Environmental Issues in Asphalt Pavement Technology

by

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EMPA Center Road Engineering/Sealing Components
Dübendorf, www.empa.ch/Abt113

COE Intensive Course 16. Feb. 2005
Graduate School of Engineering, Hokkaido University

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- Introduction
  - EMPA Vision
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- Eureka Environmental Footprint
- Porous Asphalt
- Heavy Duty Noise Reducing Aphaltic Plug Joints

Introduction

EMPA Vision

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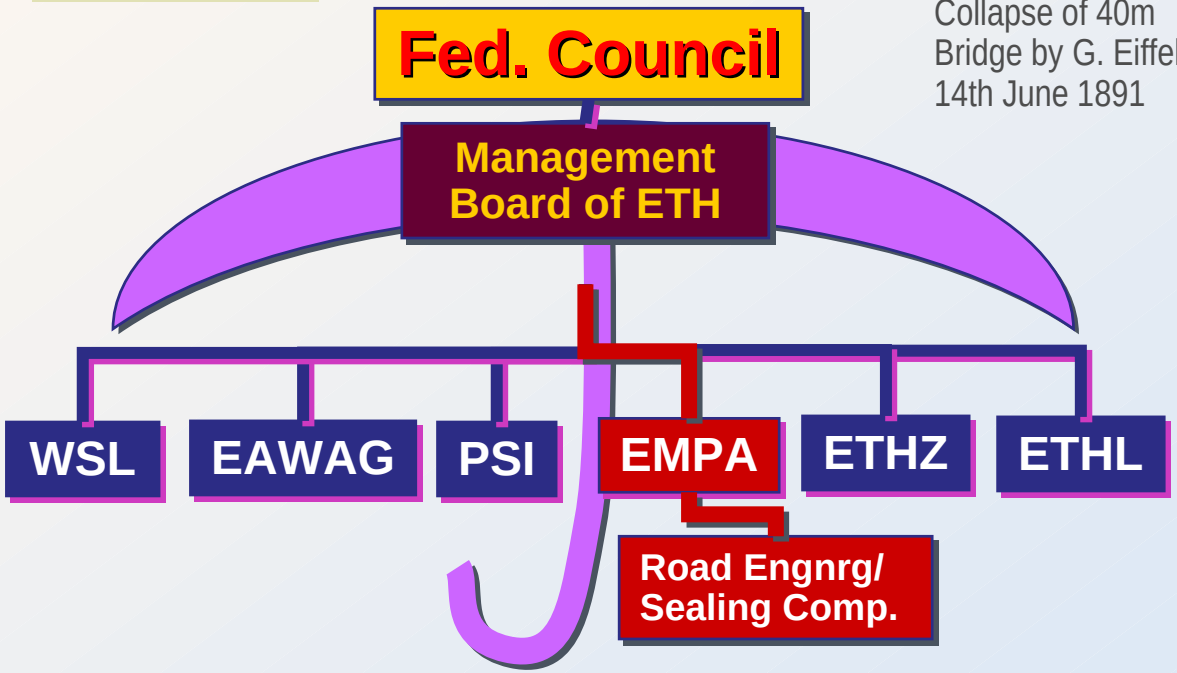
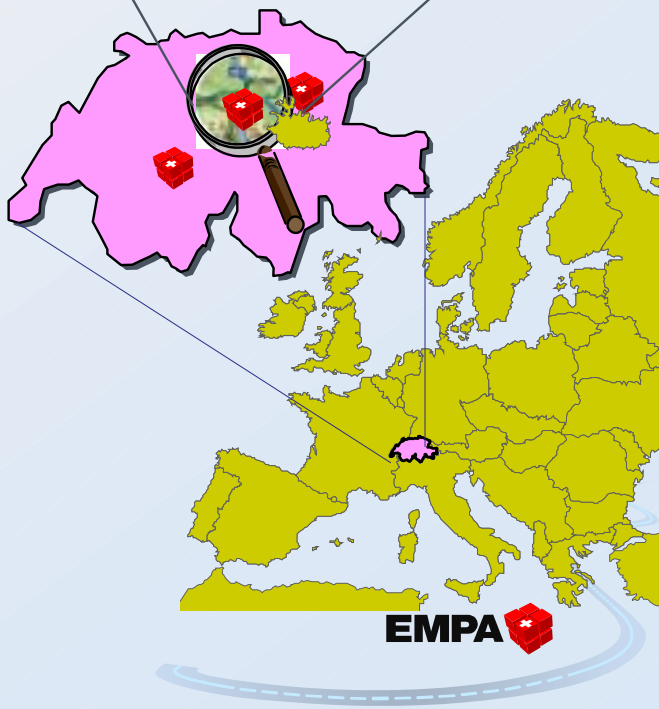
www.empa.ch

Established 1880,
125 years ago!!

Collapse of 40m
Bridge by G. Eiffel
14th June 1891

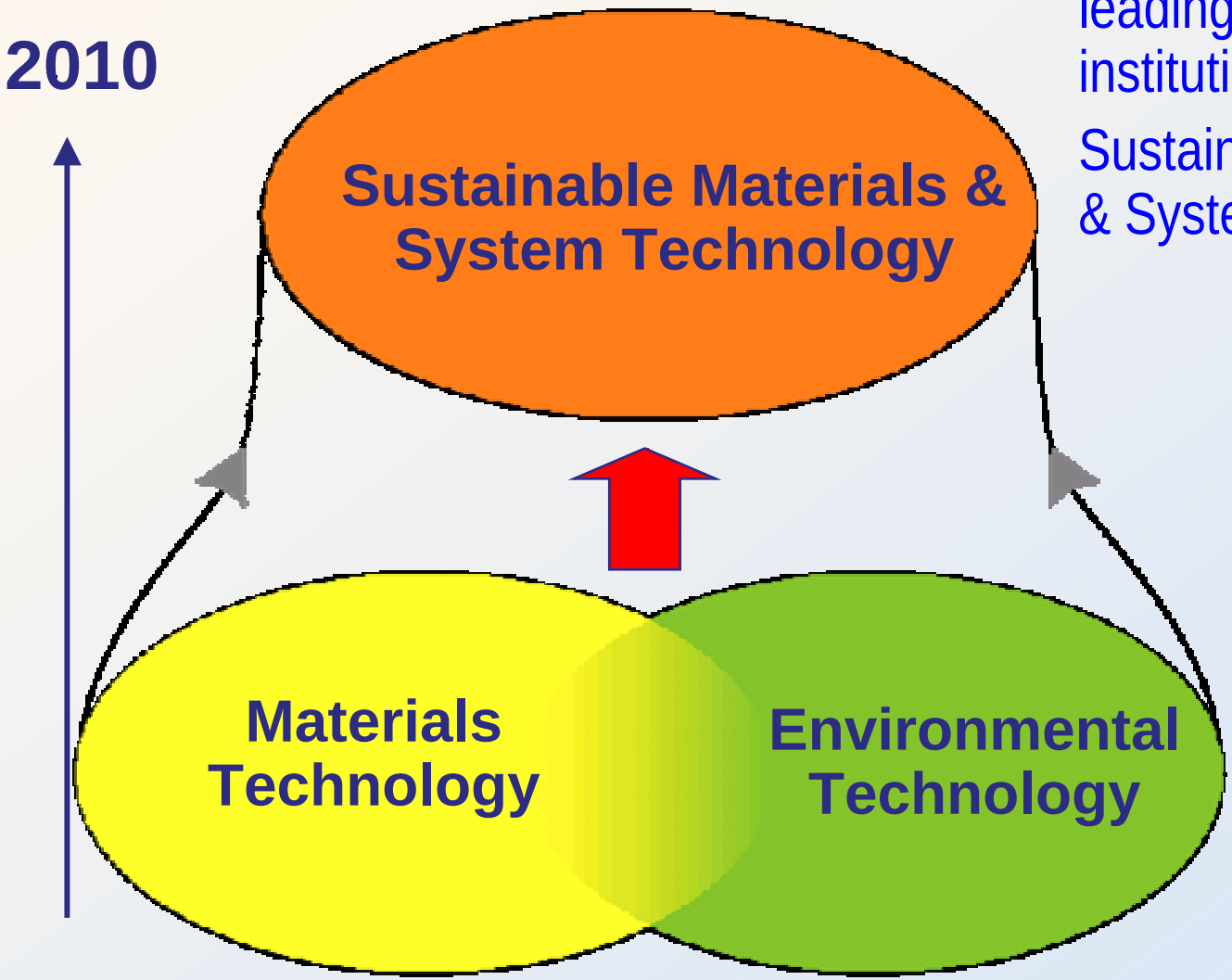




EMPA Vision 2010:

EMPA is an intern. leading technology institution in

Sustainable Materials & Systems Technology



Challenge and Chance for Asphalt Technology at EMPA:

Combine different disciplines and expertise of different labors (see following examples) for

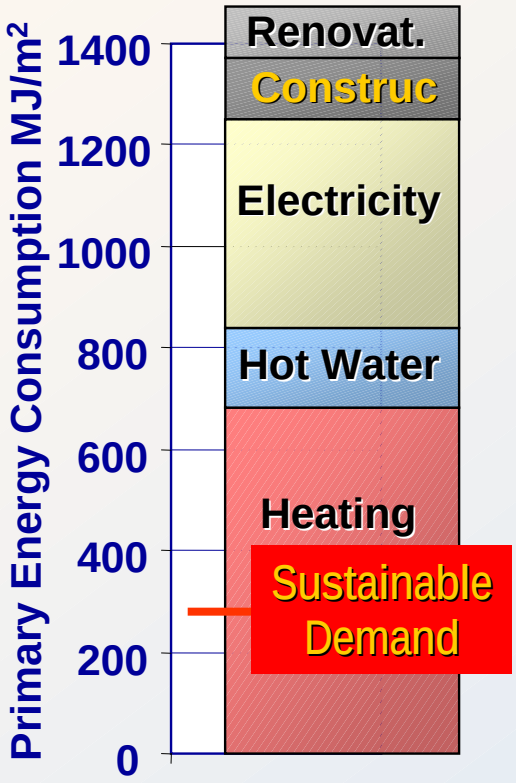
- Energy considerations, i.e. energy consumption for construction and use
- Study and modelling of air flow and transport of contaminants
- Use of secondary materials (like concrete) and nano-considerations
- Smart structures and structural analysis
- Reinforcement techniques
- etc.

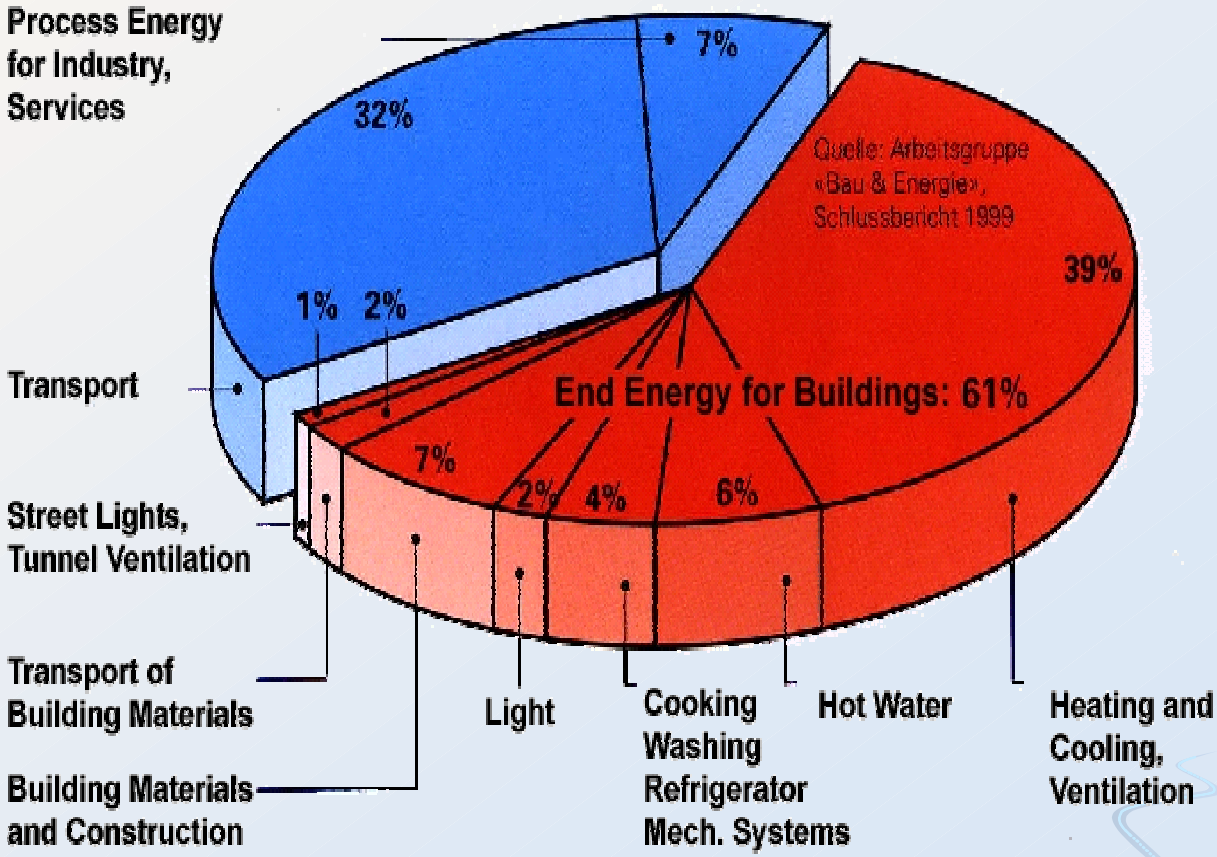
Energy Demand of Buildings

energy efficiency in buildings

- use of renewable energies
- life cycle assessment from construction to demolition

The Swiss Primary Energy Consumption is dominated by the Building Sector

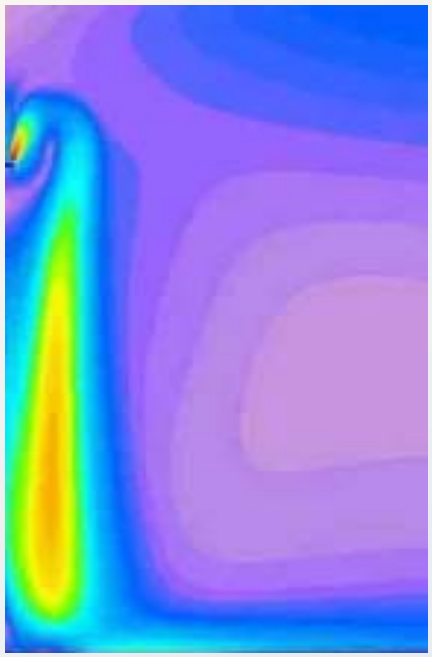




Energy Syst./Building Equipment Lab

Leader: Thomas Franck

- Emphasis on renewable energy and increased energy efficiency.
- Design of new, comprehensive energy concepts, development of necessary systems and components with industry partners, and creation of innovative simulation tools.
- Energy Efficienz Exhaust System: Compact room ventilation system with supply openings in the facade including a heat recovery system



• Air flow simulation

• Air flow visualization and comfort measurements in the room climate laboratory

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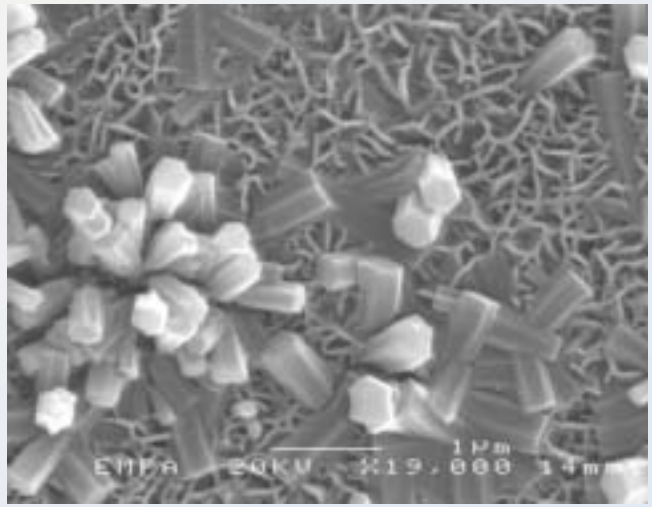
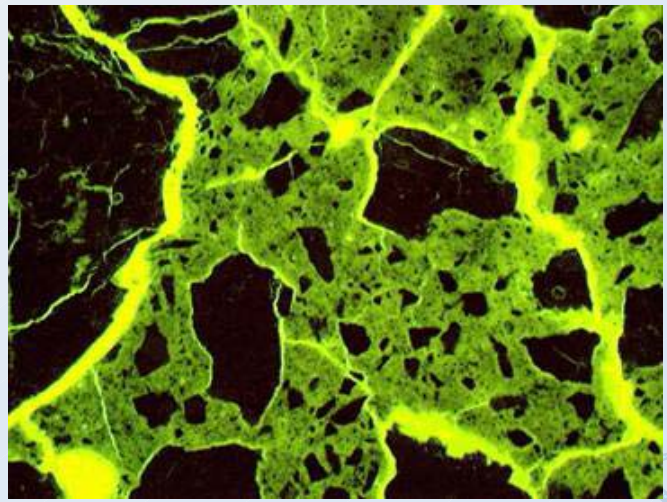
Lab for Concrete & Constr. Chem.

