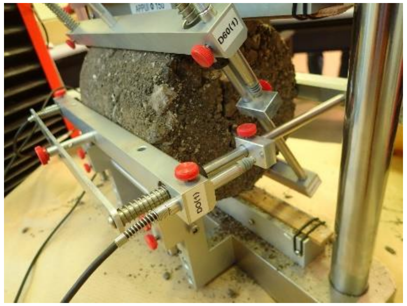
Evaluation of the impact of grain size on compactibility (PCG) at room temperature (20 °C)

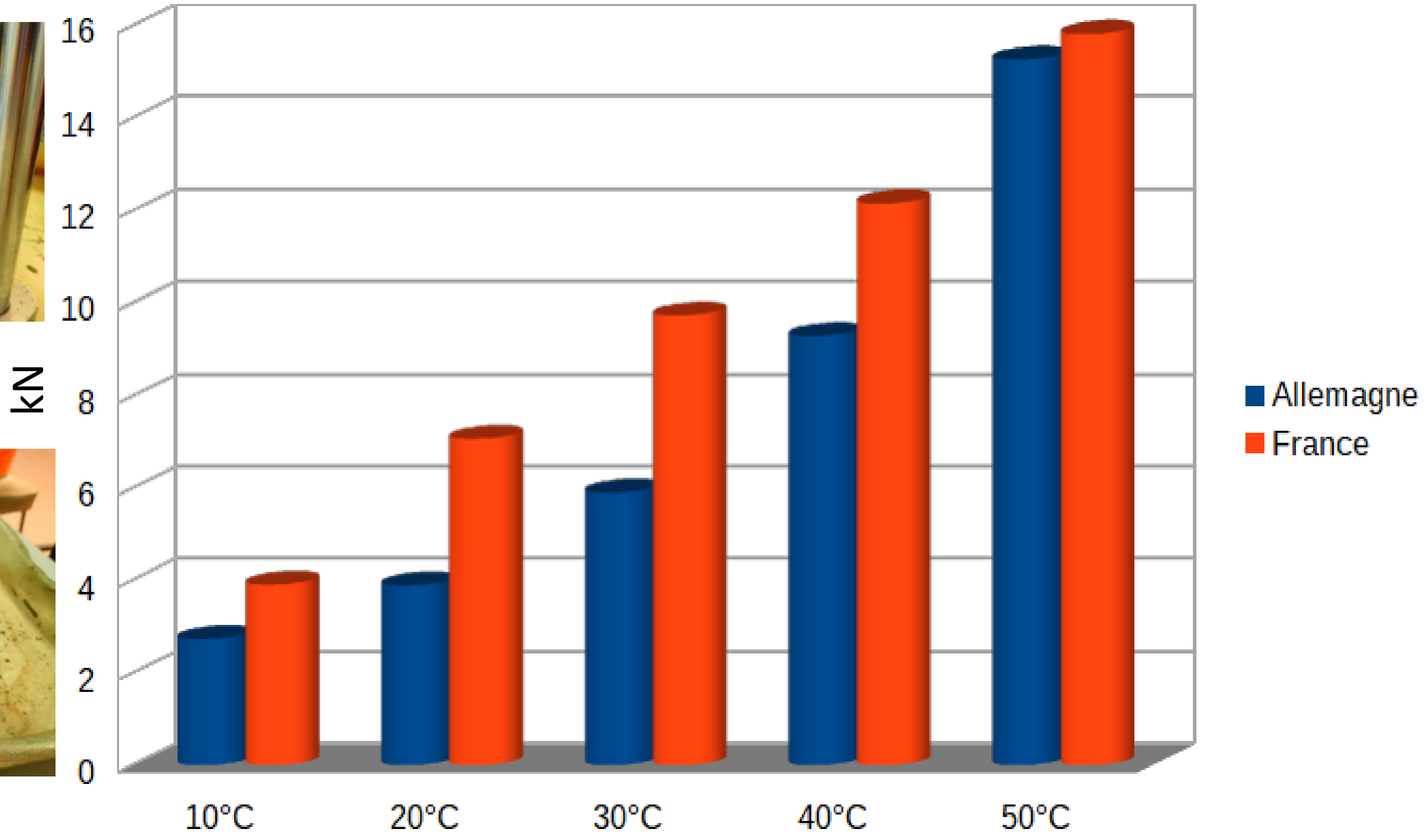


Cerema

Mechanical behaviour

Evaluation of the impact of temperature compaction on ITS at 20 °C – Stocks : Germany & France

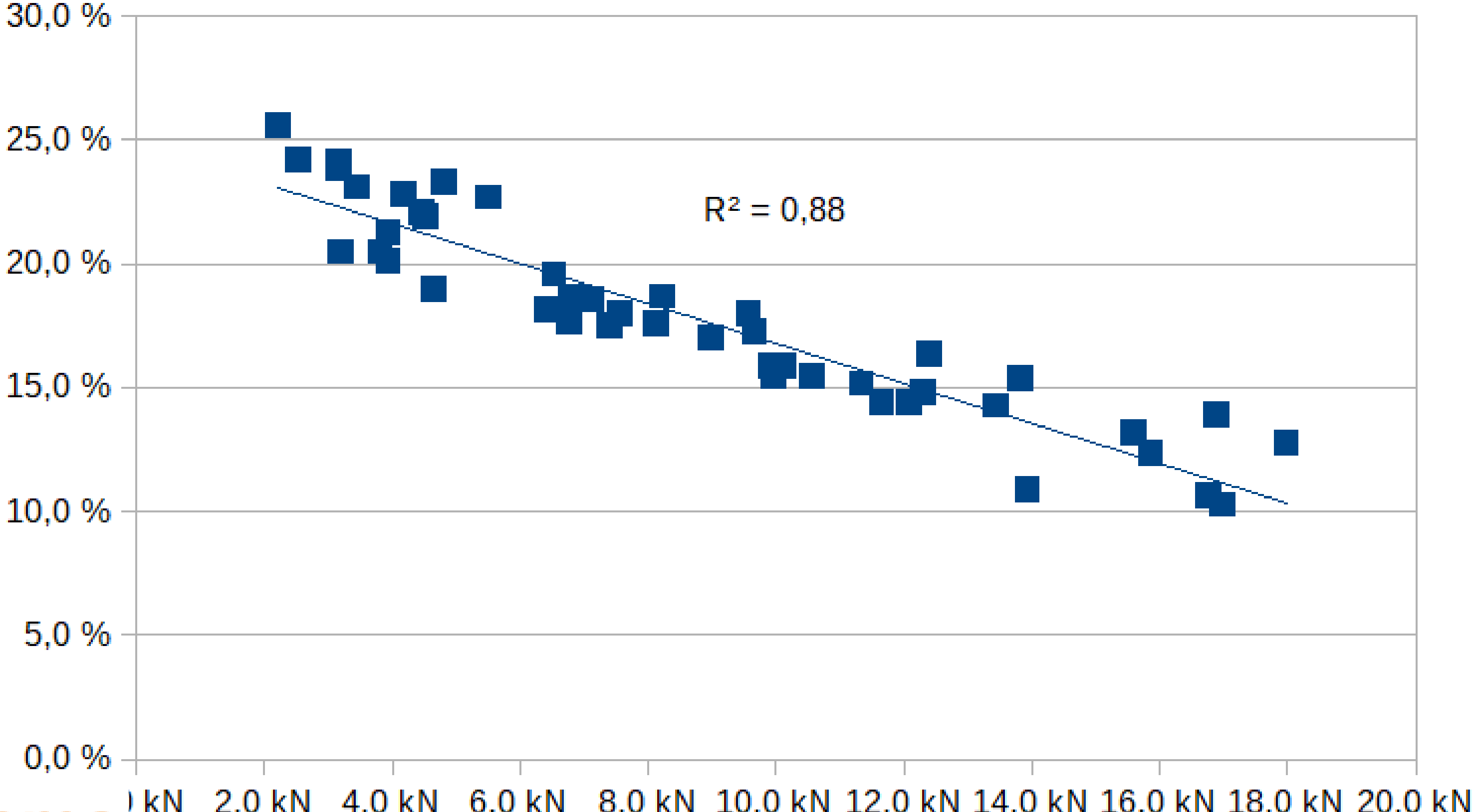




Cerema

Mechanical behaviour

Evaluation of the impact of voids on ITS at 20 °C – Stocks : Germany & France



Conclusions

- Strong impact of the compaction temperature on compactness the material and its strength
- Relatively low impact of water content on material compaction
- (Normal) impact of the void content on the strength of the material