Leader: Michael Romer

- **Cement hydration**
  - Basic understanding of cement hydration
  - Effect of polymers during cement hydration
  - Correlation of micro and macroscopic strength & durability properties
- **Materials science**
  - Optimization of mortar & concrete based on
    - Mix design, rheological properties
    - Design and testing of mech. properties
    - Use of secondary raw materials
  - Fiber reinforced composites
  - Self compacting concrete SCC
- **Durability**
  - Deterioration mechanisms, test methods
  - Service life methodology





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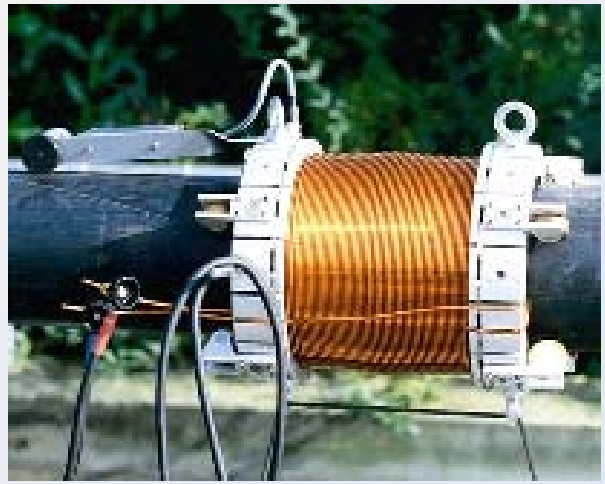
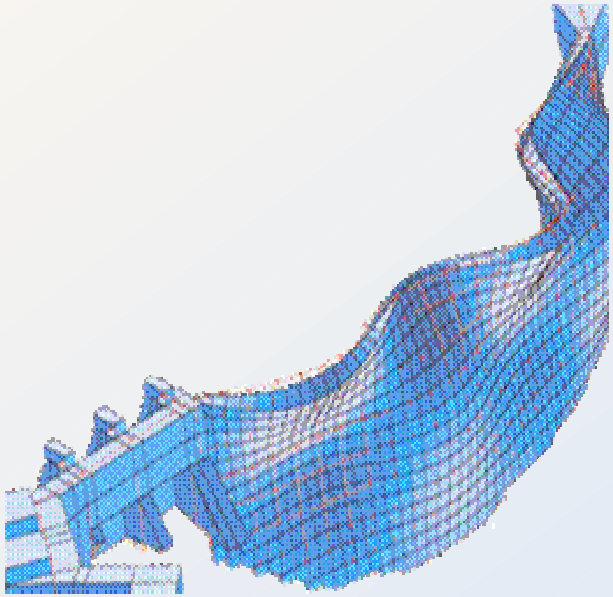
Structural Engnrg. Research Lab.

Leader: Masoud Motavalli

- System ident. & health monit. of large structures
- Smart structures
- Magneto-inductive NDT of bridge cables
- Shear strengthening of concrete struct. with CFRP
- R&D in the field of retrofitting of concrete structures
- Testing & analysis of the dynamic behavior of large structures like : Bridges,Dams





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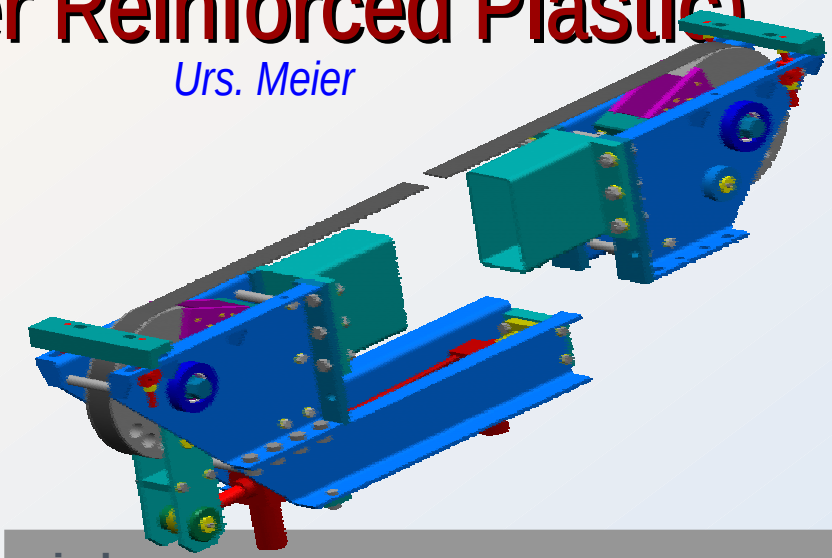
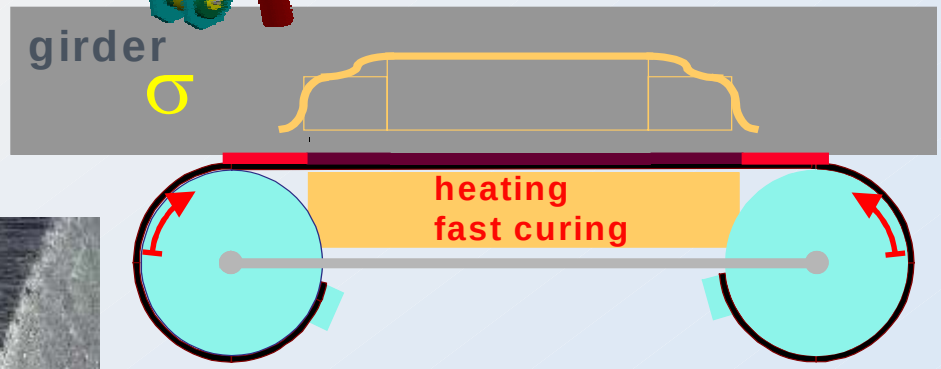
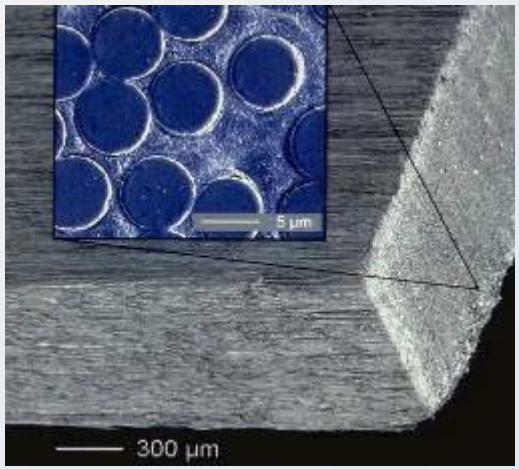
CFRP (Carbon Fiber Reinforced Plastic)

Urs. Meier







Strength: 3300 MPa
Ultimate length:10m

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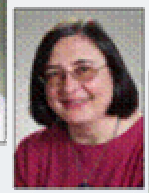
EMPA-RESC
(Road Engineering/ Sealing Components)

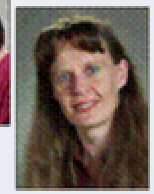
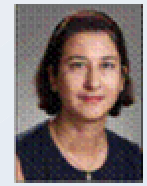
Organigram



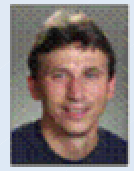
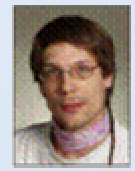




People



Board

L. Schlapbach (CEO)
U. Meier (Deputy)

Departments

- Materials & Systems for Civil Engnrg. (P. Richner)
- Advanced Materials & Surfaces
- Mat. & Syst. for Protect. & Comfort of the Body
- Information, Reliability & Simulation Technology
- Mobiliy & Environment
- Logistics, Controlling & Marketing

Centers/ Labs

- Road Engnrg/Sealing Comp.
- Applied Phys. in Buildings
- Center for Energy & Sustainability in Buildings
- Concrete / Construction Chemistry
- Energy Systems /Building Equipment
- Stength & Technology
- Structural Engineering
- Wood

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Road Engnrg/Sealg. Comp. RESC

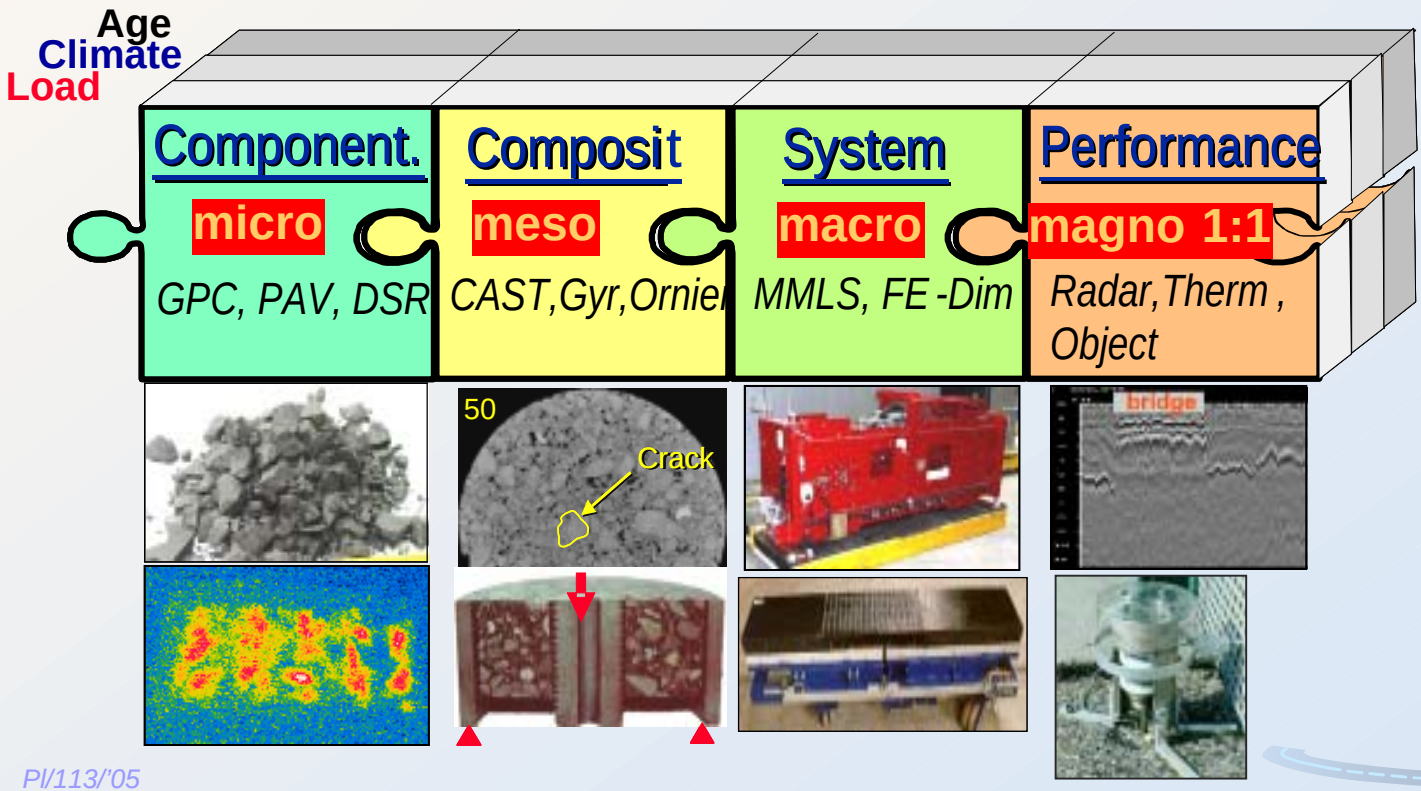
Manfred Partl

Main R&D Areas

- LTPP Studies of Field Behavior
- 2-D NDT of Pav. & Bridges (IR, GPR)
- Opt. of Bit. Road Mat. (Durab., Recycl.)
- System-Monit. (Roads, Bridges, Joints)
- APT Acclerated Pavement Testing
- Roads & Environment

Materials

- Binders: Bitumen, Polymer Bit.
- Aggregates & Filler & Additives
- Pavements
- Joint Seal. & Asph. Plug Joints
- Bit. Sealing Membranes
- Recycling Materials



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EMPA RESC-Activities Environment

- R&D Focus: Recycling of Tar Contaminated Pavements
  - PAH (Polycyclic Aromatic Hydro-Carbonate)
  - Cold-recycling
  - Foam bitumen
- Porous asphalt (noise, water drainage and water sensitivity)
- Eureka environmental footprint
- EMPA Project TECAT (Technosphere-Atmosphere)
- Alternative materials
- Heavy duty noise reducing asphaltic plug joints (APJ)

EMPA RESC-Partners Environment

- **SAEFL** Swiss Agency for the Environment, Forests & Landscape
  - Different Contracts with Dept. Air Polution
  - Collaboration SEAFL Guideline for Building Waste
- **Expert-Committee „Environment“ VSS** (Swiss Ass. Road & Transp Exp.)
  - Deals with Environment and Road/Road Construction
  - Produces Standards for Recycling of Road Materials
- **European & other intern. research institutes & companies**
- **International organizations, e.g.**
  - EUREKA E!2486- Logchain Footprint http://www.eureka.be
  - ISAP WG05 on Re-use of Construction Materials in Asphalt pavements (Coordination) http://www.insapconmod.nl/
  - RILEM TC ATB, TG5 „Recycling“ http://www.rilem.org/tc_atb.php