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Triaxial tests

Laura Gaillard

laura.gaillard6@gmail.com

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Sampling

Mix material + water

↓

Compaction of sample

Device at INSA
Vibratting hammer
Sample 300 mm x 150 mm

Device at IFSTTAR
Vibrocompression
Sample 320 mm x 160 mm

RAP

RAP after binder extraction

Rupture tests

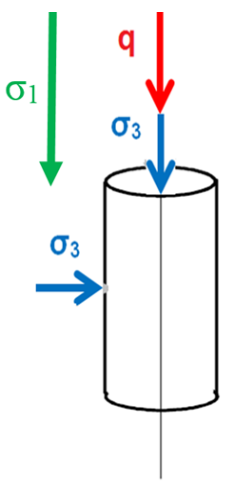
<u>Studied materials from laboratory of France</u>

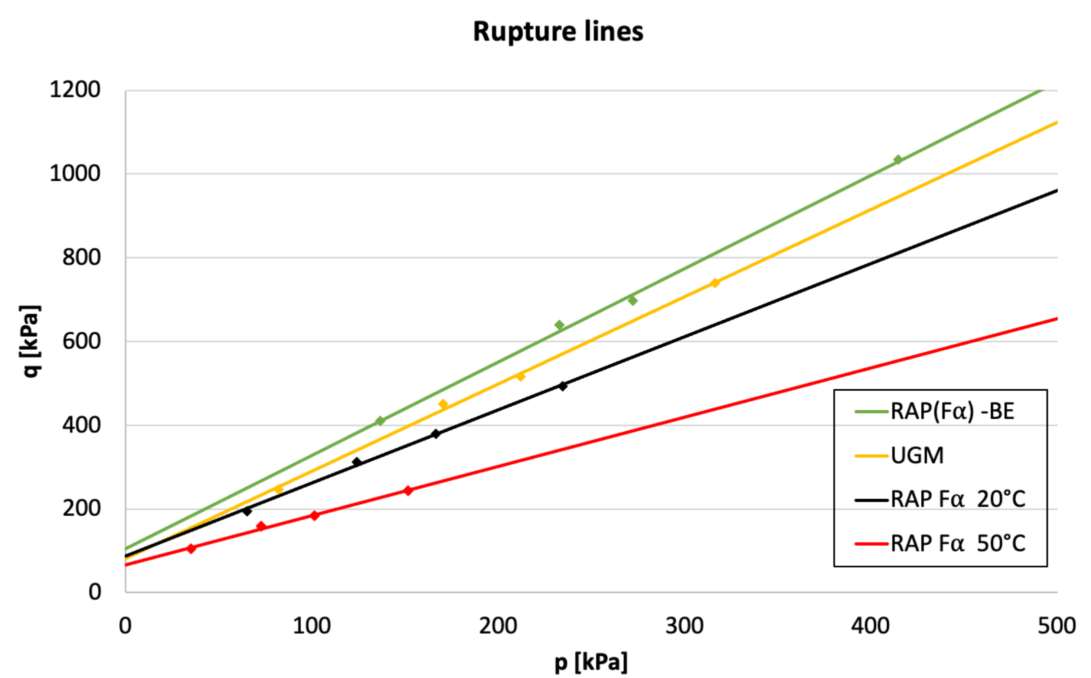
RAP Fα : French stock α with PAH

RAP$_{F\alpha}$-BE : RAP Fα after binder extraction

UGM : UGM from Rhine Region

	Friction angle ϕ [°]	Cohesion c [kPa]	Water content w [%]	Dry density γ_d [Mg/m3]	Void content
RAP Fα 20°C	42.58	45.90	3.9	1.96	0.27
RAP Fα 50°C	34.13	28.60	3.9	1.96	0.27
RAP$_{F\alpha}$-BE	54.39	66,21	3.3	2.14	0.24
UGM	50.69	47.42	3.9	1.96	0.35





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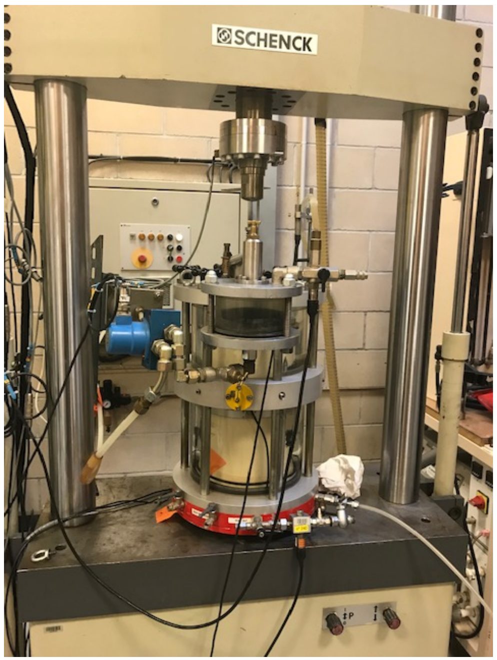
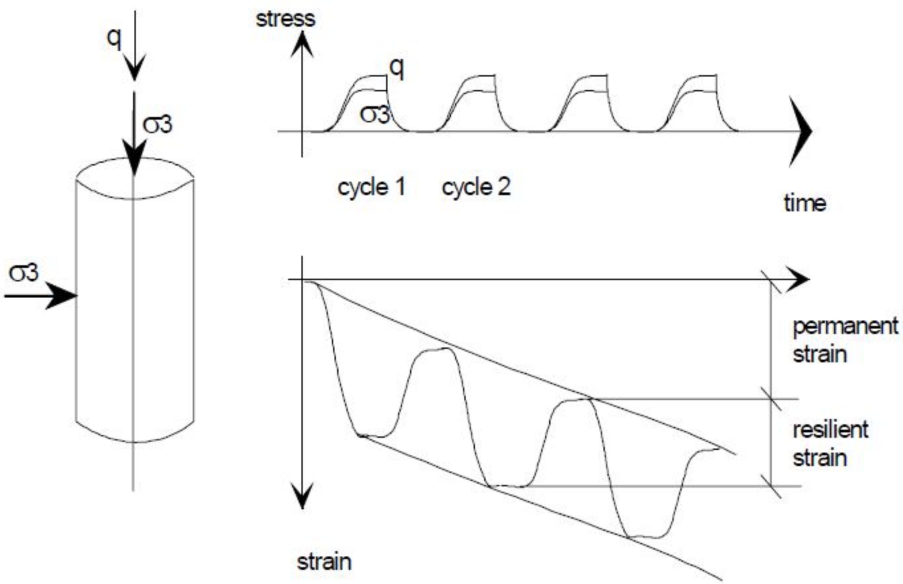
Repeated Load Triaxial Tests (RLTT)

to reproduce the traffic repeated solicitations



Triaxial cell at IFSTTAR



- **Constant or variable confining pressure σ_3**
- **Cyclic deviator stress q**

Temperature controlled triaxial cell at INSA

2 phases :

- **Conditioning:** stabilisation of permanent strains (30 000 cycles)
- **Resilient test:** study of resilient strains (100 cycler per stress path)

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Why RLTT ?