- **2nd Intermediate ISAP Symposium in Zurich on Asphalt Pavements & Environment Spring 2008**

Important Research Projects

- **European Research Project ALT-MAT**
  Possible use of recycling products from industrial origin for road constr. & necessary test methods. (finished 2000, EU 4th Framework)
- **Environm. Compatibel Recycling of Tar-Containing Pavem.**
  STAR & Recommendations for Further Steps, ASTRA Report 433, 1999)
- **Relation between PAH in Tar-Containing RAP and Vapors Emitted during Re-Paving**
  Together with other EMPA Labs (ongoing).
- **Stability of Polymers in Road Pavements Containing Polymer Bitumen in the Construction Step**
  (ongoing)
- **Relating the Environmental Footprint of a Vehicle to the Lifetime Cost of Maintaining the Infrastructure**
  Eureka Logchain Footprint, with Swiss and European Partners (ongoing)
- **TECAT Technosphere-Atmosphere**
  Undestand creation & emission of pollutants, and their transport betw. technosphere & atmosphere (e.g. vehicle exhaust gas) & create solutions (ongoing EMPA Project)

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Air Quality and Therm. Process

Contact

Dr. Martin Hugener

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Pavements

Pavements: Hot Mixes

- **Today in CH 95% of bitum. pavements are hot paved mixes**
  - **Hot Mix Asphalt (HMA)**
    - typical paving temperatures 140 … 180°C
  - **Mastic Asphalt (MA)**
    - typical paving temperatures 220 … 250°C
    - manual paving <280°C

Hot Mix Asphalt

Manual Paving

Machine-Paving

Mastic Asphalt

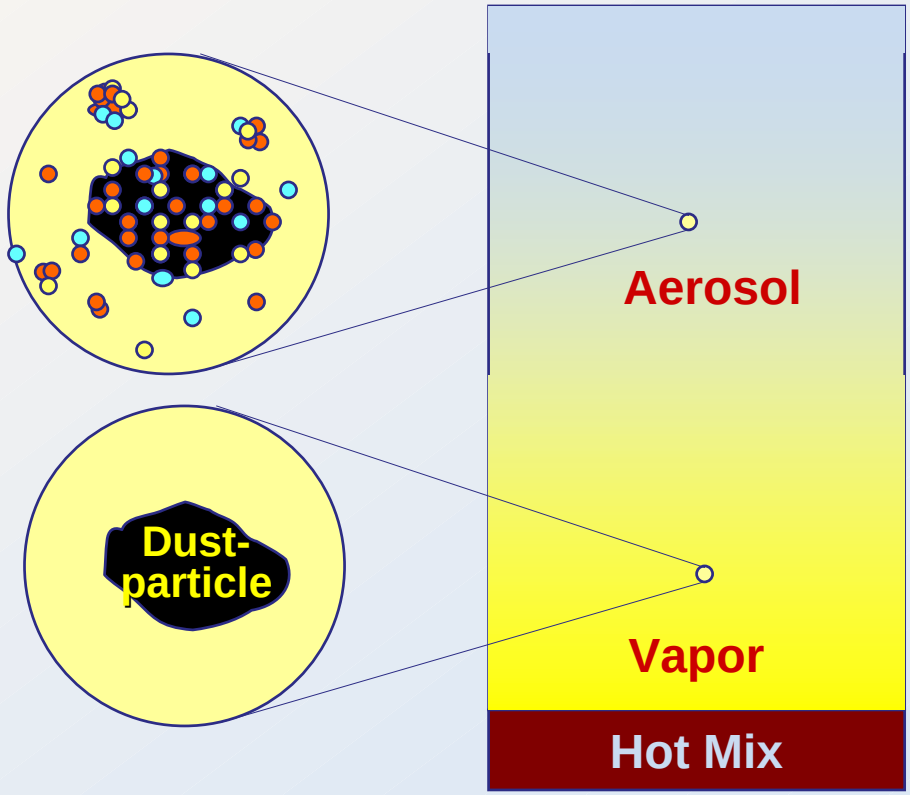
Manual Paving

Machine-Paving

Fog, Smoke, Aerosol

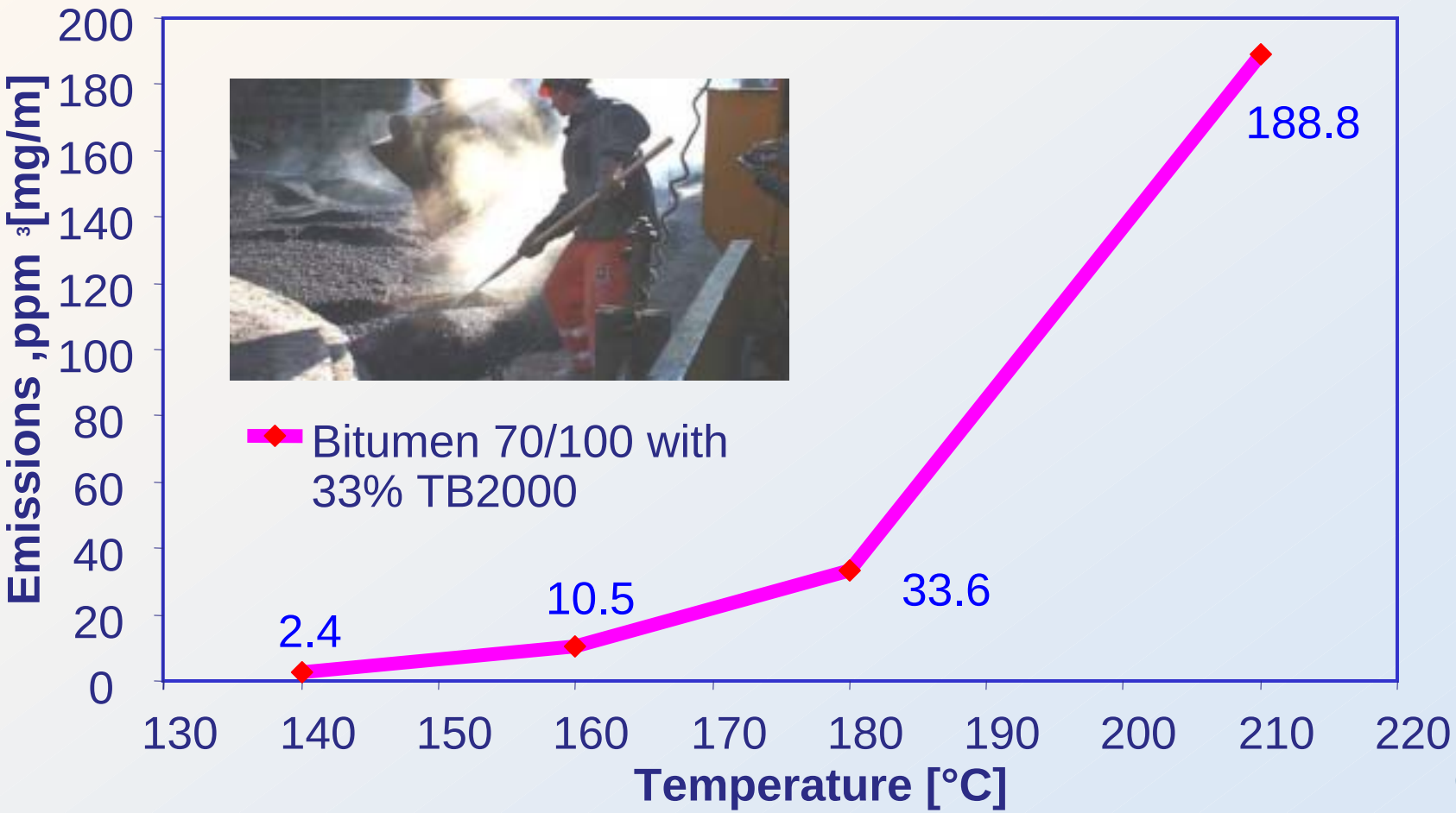
Definitions

- **Fog:** Gas (e.g. air) with dispersed small **liquid** particles
- **Smoke:** Gas (e.g. air) with dispersed small **solid** particles
- **Aerosol:** Gas (e.g. air) with dispersed small **solid** or **liquid** particles



Tar- Emissions

Labor Test EMPA: Emissions as Function of Temperature



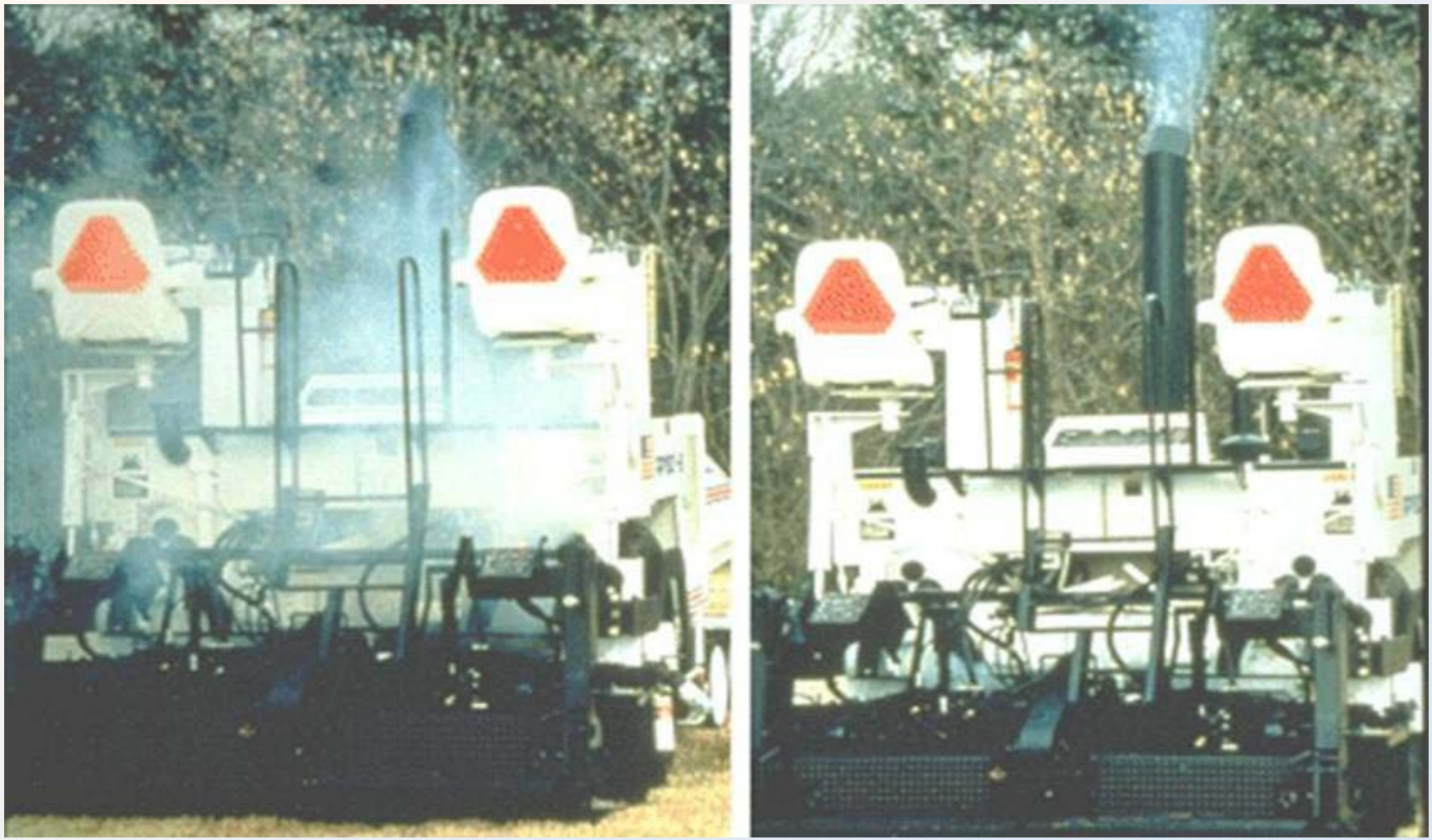
(M. Hugener EMPA)

Reduction of Energy & Emissions (1)

- Use **components** with low emissitivity (e.g. low emission rate of tar free bituminous binders
  - **Main components**
    - **Bitumen:** low content of hazardous substances
    - **Stones**: in most cases inert
  - **Side components:**
    - **Solvents:** evaporates
    - **Polymers:** in most cases no emission (must be verified)
    - **Tar:** high concentration of PAH and Phenol
- **Keep to** work instructions and max. temperatures
- **Vapor collectors** and **paver cover**
- **Hot rolled asphalt:** if little tar (<20'000ppm) temp <160°C ok
- **Mastic Asphalt Gussasphalt:** collect vapor, NO tar contamin.
- Develop tech. processes to reduce **working temperature**

Emission: Cover of Paver Zone

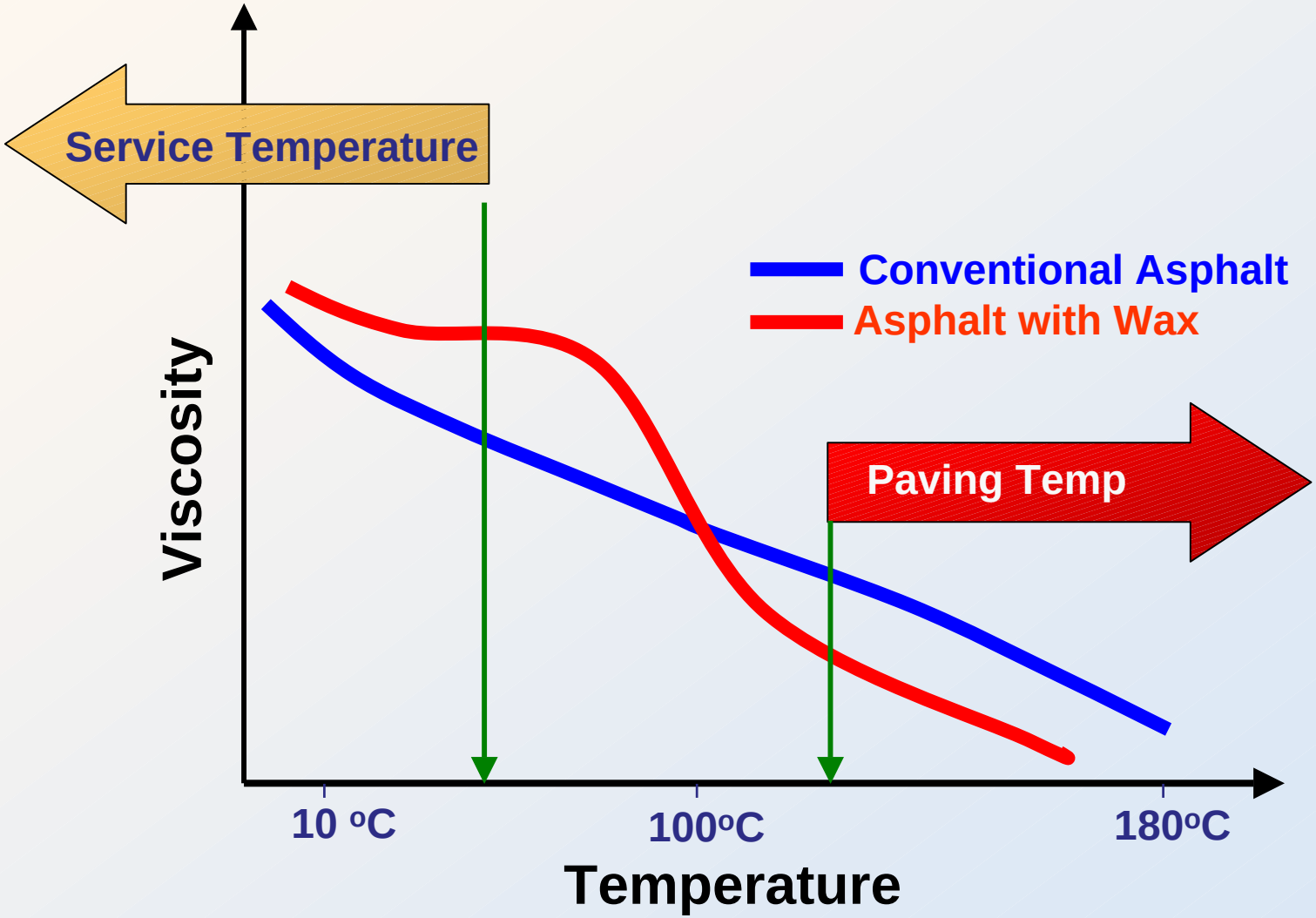
M. Hugener



Asphalt: Energy & Emission Reduction

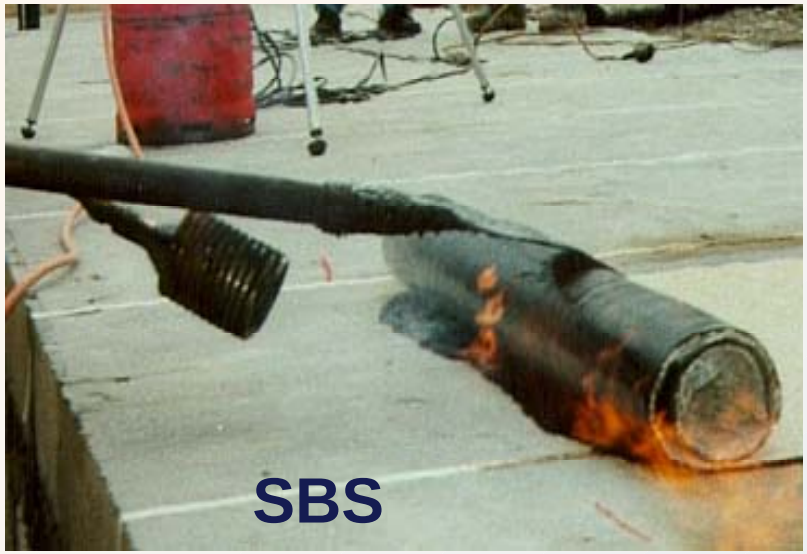
- **Promote trend towards Energy & Emission Reduction in Paving: Hot→Cold Recycling**
  - **Hot/warm: temp-reducing additives**
    - Wax additives (reduction by 10..20°C)
    - Rapeseed-oil ester additives (Placing T=100°C)
  - **Lukewarm: Foam bitumen**
    - New in CH (Know-How still uncertain)
    - New test methods required (e.g. curing history)
    - Problem: Coating of minerals
    - Waiting time until ready for traffic
    - Only for compacted asphalt
  - **Cold: Emulsions**
    - Complicated, greater know-how required
    - Other test methods (e.g. breaking time)
    - Pav. thickness restricted, to allow water disappear
    - Only for compacted asphalt
    - Expensive

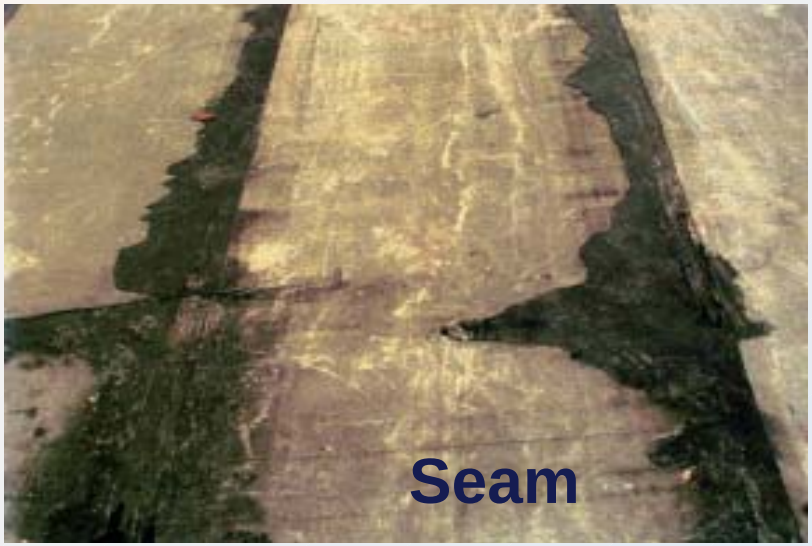
Warm Pavements



Waterproofing

Torching Process





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Heating of Bitumen

Undefined temp, open flame

Temp. Control

Recycling

Contact

Dr. Martin Hugener

martin.hugener@empa.ch

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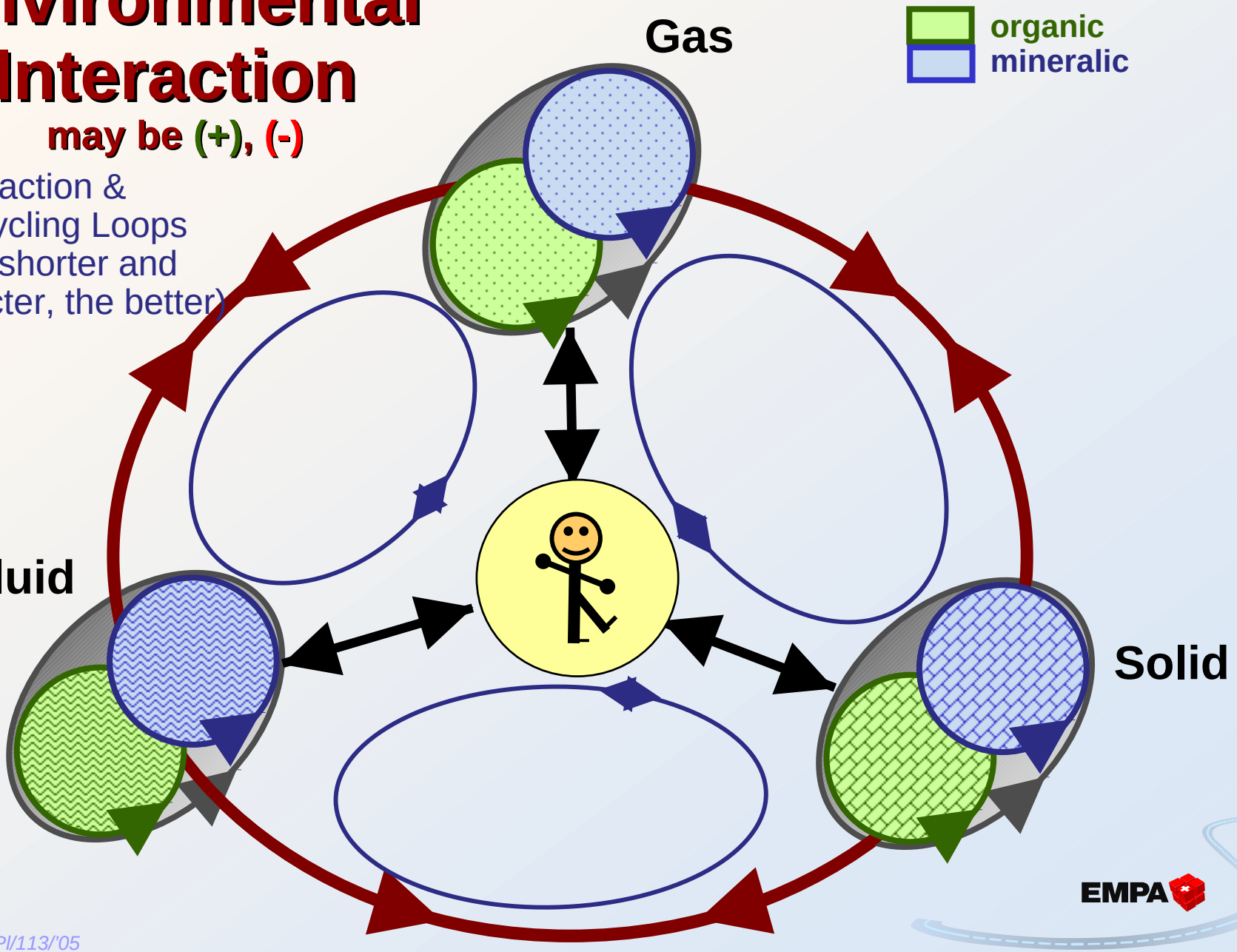
General

Environmental Interaction

may be (+), (-)

Interaction & Recycling Loops (the shorter and directer, the better)



Swiss Recycling Principals (1) (SAEFL 1997)

SAEFL Swiss Agency for the Environ., Forests & L.scape (BUWAL)

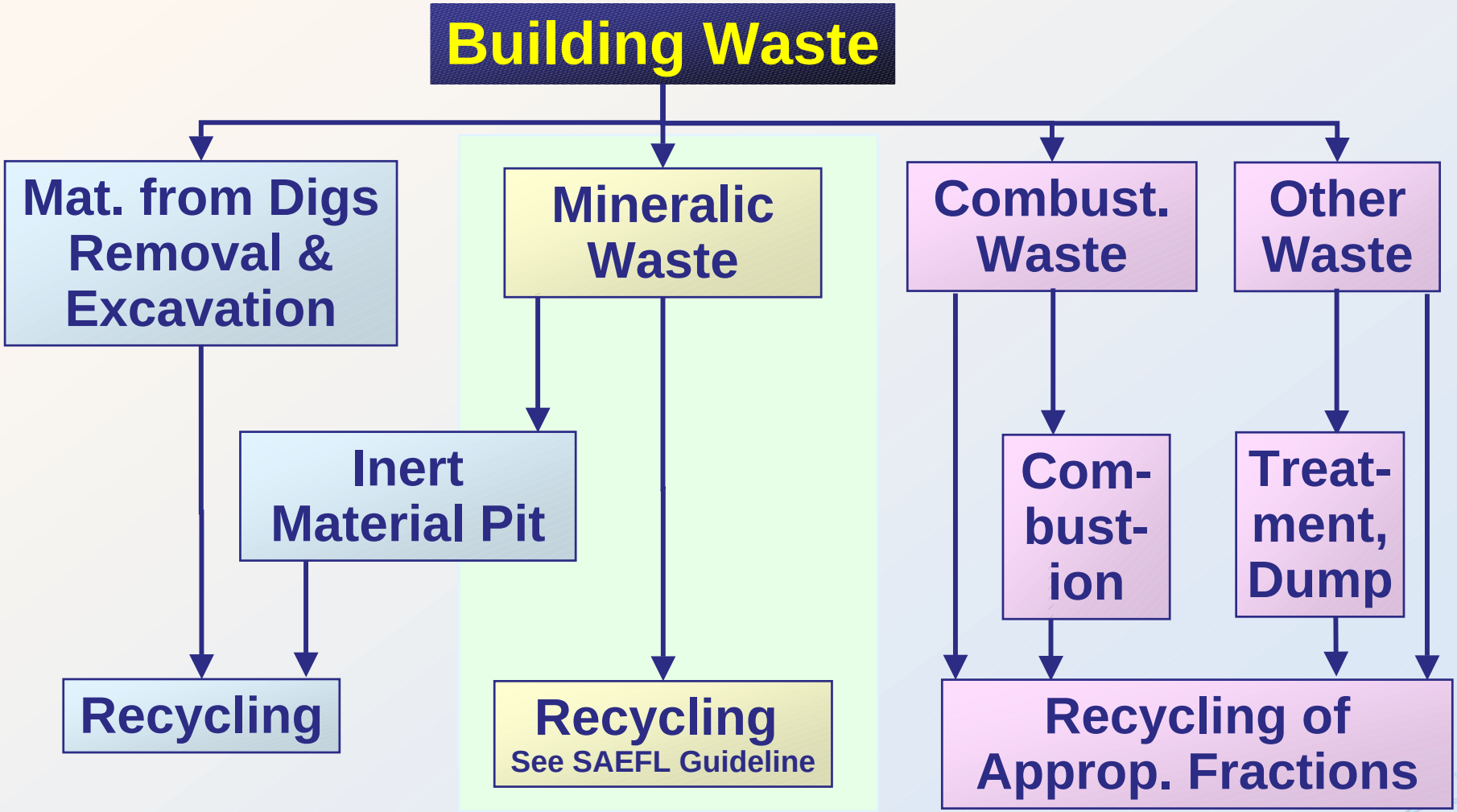
- **Promotion of Closed Loop Material Cycles**
  - Recycle for the **same** material application
  - More than 95M% **must** be **mineralic**
  - Recycle to the highest possible **quality**
- **Principle of Precaution**
  - Avoid **risky** materials from the very beginning
  - Check **technical practicability** of recycling early
- **No Problem Shifting**
  - Don't recycle **hazardous** materials with future risks
  - No **thinning** and **dispersion**!
  - No **shift** from one media to another, e.g. air→water

Swiss Recycling Principals (2) (SAEFL 1997)