PHASE 1 : conditioning

↓

Permanent strains

↓

Rutting resistance

PHASE 2 : resilient test

↓

Resilient strains

↓

Resilient modulus
Characteristic Elastic modulus

French Standard for UGM NF EN 13286-7

Traffic category T3 : low traffic

Permission to use the material in base and subbase courses if :

Mechanical properties	**Characteristic permanent axial strain ε_1^c**	**Characteristic elastic modulus E_c**
OR	$2.5 \times 10^{-3} < \varepsilon_1^c \leq 6 \times 10^{-3}$	$500 \text{ MPa} \leq E_c$
	$\varepsilon_1^c \leq 6 \times 10^{-3}$	$250 \text{ MPa} \leq E_c < 500 \text{ MPa}$

E_c : characteristic elastic modulus is determined on stress path : p_{max} = 250 kPa and q_{max} = 500 kPa

ε_1^c : characteristic permanent axial strain is measured at the end of conditioning (after 20 000 cycles)

$$\varepsilon_1^c = \varepsilon_1^p(20\,000) - \varepsilon_1^p(100)$$

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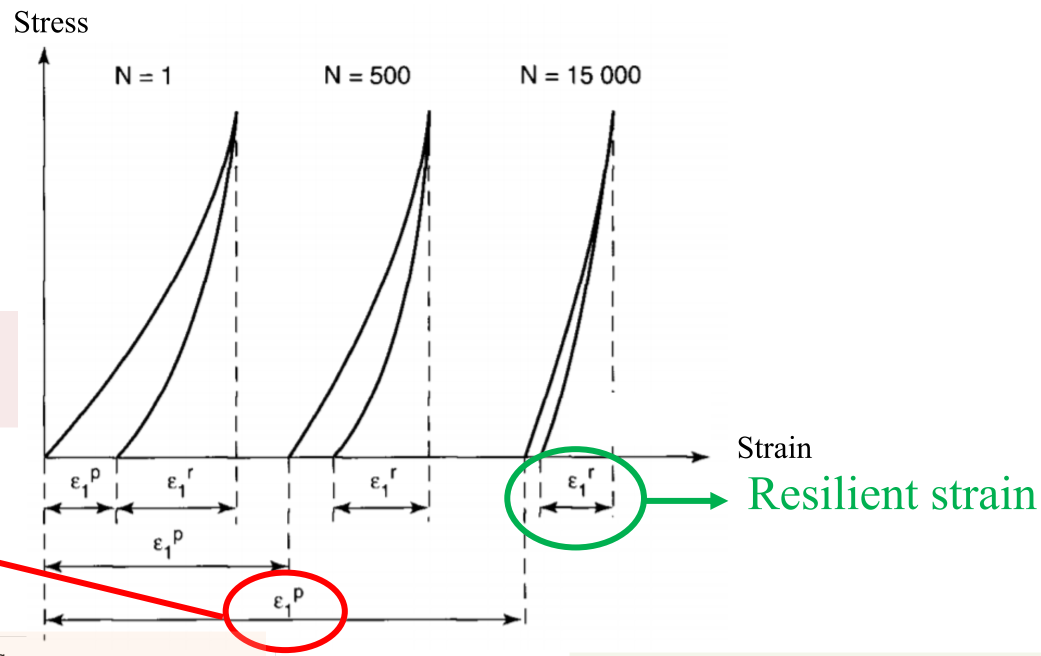
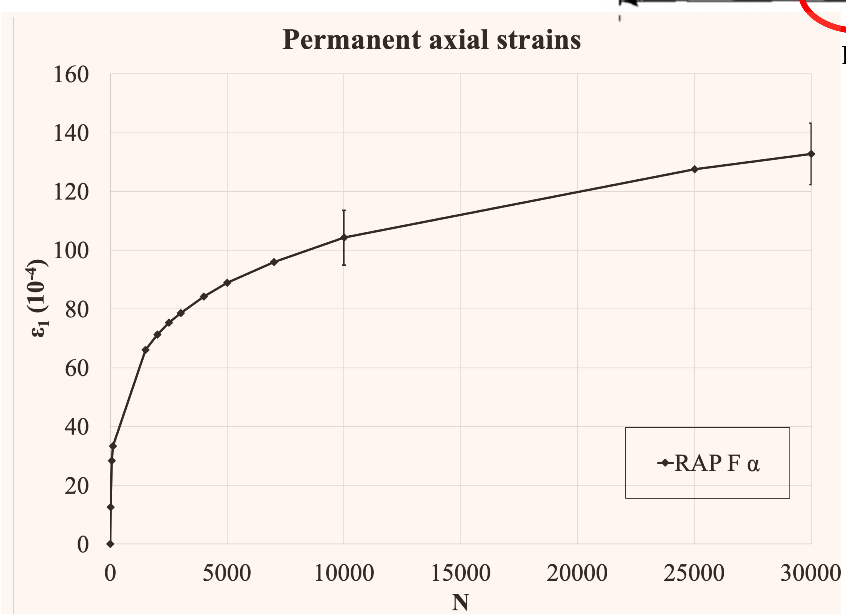
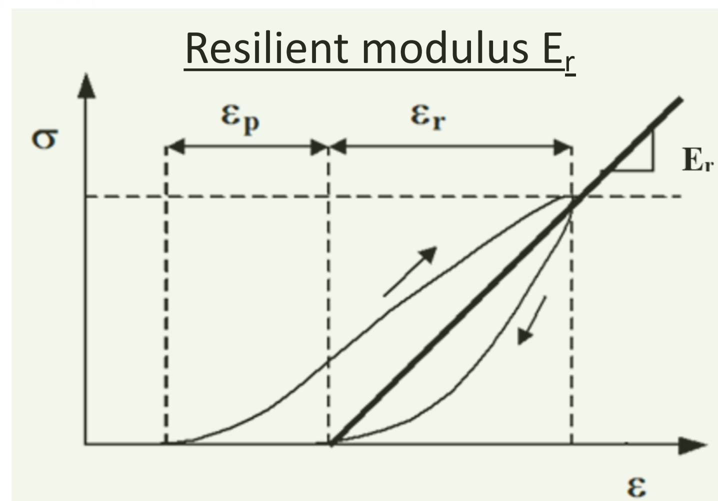
How ?