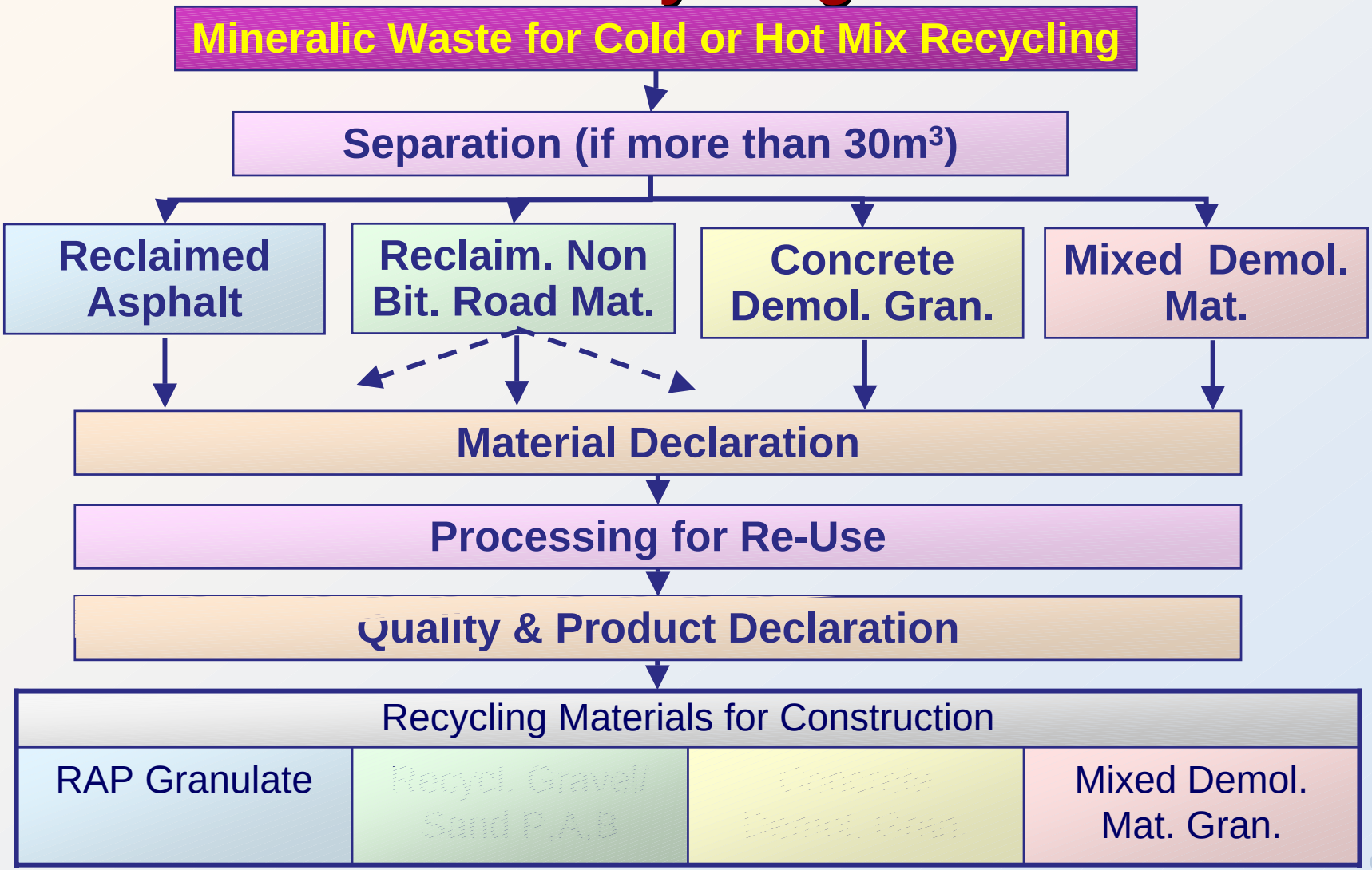
- **Economic Cost - Ecological Benefit**
  - **Economically** bearable
  - **Ecologically** reasonable (e.g. energy aspects)

- **Mineralic Building Waste Recycling Fractions** (see SN 670 062):
  - Reclaimed Asphalt (RAP)
  - Mixed Demolition Material
  - Concrete Demolition Material
  - Reclaimed non Bituminous Road Material

General Building Waste Flow (SAEFL 1997)



From Waste to Recycling Material (SAEFL 1997)



Criteria for Separation & Recycling (SAEFL 1997)

Recycling Possibility	PAH-Content in Binder	Material Classification
Unrestricted Recycling	0...5000 ppm	Tar-Free
Restricted Recycling with Cold- or Hot-Recycling: Must be diluted to 5000 ppm & MAK-value for BaP during construction must not be exceeded	5000..20'000 ppm	Little Tar Contamination (Mixes with Tar-Bitumen TB2000)
Disposal (Dump)	> 20'000 ppm	Heavy Tar Contamination (Tar-treated & soaked)

PAH: **PAH: Polycyclic Aromatic Hydro-Carbonate**

MAK: Max. Tolerable Concentration of Cancerogeneous Material at Working Place

PAH Determination required if more than 30m³ RAP

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Waste Recycling: Use

Recycl. Mat.	RAP	Recycl. Gravel/ Sand P	Recycl. Gravel/ Sand A	Recycl. Gravel/ Sand B	Stabi-Gran.	Concrete Demol.	Mixed Demol
Asph. Surf. C	Ideal Use						
Asph. Base C		Possible Use					
Asph.Fund.							
Bit Stab F.	Possible Use						
Concr. Pav.		Possible Use		Possible Use		Ideal Use	
Hydr Stabi		Possible Use		Ideal Use			
Un-bound Fund	Use under Bound Layer OK	Ideal Use	Use under Bound. Lay. OK	Ideal Use	Use under Bound Layer (Asphalt, Concrete) OK		
Un-bound Suface	Possible Use						
Concrete		Possible Use				Recycling Concrete accord. SIA 162/4	

Use possible

Ecologically and technically not appropriate

ALT-MAT

EU-Project ALT-MAT

Research by M. Hugener, EMPA

Materials:

VRG-Slag (glass-like, not crushed)

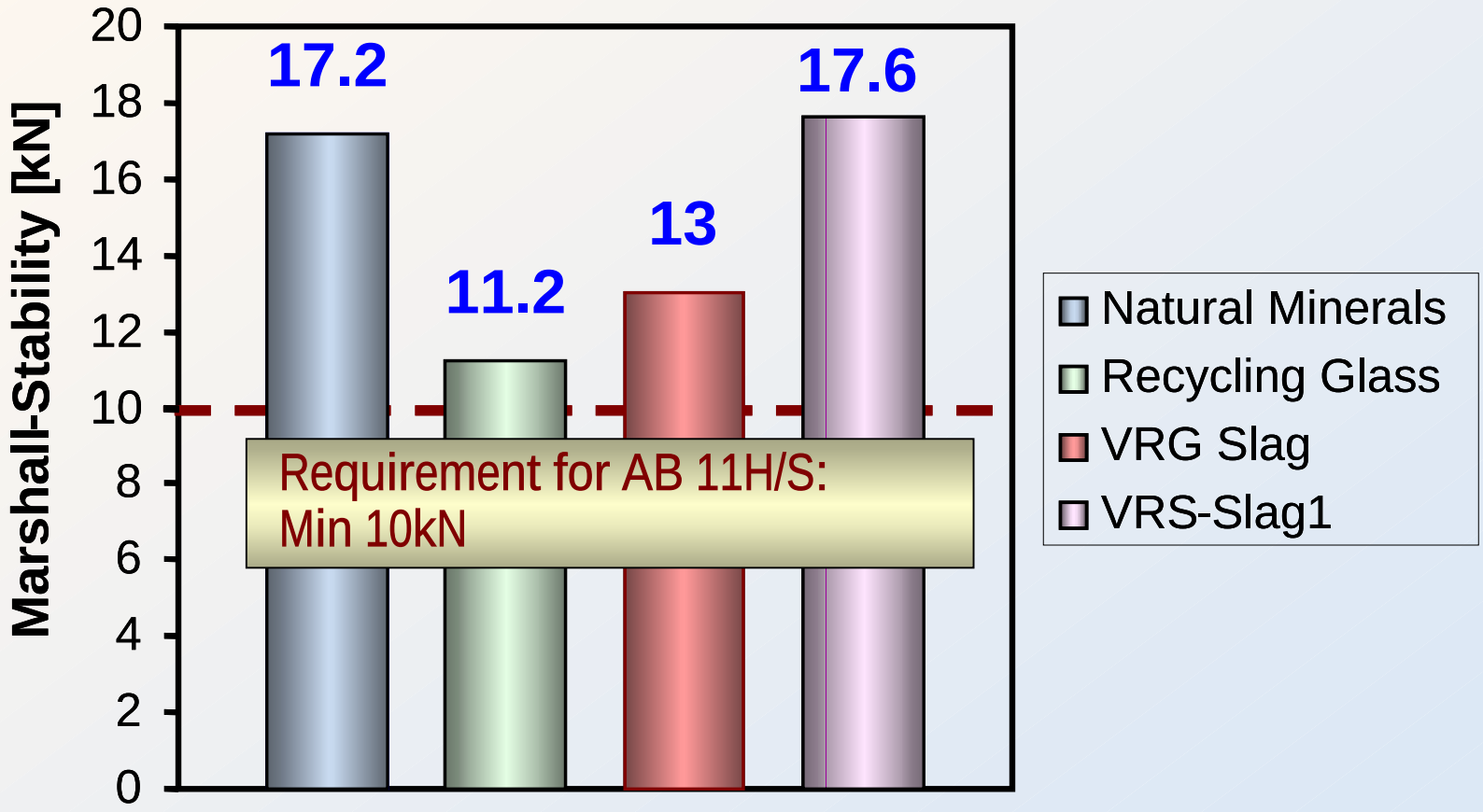
VRS-Slag (mineral-like, crushed, slow cooling proc.= cristals)

Thermal waste incinera-tion process

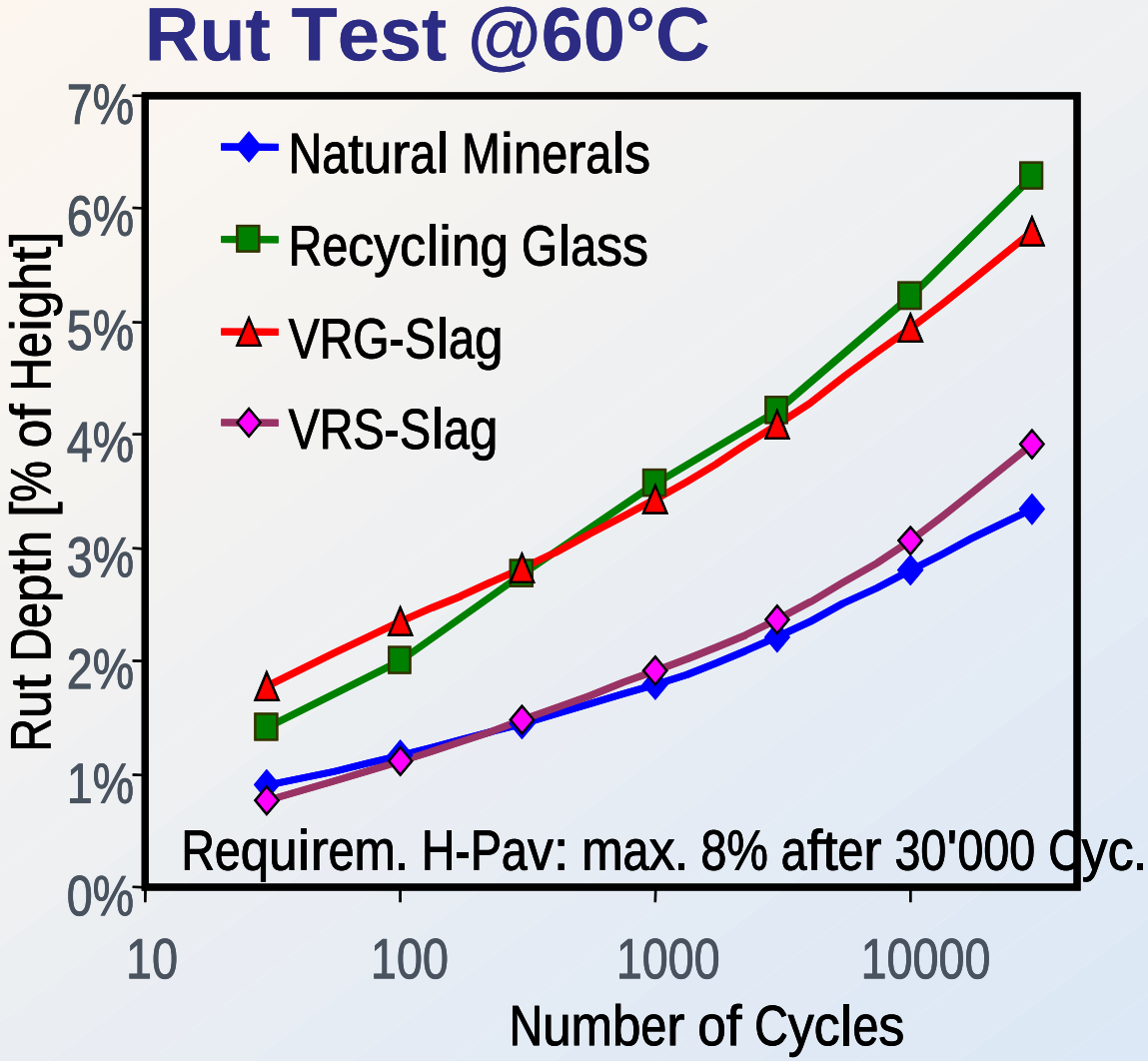
Report on web site 2001:
www.trl.co.uk/altmat/index.htm

Recycling-Glass

Marshall- Stability



Test Results



Tar

Relation betw. PAH in Tar-Cont. RAP & Vapors Emitted during Re-Paving

- **Problem**: old tar-containing pavements evaporate hazardous vapors during heating (recycling)
- **Goal**: Estim. of emissions for known material & process param.
  - Estimate PAH emissions from data of the original substance
  - Estimate total gas emissions from field tests
  - Is the PAH-determ. from only a few substances sufficient??
- **Procedure**: Lab simul. of PAH emissions for different parameters (temp, PAH-cont, binder type;..); varify relation in field tests with min. two tar-containing mixes
- **Results**: Data to fix limits for hot placing of recycling granulate
- **Benefit**: Health protection of road workers

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Limits for Hygiene at the Workplace

- **Emission von Bitumen Aerosols ("Fume"):**
  - Germany: 12 mg/m^3
  - USA: 5 mg/m^3 (in future 0.5 mg/m^3)
- **Emission of Single Components**
  - Switzerland (MAK-Values)
    - Benzo(a)pyren: 2000 ng/m^3
    - Phenol, Cresol: 19-20 mg/m^3

MAK: Max. Tolerable Concentration of Cancerogeneous Material at Working Place

- **Measured Emissionen in tar-free Material**
  - **Mix** (150°C) Fume: 0.5mg/m^3; BaP:190 ng/m^3
  - **Mastix Asphalt** (240°C) Fume: 30mg/m^3; BaP: 2900 ng/m^3

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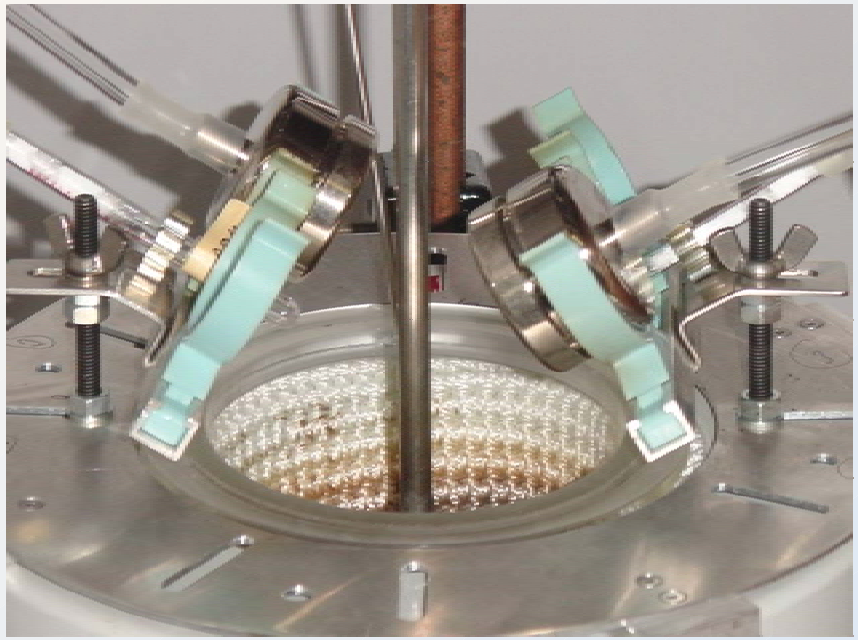
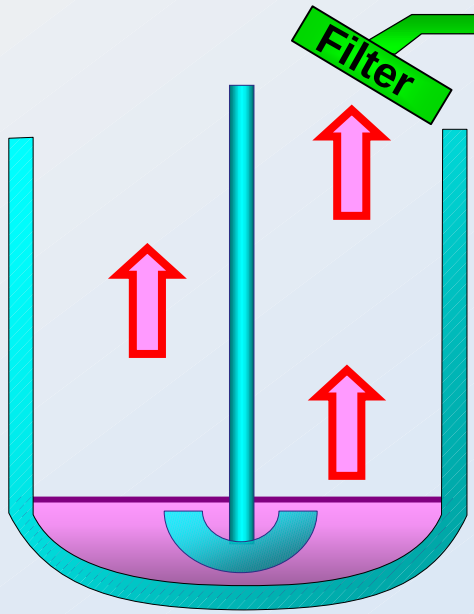
PAH Content in Bituminous Binders

Binder	EPA-PAH, [mg/kg]	Benzo(a)pyrene, BaP [mg/kg]	Phenol, Cresol, [mg/kg]
Bitumen	10 ... 40	0.2 ...1.8	0.3…2
Tarbitumen with 5 % Tar	5'000 ... 15'000	450 ... 600	220…250
Tar	100'000 ... 300'000	9'000 ...12'500	4400…5000

- EPA: US Environmental Protection Agency
- PAH: Polycyclic Aromatic Hydro-Carbonate
- Limit SAEFL: 5000 mg/kg in Binder (provisional 20'000 mg/kg)
- **Remark**:
  EMPA-Measurement 1 (SZ): 35'000 mg/kg
  EMPA-Mesurement 2 (BE): 75'000 mg/kg

Labor Test: Fume Generator





PAH,Fume, Phenol/ Cresol, BTX, PID/FID PAS

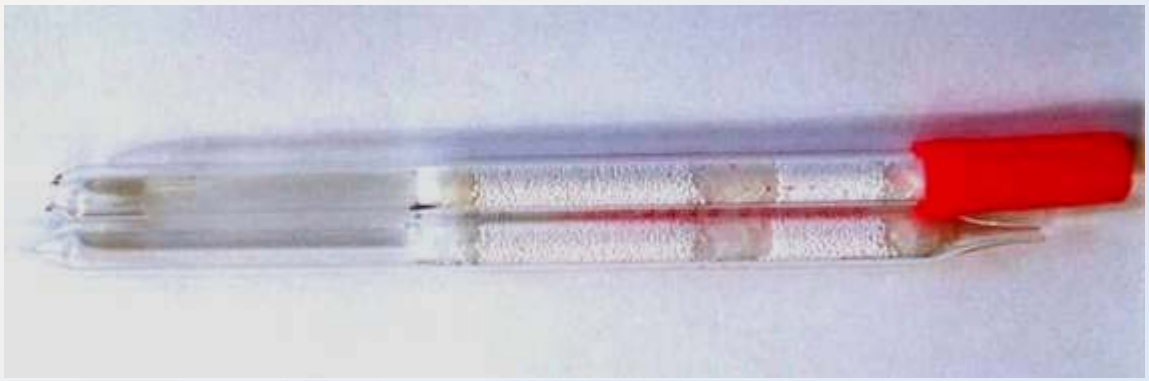
Parameter:
Temperature
Binder
Tar-Content

PAH
Viscosity
TGA

EMPA

Tools

Filter for non volatile substances

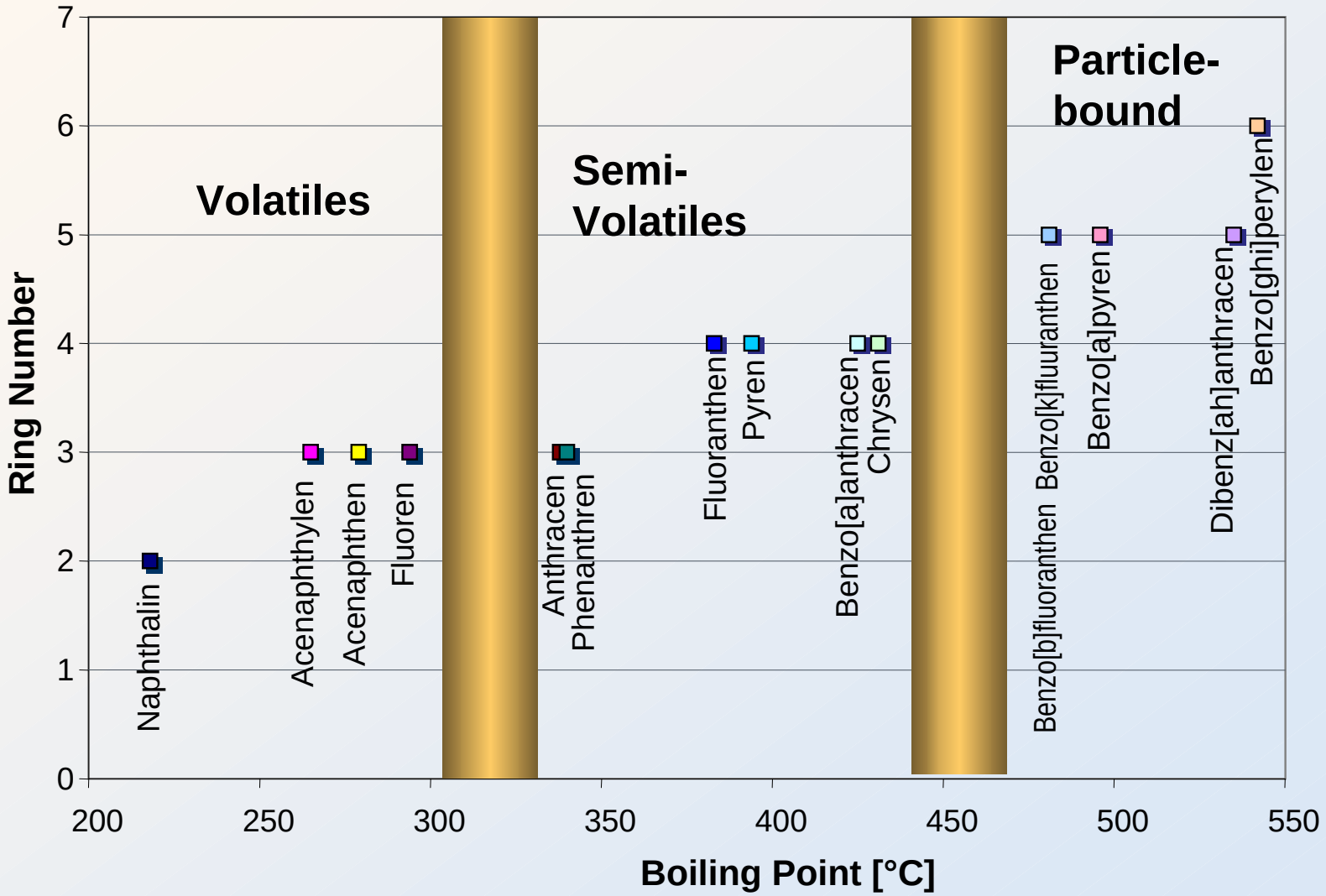


Adsorption tubes for volatile substances

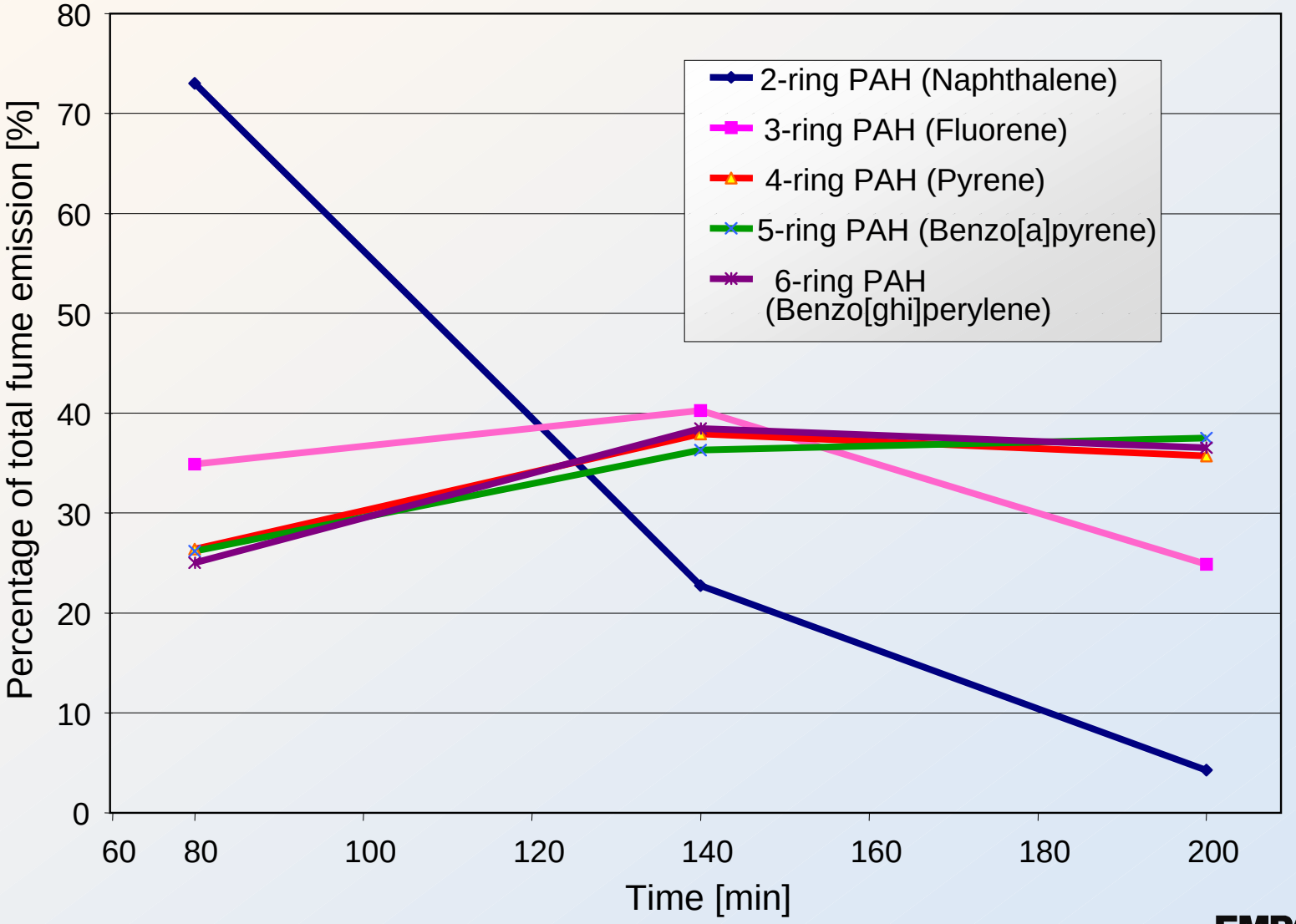
PAH List

PAH Vapor Press., ca. [Pa]	16-EPA-PAH	Swiss Nat. Accid Ass. SUVA (´99)	PAH Vapor Press., ca. [Pa]	16-EPA-PAH	Swiss Nat. Accid Ass. SUVA (´99)
2-Ring [10^{2}]			*5-Ring [10^{6} - 10^{9}]*		
Naphthalin	x		Benzo(a)pyren	x	xx
			Benzo(e)pyren		
3-Ring [10^{1} - 10^{-3}]			Benzo(b)fluoranthen	x	x
Acenaphthylen	x		Benzo(j)fluoranthen		x
Acenaphthen	x		Benzo(k)fluoranthen	x	x
Fluoren	x		Dibenz(a,h)anthracen	x	x
Phenanthren	x				
Anthracen	x		*6-Ring-PAH [10^{8}]*		
			Benzo(ghi)perylen	x	
4-Ring [10^{3} - 10^{-6}]			Indeno(1,2,3-cd)pyren	x	x
Fluoranthen	x		Dibenzo(ae)pyren		x
Pyren	x		Dibenzo(ah)pyren		
Benz(a)anthracen	x	x	Dibenzo(ai)pyren		x
Chrysen	x	x	Dibenzo(al)pyren		x