ε^p are stabilised if $\Delta\varepsilon/\Delta N < 10^{-7}$ (NF EN 13286-7, 2004)



Balay et al. (1998)





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STUDIED MATERIALS

UGM from Rhine Region
Control material

RAP

- **RAP from laboratory**
  - **RAP Fα :** French RAP stock α (with PAH)
  - **$RAP_{F\alpha}$-BE :** after binder extraction
  - **RAP Fβ :** French RAP stock β (without PAH)
  - **RAP CH :** Swiss RAP
- **RAP used for road constructions**
  - **RAP F road construction :** French RAP
  - **RAP CH road construction :** Swiss RAP

FOCUS ON

RAP Fα : French RAP stock α (with PAH)

2 water contents tested :
3.9 % (w_{OPM}-2%)
4.9 % (w_{OPM}-1%)

2 temperatures tested :
20°C
40°C

Test without bitumen :
$RAP_{F\alpha}$-BE

	Modified Proctor Test	
	w_{OMP} (%)	$\gamma_{d,OMP}$ (Mg/m³)
RAP Fα	5.9	2.02
RAP Fα-BE	5.3	2.21
UGM	7.6	2.16

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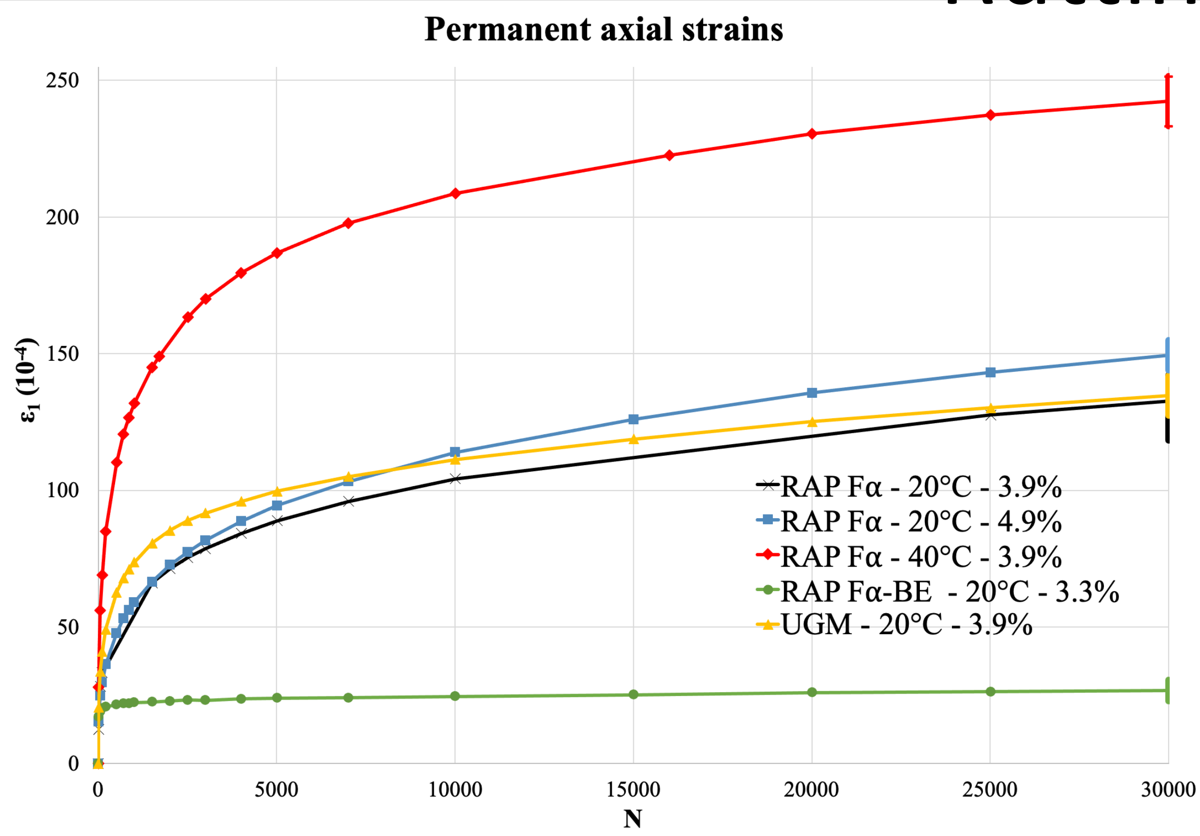
Rutting resistance



Frequency : 2 HZ

T (°C)	Δq (kPa)	Δp (kPa)
20	340	113
40	200	67

	Strain rate over the last hundred cycles $\Delta\varepsilon_1/\Delta N$
RAP Fα - 20°C – 3.9%	$1{,}04 \cdot 10^{-7}$
RAP Fα - 20°C – 4.9%	$1{,}26 \cdot 10^{-7}$
RAP Fα - 40°C – 3.9%	$1{,}01 \cdot 10^{-7}$
RAP Fα-BE - 20°C – 3.3%	$8{,}85 \cdot 10^{-9}$
UGM- 20°C – 3.9%	$9{,}06 \cdot 10^{-8}$

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	Temperature (°C)	Water content (%)	Dry density γ_d (Mg/m³)	Void content	Characteristic permanent axial strain ε_1^c (10^{-4})
RAP Fα	20	3.9	1.96	0.27	133
RAP Fα	20	4.9	1.96	0.27	150
RAP Fα	40	3.9	1.96	0.27	242
RAP Fα-BE	20	3.3	2.14	0.24	27
UGM	20	3.9	1.96	0.35	135

- Permanent strains increase with water content
- Permanent strains increase with temperature → due to the viscosity of bitumen
- RAP and UGM : similar levels of strain
- RAP-BE (after binder extraction) : very low strains → due to the high fines content of RAP-BE

Elastic modulus

q_{max} (kPa)	p_{min} (kPa)
500	250

	Temperature (°C)	Water content (%)	Dry density γ_d (Mg/m³)	Void content	Characteristic elastic modulus at 0.1 Hz E_c (MPa)
RAP Fα	20	3.9	1.96	0.27	475
RAP Fα	20	4.9	1.96	0.27	342
RAP Fα	40	3.9	1.96	0.27	349
RAP Fα-BE	20	3.3	2.14	0.24	445
UGM	20	3.9	1.96	0.35	222

The RAP Fα presents a higher level of elastic modulus than UGM

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different sources of RAP

RAP from laboratory

RAP Fα : French RAP stock α (with PAH)

RAP Fβ : French RAP stock β (without PAH)

RAP CH : Swiss RAP

RAP used for road constructions

RAP F road construction : French RAP

RAP CH road construction : Swiss RAP

	Modified Proctor Test	
	w_{OMP} (%)	$\gamma_{d,OMP}$ (Mg/m^3)
RAP Fα	5.9	2.02
RAP Fβ	5.5	1.79
RAP CH	4.3	1.81
RAP F road construction	7.2	1.96