PAH Volatiles



PAH Emission vs. Time



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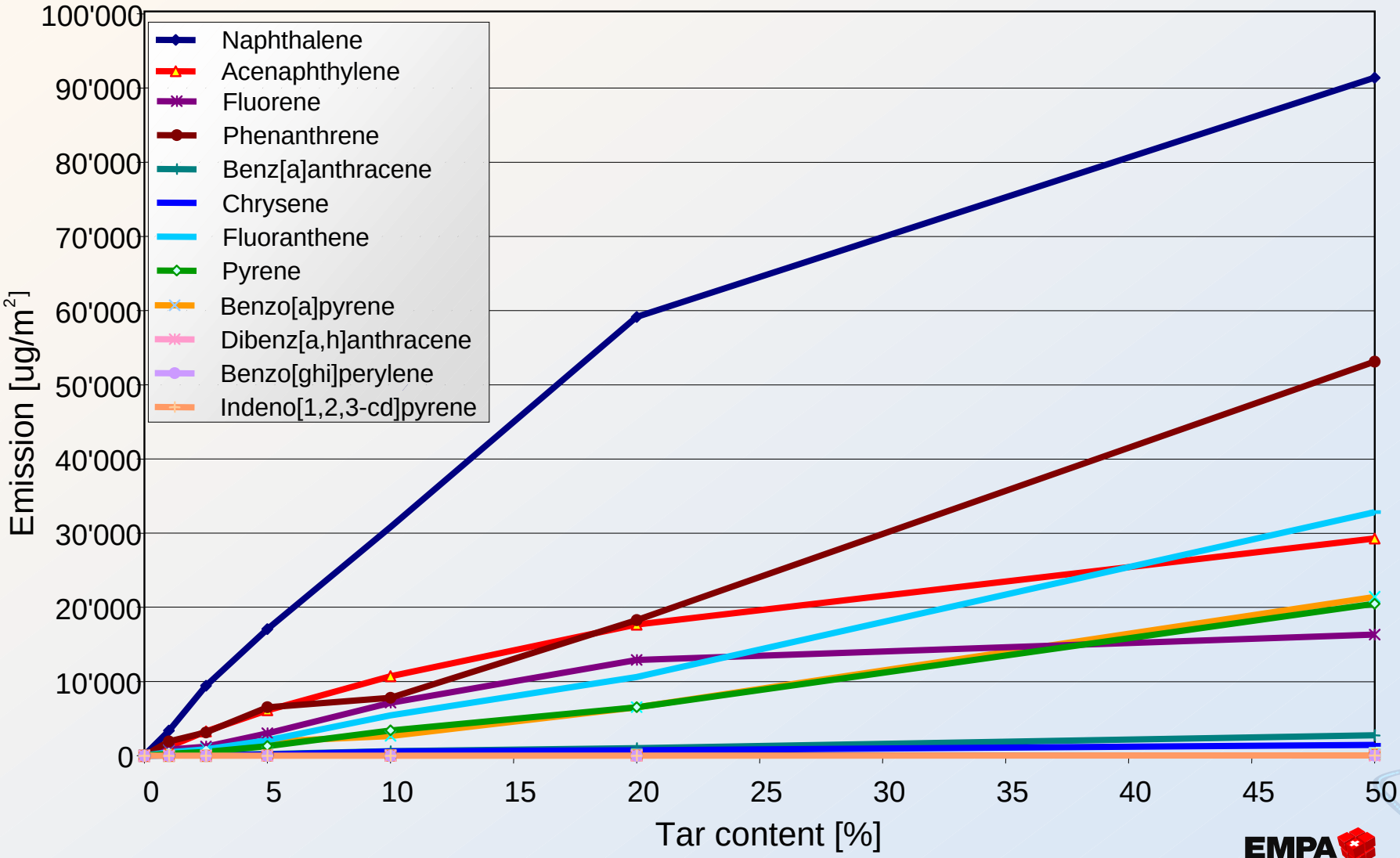
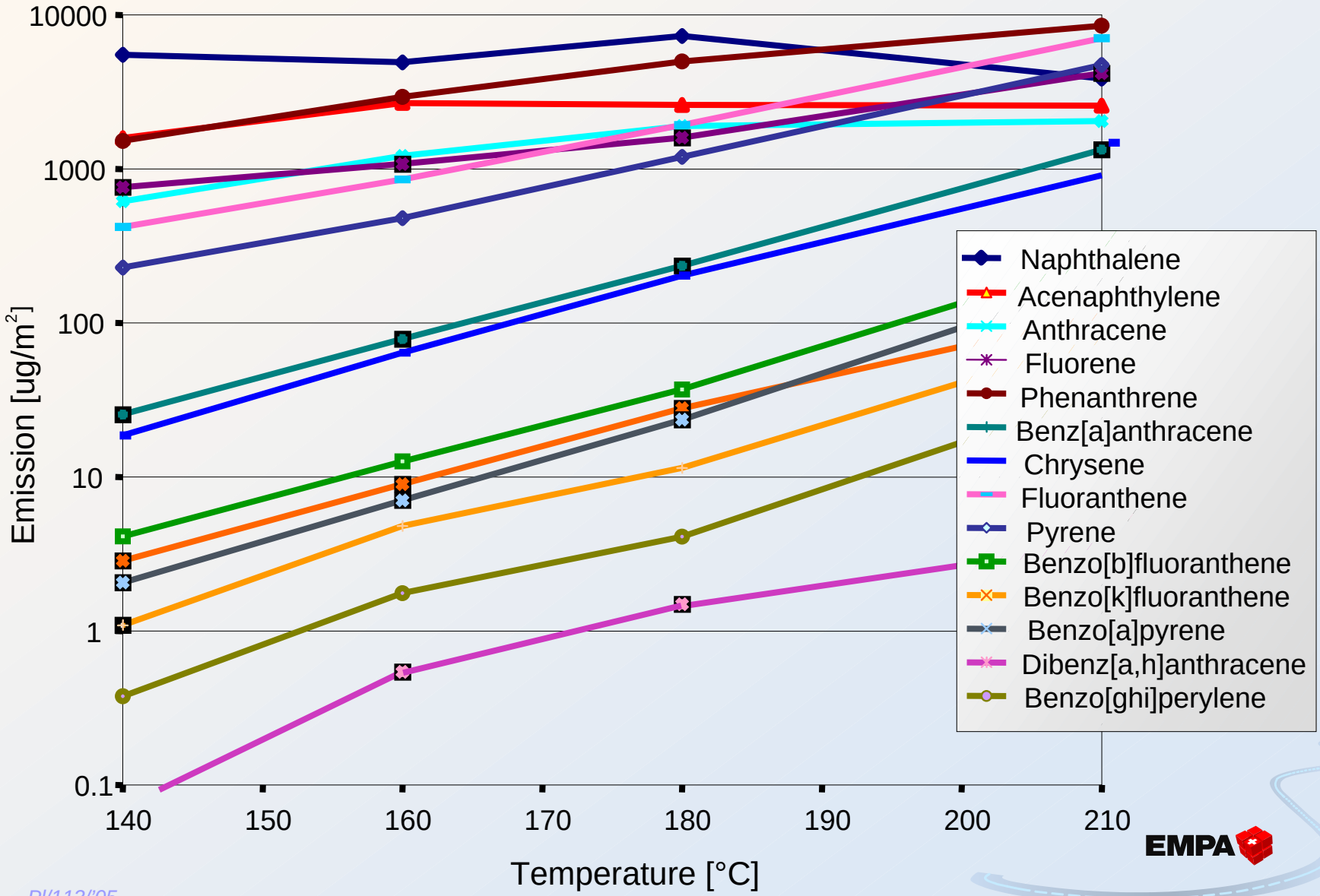
PAH Emission vs. Tar Content



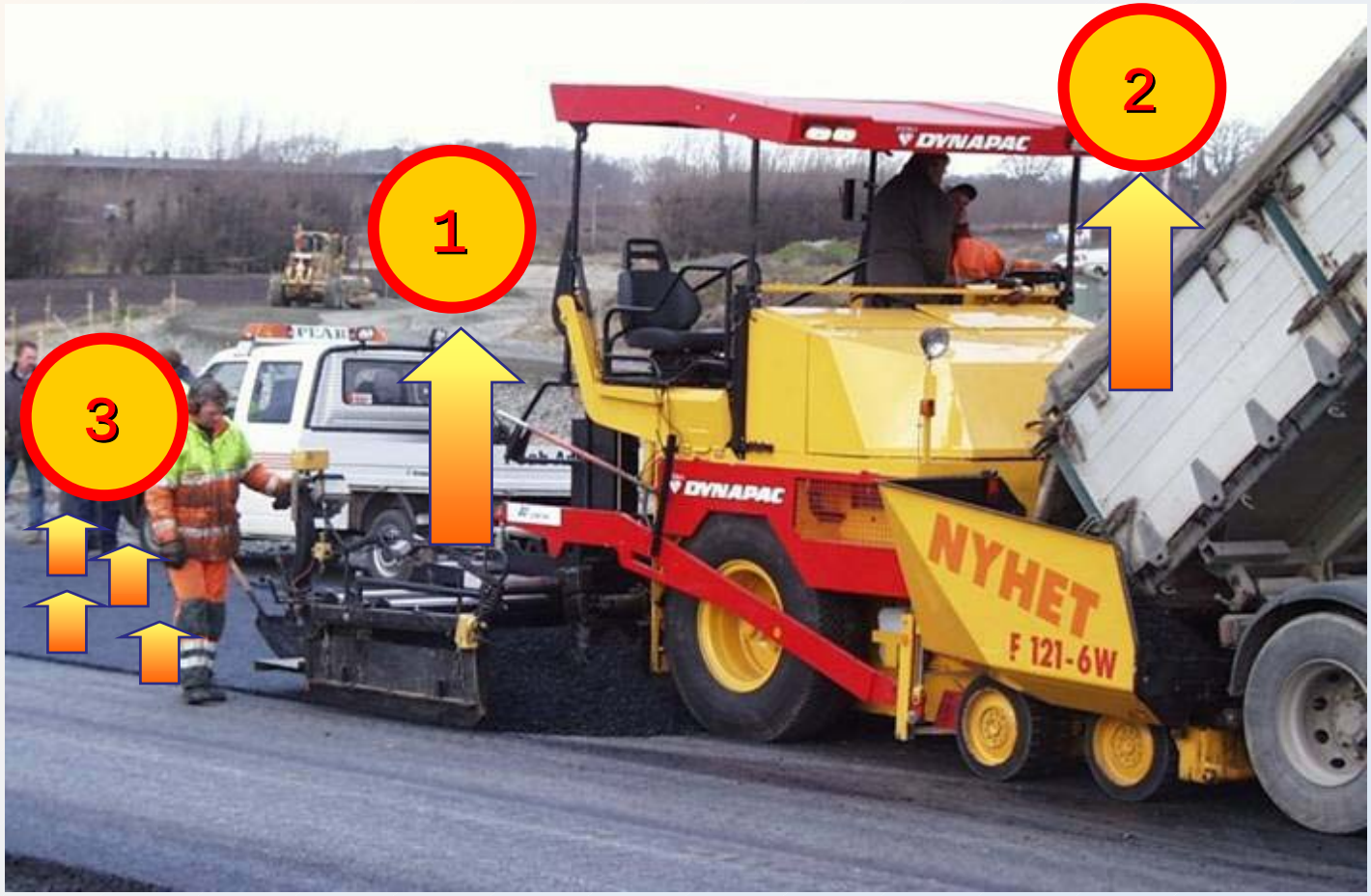
EMPA

PAH Emission vs. Temp



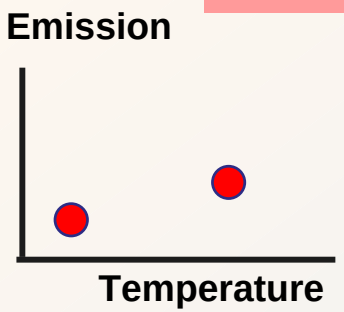
EMPA

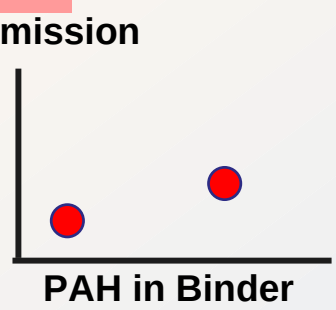
Main Emission Sources/Locations



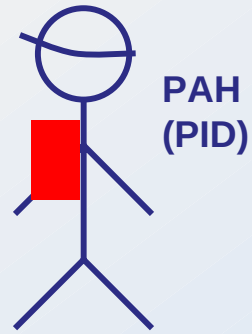
Sampling

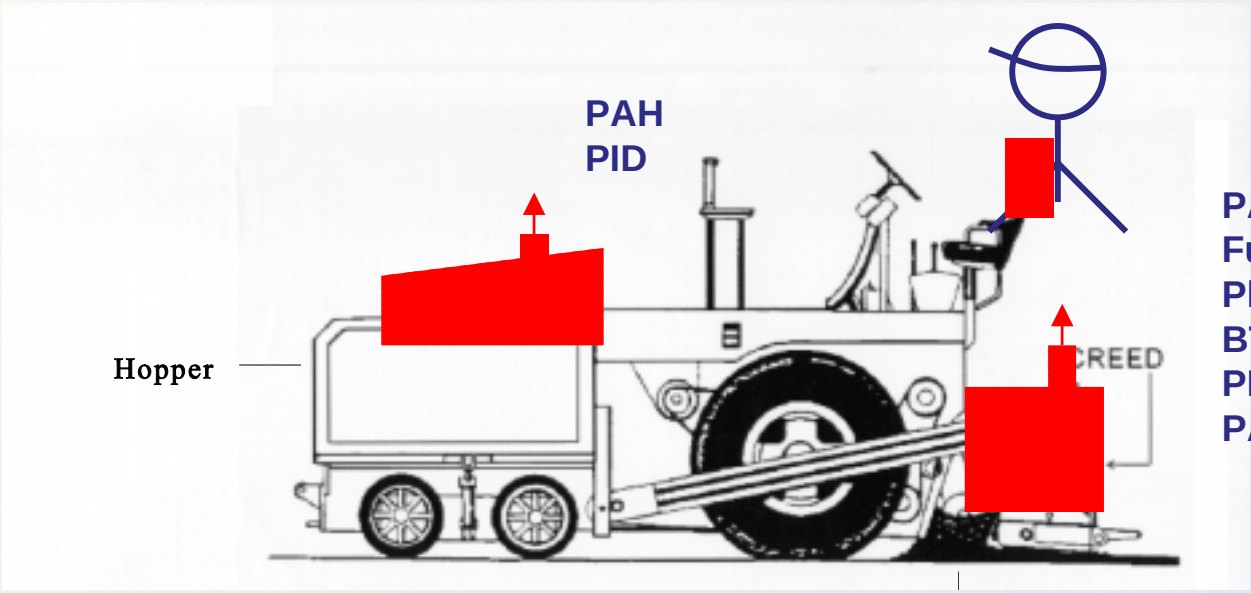
Total Emission





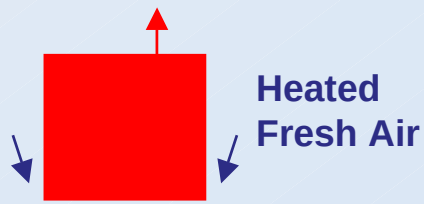
Emission at Working Place





PAH
Fume
Phenol/Cresol
BTX
PID / FID
PAS

PAH
PID



Sampling #1: Compaction Plank

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Sampling #2: Asphalt Input

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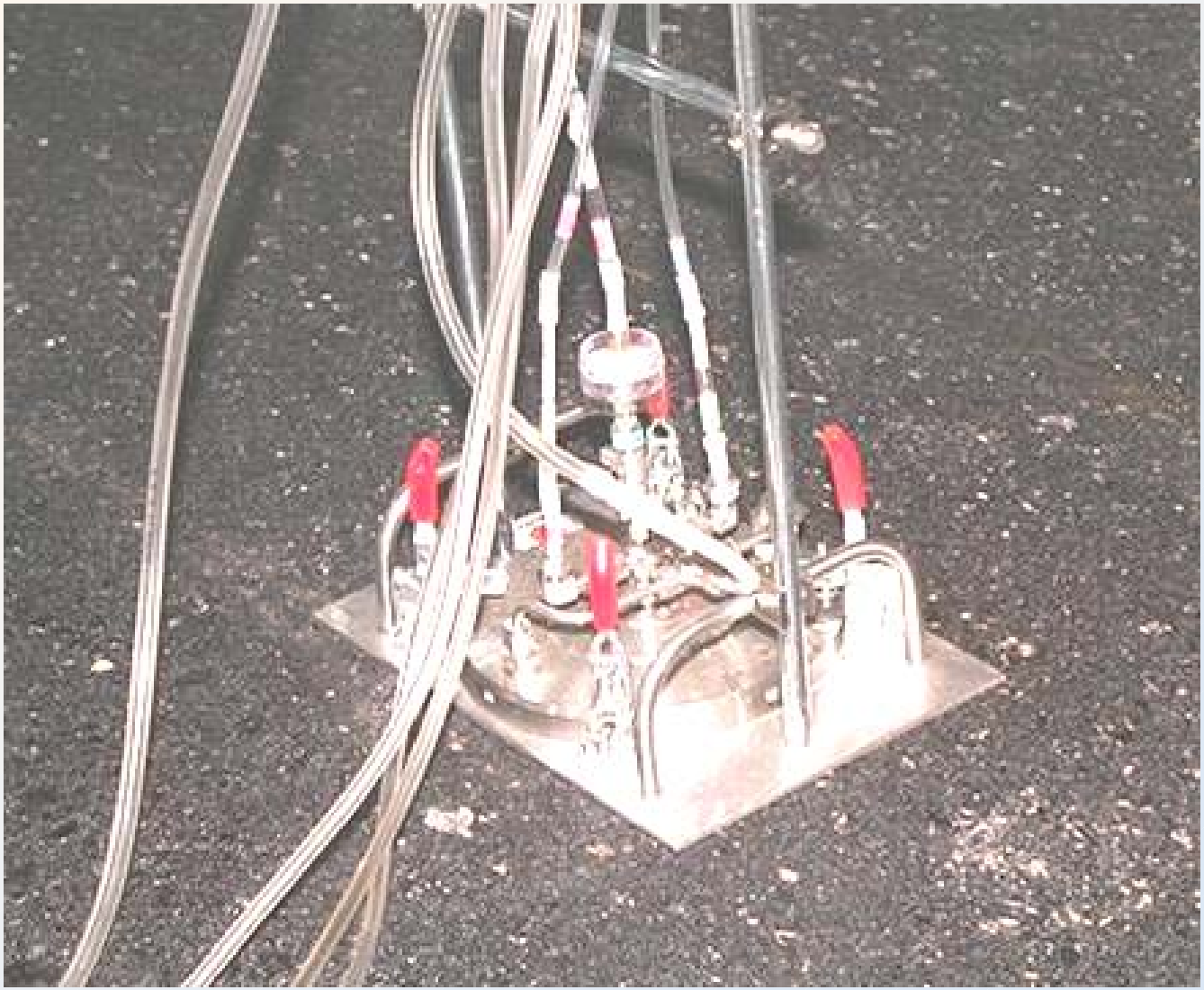
Sampling #3 Pavement