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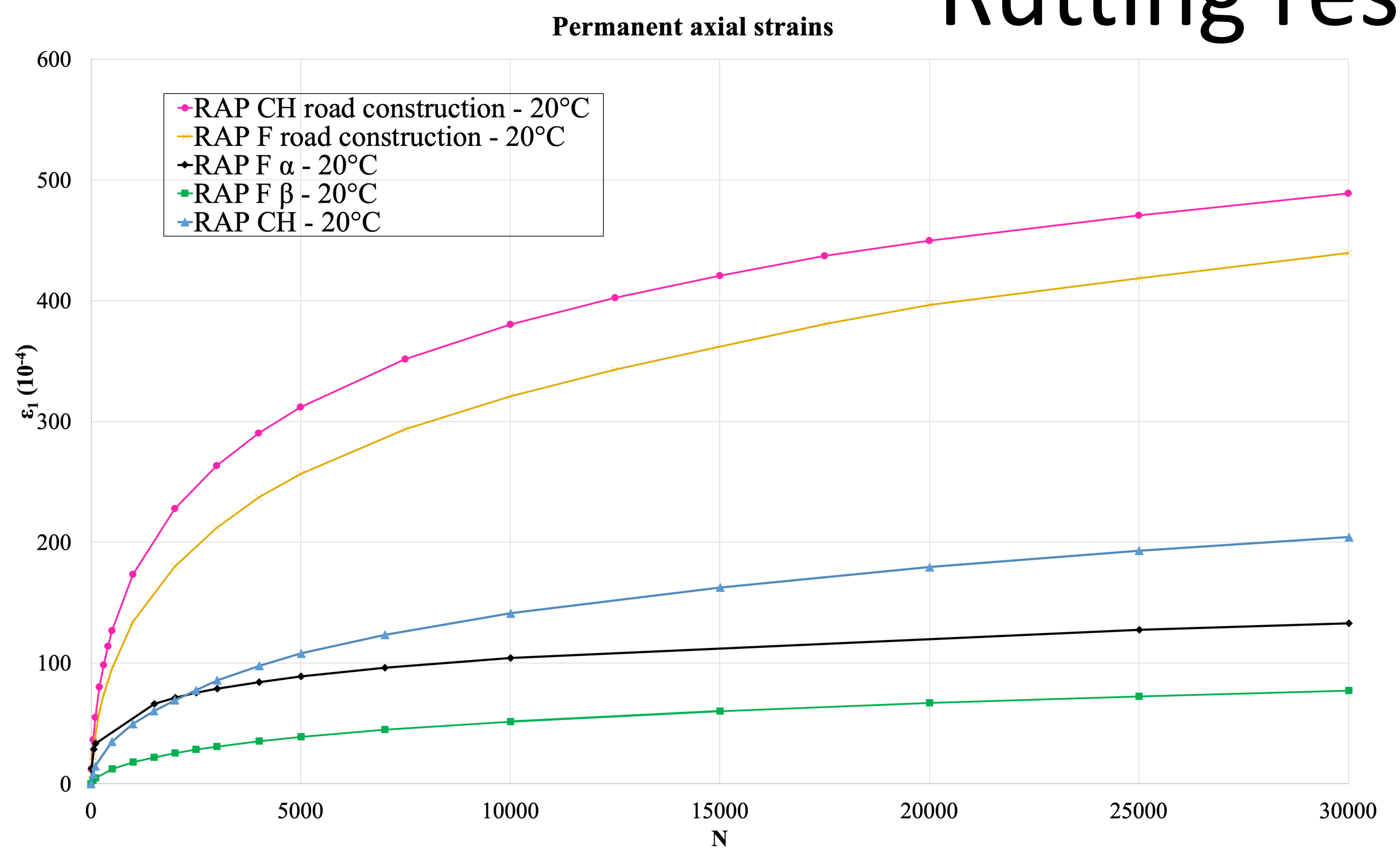
Rutting resistance



Frequency : 2 HZ

Δq (kPa)	Δp (kPa)
340	113

	Strain rate over the last hundred cycles $\Delta\varepsilon_1/\Delta N$
RAP Fα – 3.9%	$1,04 \,.\, 10^{-7}$
RAP Fβ – 3.5%	$3,57 \,.\, 10^{-8}$
RAP CH – 3.7%	$1,81 \,.\, 10^{-7}$
RAP F road construction – 3.9%	$3,17 \,.\, 10^{-7}$
RAP CH road construction – 3.7%	$3,83 \,.\, 10^{-7}$

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Elastic modulus

q_{max} (kPa)	p_{min} (kPa)
500	250

	Temperature (°C)	Water content (%)	Dry density γ_d (Mg/m³)	Characteristic elastic modulus at 0.1 Hz E_c (MPa)
RAP Fα	20	3.9	1.96	475
RAP Fβ	20	3.5	1.95	551
RAP CH	20	3.7	1.96	505
RAP F road construction	20	3.9	1.90	425
RAP CH road construction	20	3.7	1.87	372

The elastic moduli of RAP correspond to a good quality UGM

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Conclusions

➢ <u>According to the French Standard for UGM NF EN 13286-7 :</u>

Traffic category T3 : low traffic
Permission to use the material in base and subbase courses if :

Mechanical properties	**Characteristic permanent axial strain ε_1^c**	**Characteristic elastic modulus E_c**
OR	$2.5 \times 10^{-3} < \varepsilon_1^c \leq 6 \times 10^{-3}$	500 MPa $\leq E_c$
	$\varepsilon_1^c \leq 6 \times 10^{-3}$	250 MPa $\leq E_c < 500$ MPa

The permanent strain criterion is not checked

The modulus criterion is checked

Solutions :
Positive evolution in the long term
Increase the compaction density

These results confirm that the RAP can be used instead of UGM, in base and subbase layers in low-traffic roads: an alternative to deposit solution for contaminated RAP

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ACKNOWLEDGMENTS

- The ORRAP **project is supported by the INTERREG Upper Rhine program** from the ERDF **(European Regional Development Fund)** to the tune of **622 553€** and by the **Swiss Confederation, Canton Basel-Landschaft Canton Aargau.**
- ORRAP started in November 2016 with a total budget of 1.48 M€. Due to ongoing experimental requirements, its duration has been extended until December 2020.

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Medium size specimens compaction and testing

Christiane Raab, Empa

Empa
Materials Science and Technology

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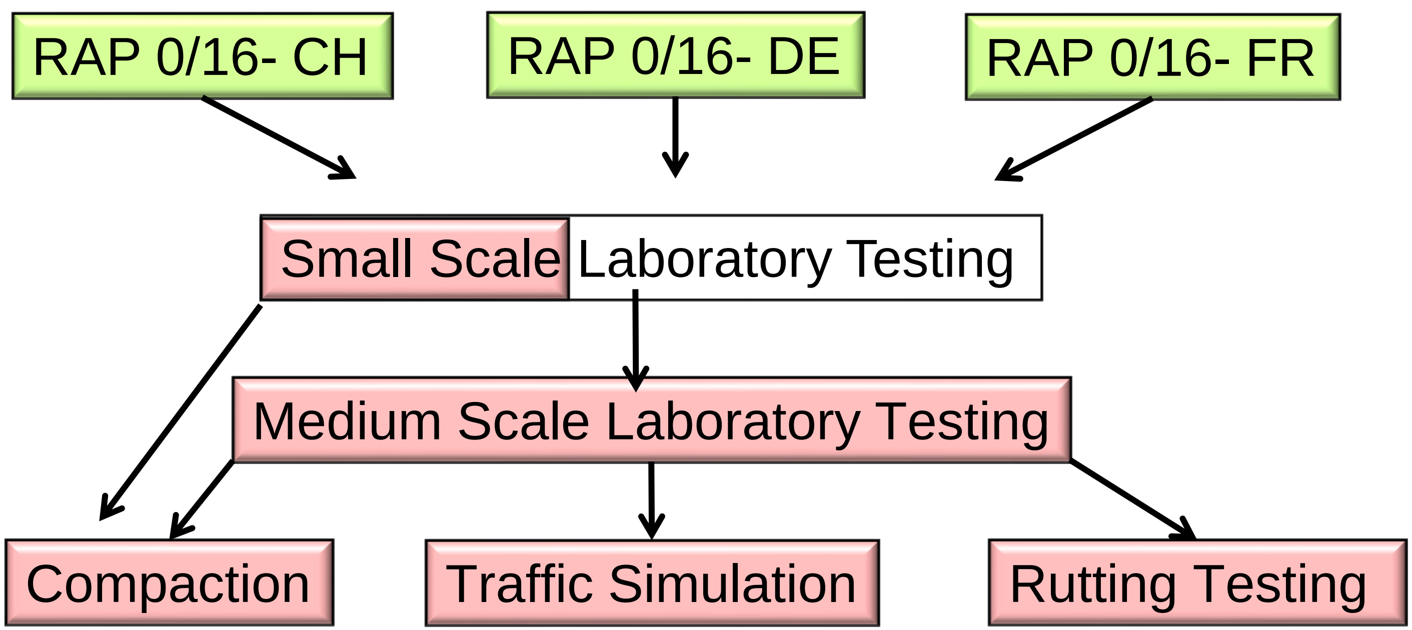
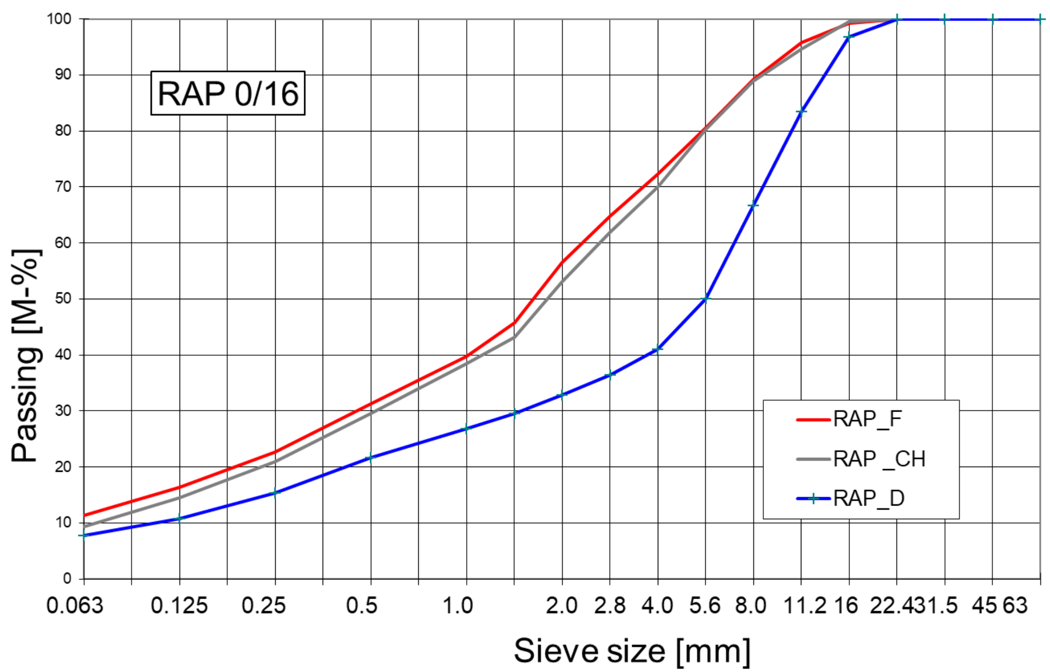
Empa's contribution



Empa
Materials Science and Technology

RAP Material

		RAP Properties			RAP Binder Properties	
RAP Type	RAP Source	Bit. Cont. [w%]	Density [kg/m³]	Water Cont. [w%]	Pen [0.1mm]	R&B [°C]
RAP 0/16	CH	6.2	2.371	1.6	17	69.0
	DE	4.3	2.347	3.5	17	68.4
	FR	6.3	2.408	5.0	16	69.4



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Compaction: Small RAP-CH Specimens

Parameters

- 2 Types: Marshall & Gyratory
- 2 Compaction Efforts
- 4 Temperatures

Type	Effort [Number]		RAP Temperature [°C]			
Marshall [Blows]	50	100	20	60	80	100
Gyratory [Gyrat.]	204	410	20	60	80	100

		0/16			
		Marshall Test		Gyrator Test	
		50 Blows	100 Blows	205 Gyrat.	410 Gyrat.
Temperature	Room (20°C)	Impossible	Too Weak	Good Enough	Good Enough
	80°C	Good	Good	Very Good	Very Good
	100°C	Good	Good	Very Good	Very Good

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Compaction: Small RAP-CH Specimens

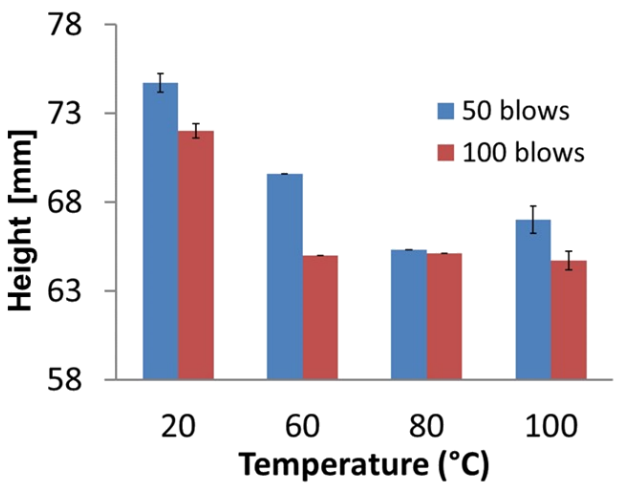
Parameters

- 2 Types: Marshall & Gyratory
- 2 Compaction Efforts
- 4 Temperatures

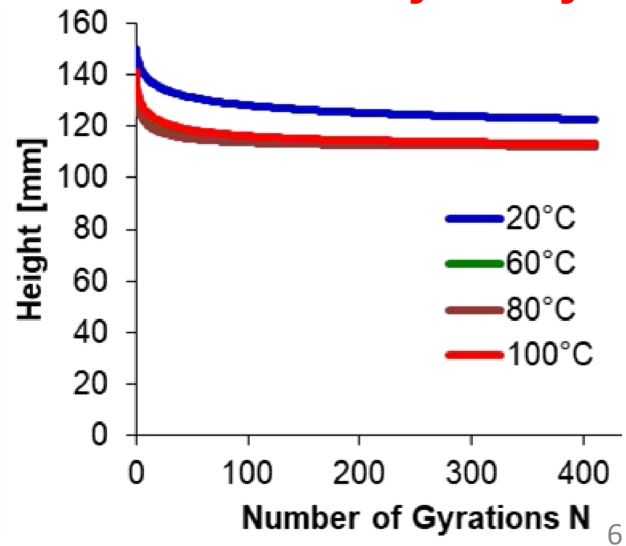
Type	Effort [Number]		RAP Temperature [°C]			
Marshall [Blows]	50	100	20	60	80	100
Gyratory [Gyrat.]	204	410	20	60	80	100

60°C seems OK with more compaction effort

Marshall



Gyratory



Compaction: Medium Size RAP Specimens

- Large Wheel Rut Test
- Specimen Size: 500 x 180 x 50 (100) mm

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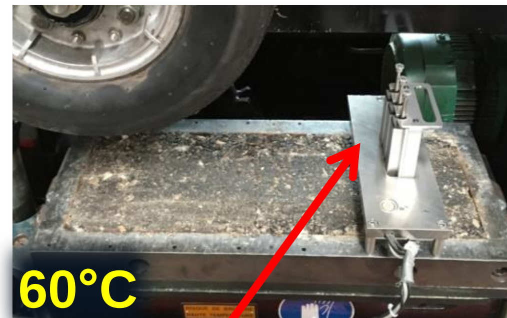
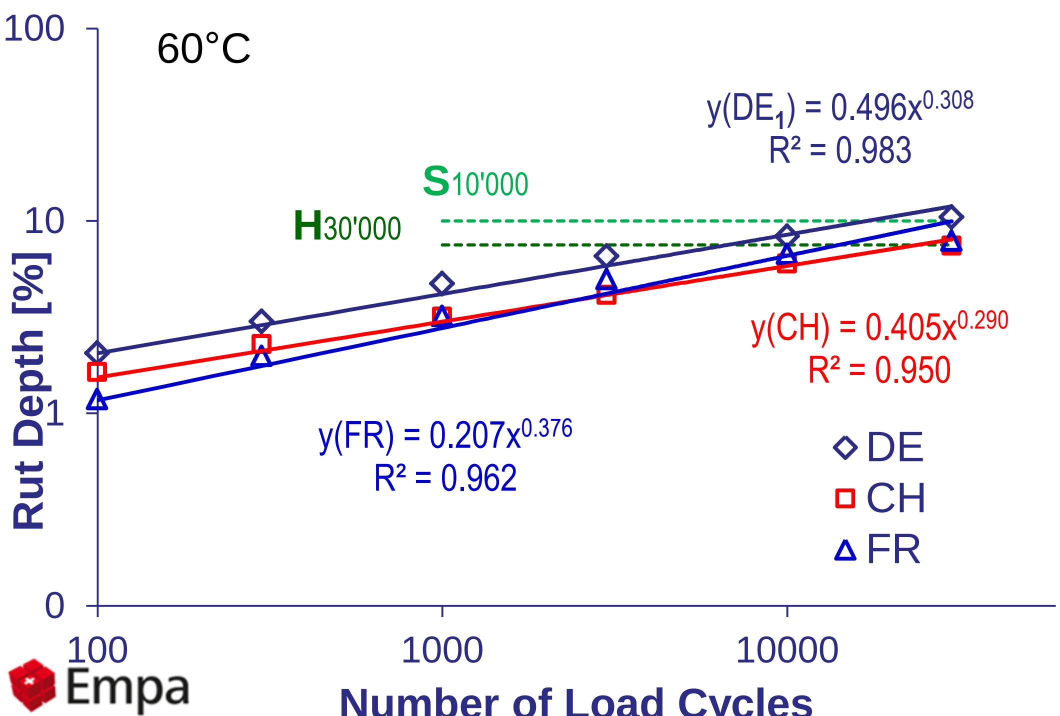
Large Wheel Rutting Test Results

- Mean Values (2 Tests, 5 Profiles)
- 30’000 Cycles,T=60°C



Profile Meas. LVDT Table



- CH → OK for Very Heavy Traffic
  <7.5% @ 30’000 Cycles (**H**)
- FR,(DE$_1$) → OK for Heavy Traffic
  <10% @ 10’000 Cycles (**S**)

(According to CH Standard)

Compaction: Medium Size RAP Specimens

- Plate Compactor
- Specimen Size: 1200 x 400 x 50 mm

Compaction: Medium Size RAP Specimens

- Static Roller Compactor
- Specimen Size: 1300 x 430 x 65 mm

During Compaction

Aggregate Loss: ca. 0.1% by weight

Specimen after compaction: surface

430mm

1300 mm

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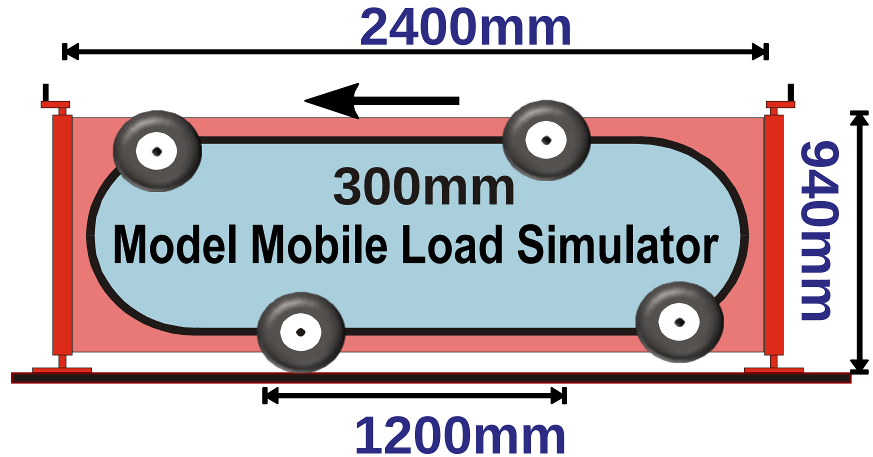
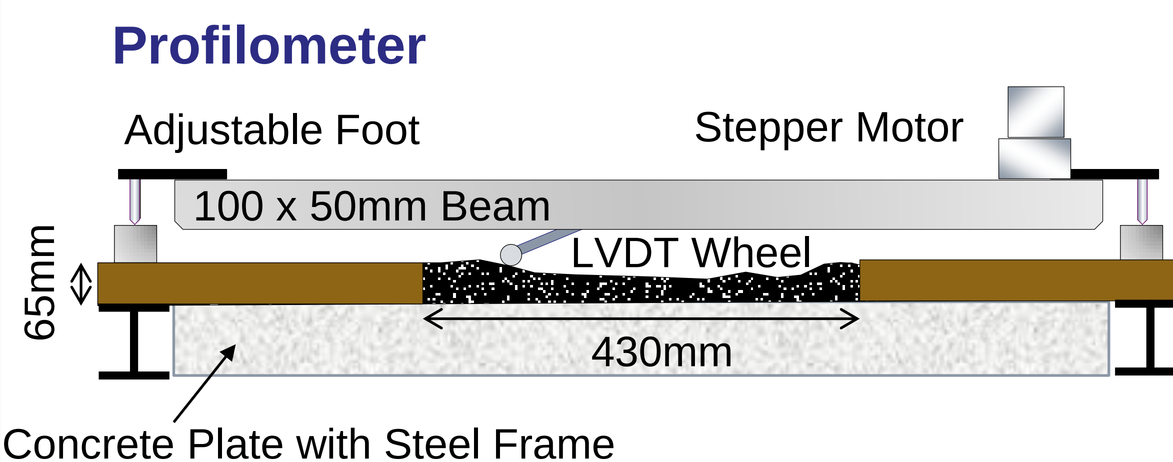
MMLS3: Lab-Scaled Traffic Simulator Testing



N=7200 Passg/h; v=9.4km/h= 2.6 m/s
50'000 Passings; F=2.1kN; p=600kPa



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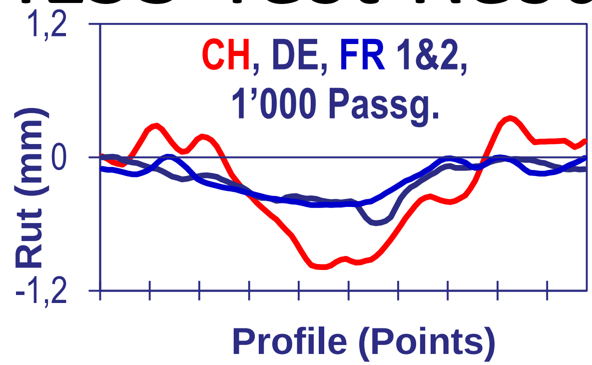
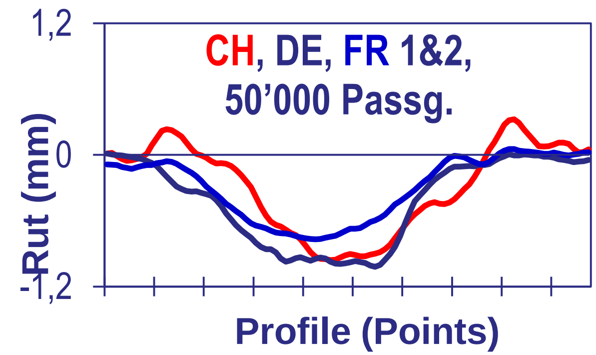
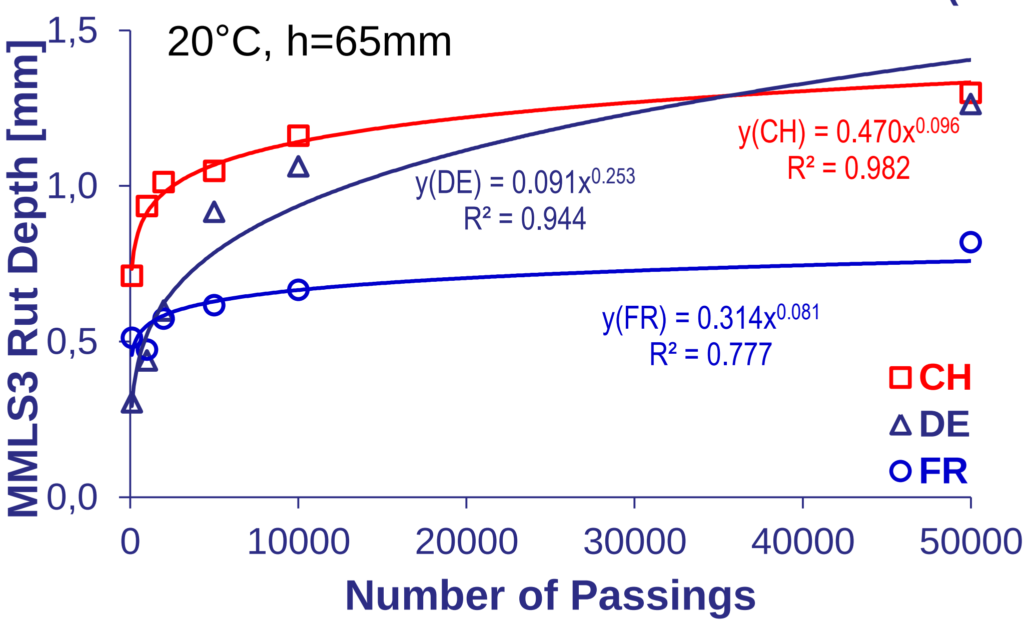
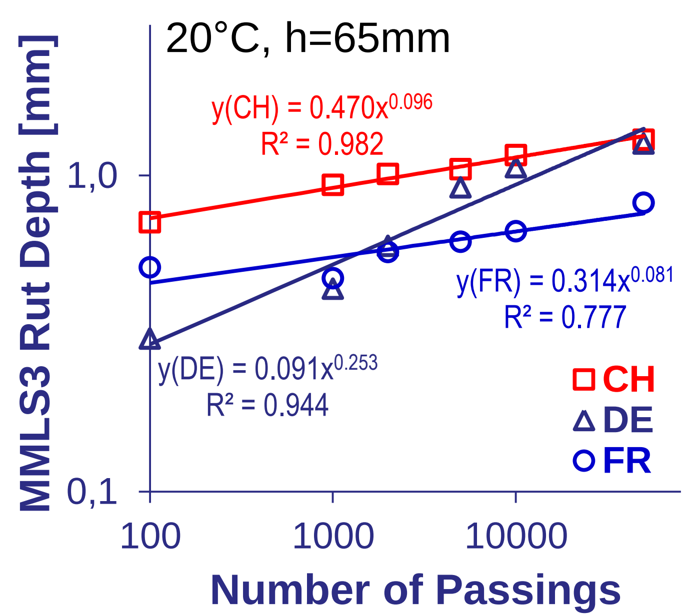
MMLS3 Test Results

- Mean Values (2 Tests, 3 Profiles)
- 50'000 Cycles, **T=20°C**









- CH → Most Rutting at Beginning, then Stable
- DE → Fastest Rutting Speed, Not Stable
- FE → Least Rutting, Long-term Stable like CH

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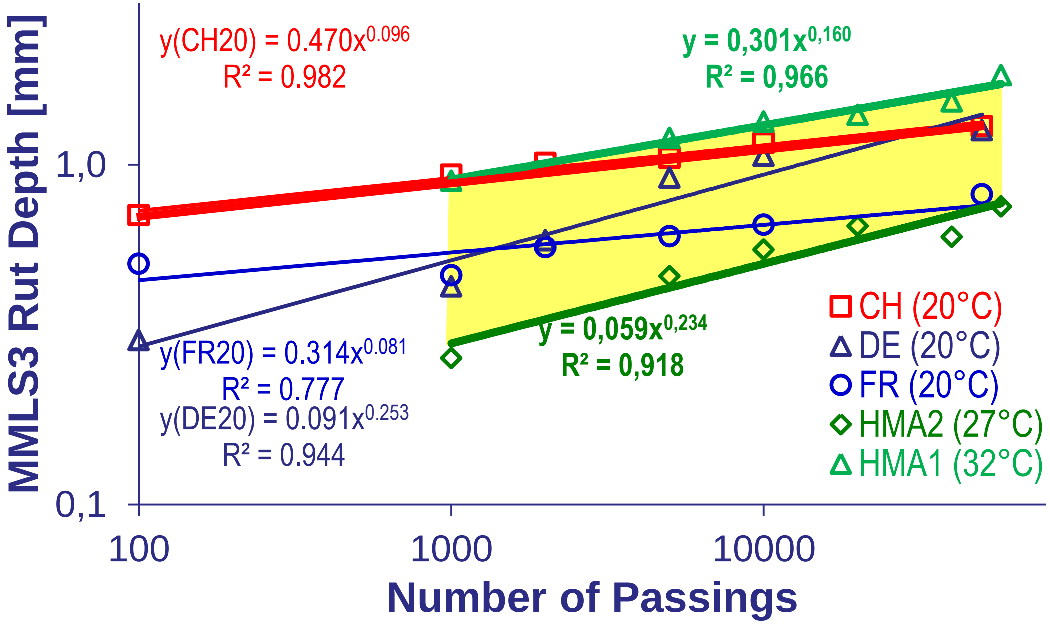
Rutting Results Discussion

- Comparison with other MMLS3 Tests in Situ on Hot Mix Asphalt **AC8L**:
  - **HMA1** no RAP (Test @ 32°C)
  - **HMA2** with 80%RAP (Test @27°C)



- Rutting Similar to **HMA** AC8L
- Generally: **Little** Rutting

- Comparing Large Wheel Rutting Test (LWRT) & MMLS3:
  - Generally: **FR** was Good, **DE** was not so Good
  - **FR** best @ 20°C (MMLS3), **CH** best @ 60°C (LWRT)

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Conclusions

- **Lab compaction** of small and medium size specimens at **20°C** not sufficient, **but** increasing the temperature very little (**60°C**) changed compaction behavior drastically and made it possible to **construct stable and rutting resistant asphalt aggregate samples**.
- Rutting resistance with **large wheel rutting tester at 60°C** and **scaled traffic simulator MMLS3** at ambient temperature, both under laterally confinement of the specimens, produced **low rut depth**. For RAP-CH rutting resistance (30'000 cycles) with **large wheel device** even fulfilled the **requirements for very heavy trafficked roads**. All RAP fulfill requirements for (10'000 cycles) **heavy traffic.**
- The investigation clearly showed the **potential of using asphalt aggregates at low compaction temperatures** and was therefore very promising for a **successful in situ installation** of these materials.

ACKNOWLEDGMENTS

- The ORRAP **project is supported by the INTERREG Upper Rhine program** from the ERDF **(European Regional Development Fund)** to the tune of **622 553€** and by the **Swiss Confederation, Canton Basel-Landschaft Canton Aargau.**
- ORRAP started in November 2016 with a total budget of 1.48 M€. Due to ongoing experimental requirements, its duration has been extended until December 2020.

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Thank you for you attention