Sampling at Working Place

Personal Sampler

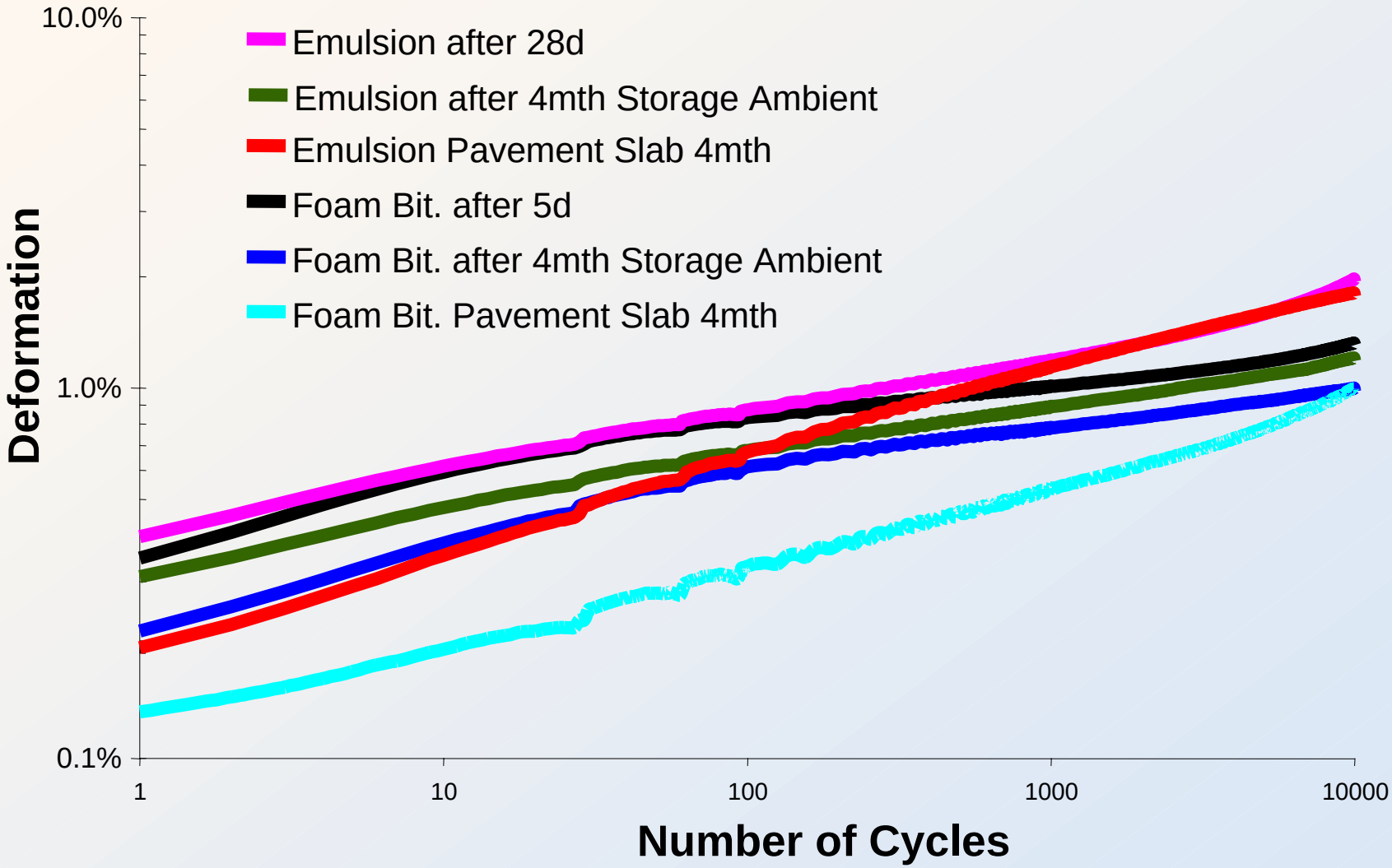
Cold Mixtures

Foam Bitumen/Emulsion Study

- KMF 32 (Foam Bitumen)
  - Binder Cont. 7.22 M%
  - RAP: 92.1 M%
  - River Gravel: 7.9M%
  - Water Cont in RAP: 4.7M%

- KMF32 (Cement-Bitumen-Emulsion)
  - RAP: 100M%
  - Emulsion: 8.85M% of tot. Mix

Summary Cyclic Compression



Summary Findings Foam Bit/Emuls

M. Hugener, C Raab

- Compaction & Conditioning extremely important
  - **Comp. & cond. must be optimized separately for each mix**
  - **Accelerated curing at elevated temp is recommended**
  - **Time between sampling and testing is important**
- Marshall Compaction is not suitable (water remains in specimen)
- Gyratory is promising but may lead to over-compaction (optimization necessary)
- Wheel Tracking test was not satisfying. Scatter!
- TSR 77% (Pav. slabs) in both cases acceptable?

Cold Recycling Project (ongoing)

Goals

- Recycling in-place
- Cold recycling without heating
- Use of 100% recycling material
- For foundation and base courses
- For small jobs in communities
- Use of traditional paving machines
- Development in the lab, validation in situ

Mix design

Uniaxial compr. test UCT:

23°C; 50mm/s

3 Gyratory specimen

D=100mm

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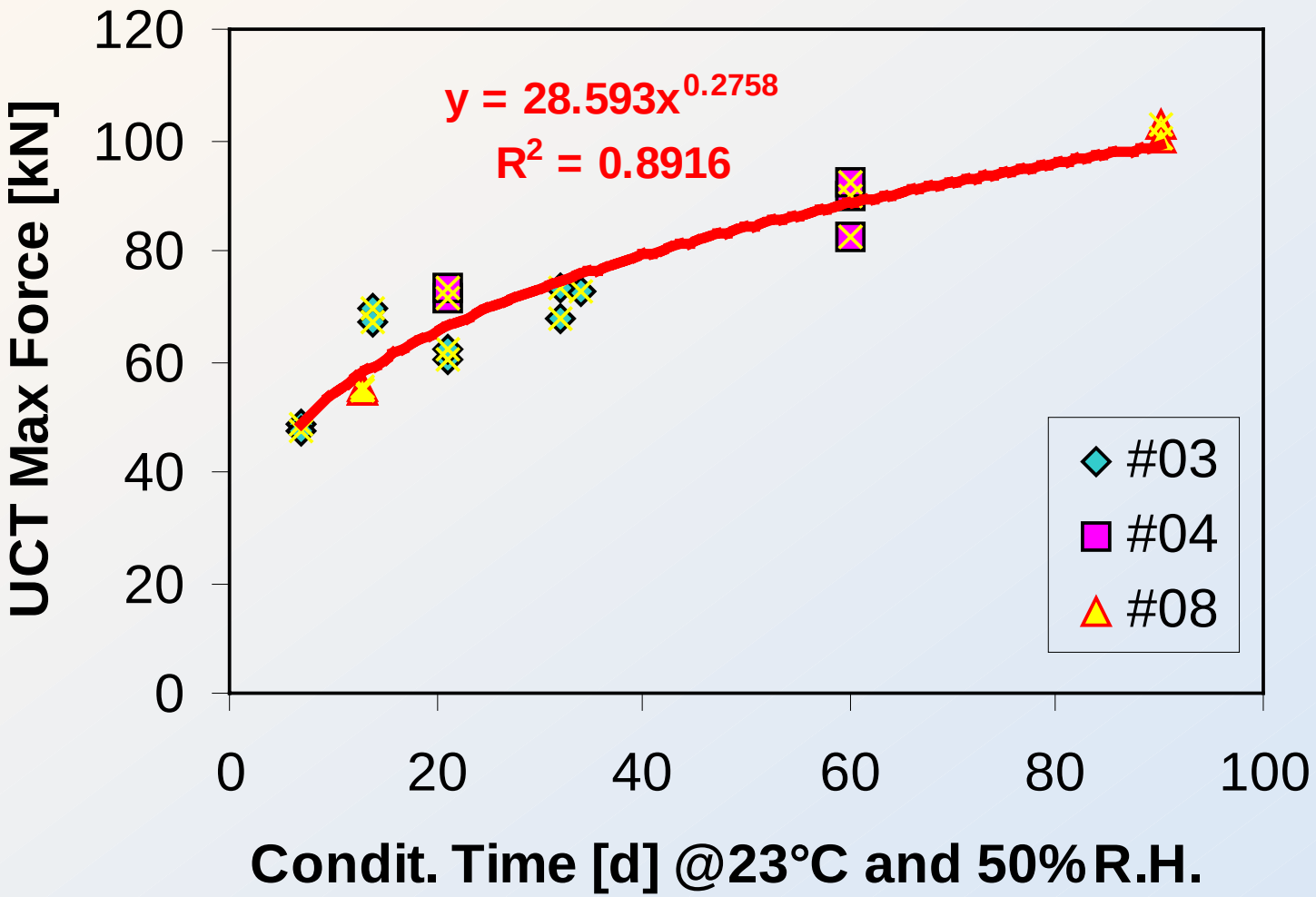
Increase in Strength over Time

UCT Uniaxial Compression Test



Eureka Environmental Footprint

Contact

Lily Poulikakos

lily.poulikakos@empa.ch

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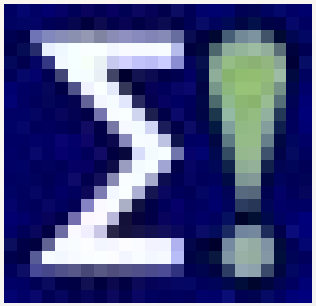
Eureka Logchain Footprint E!2486

- Relate the environmental footprint of a vehicle to maintenance costs
- Develop and use same methodology for road and rail to facilitate intermodality (Road: EMPA, Rail: NL, UK,AT)
- Concentrate on freight vehicles



Footprint in terms of:

- Dynamic load of vehicle (wim)
- Audible noise
- Ground borne vibration
- Gaseous emissions

25 participants, 7 countries (CH,NL,CZ,FR ,UK,AT,HU)

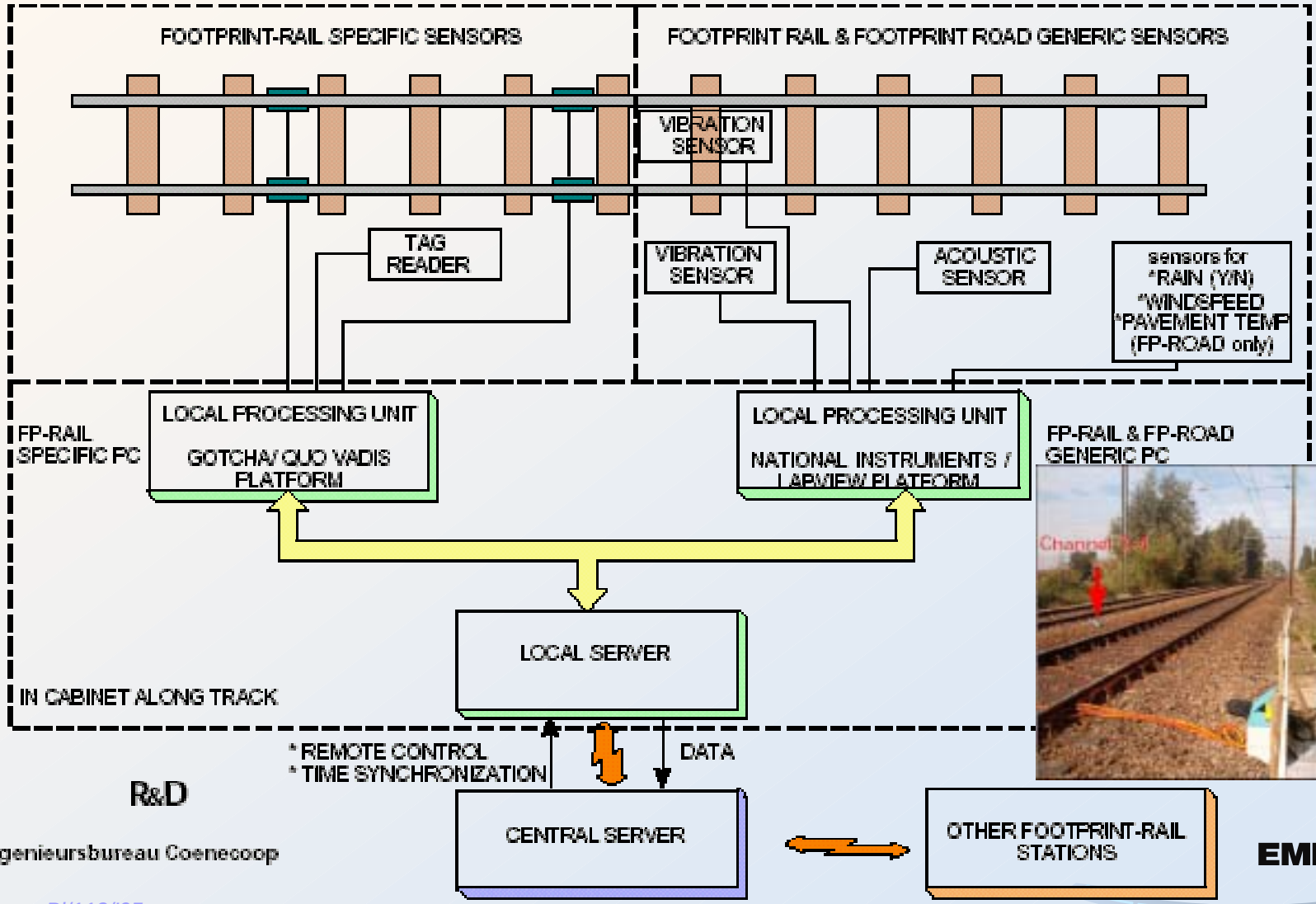
- **Phase 1**-Analysis of existing knowledge
- **Phase 2**-Modeling
- **Phase 3**-Measurements of the dynamic interaction and footprint
- **Phase 4**-Life cycle costing
- **Phase 5**-Reducing the environmental impact of freight transport
- **Phase 6**-Discussions, recommendations and dissemination

ASTRA KTI/CTI Bundesamt für Umwelt, Wald und Landschaft BUWAL BUNDESAMT FÜR VERKEHR OFFICE FÉDÉRAL DES TRANSPORTS UFFICIO FEDERALE DEI TRASPORTI FEDERAL OFFICE OF TRANSPORT KISTLER measure. analyze. innovate. EMPA

Footprint Station, Rail

Wadinxween, NL

DATA ACQUISITION ARCHITECTURE FOR FOOTPRINT-RAIL STATIONS:

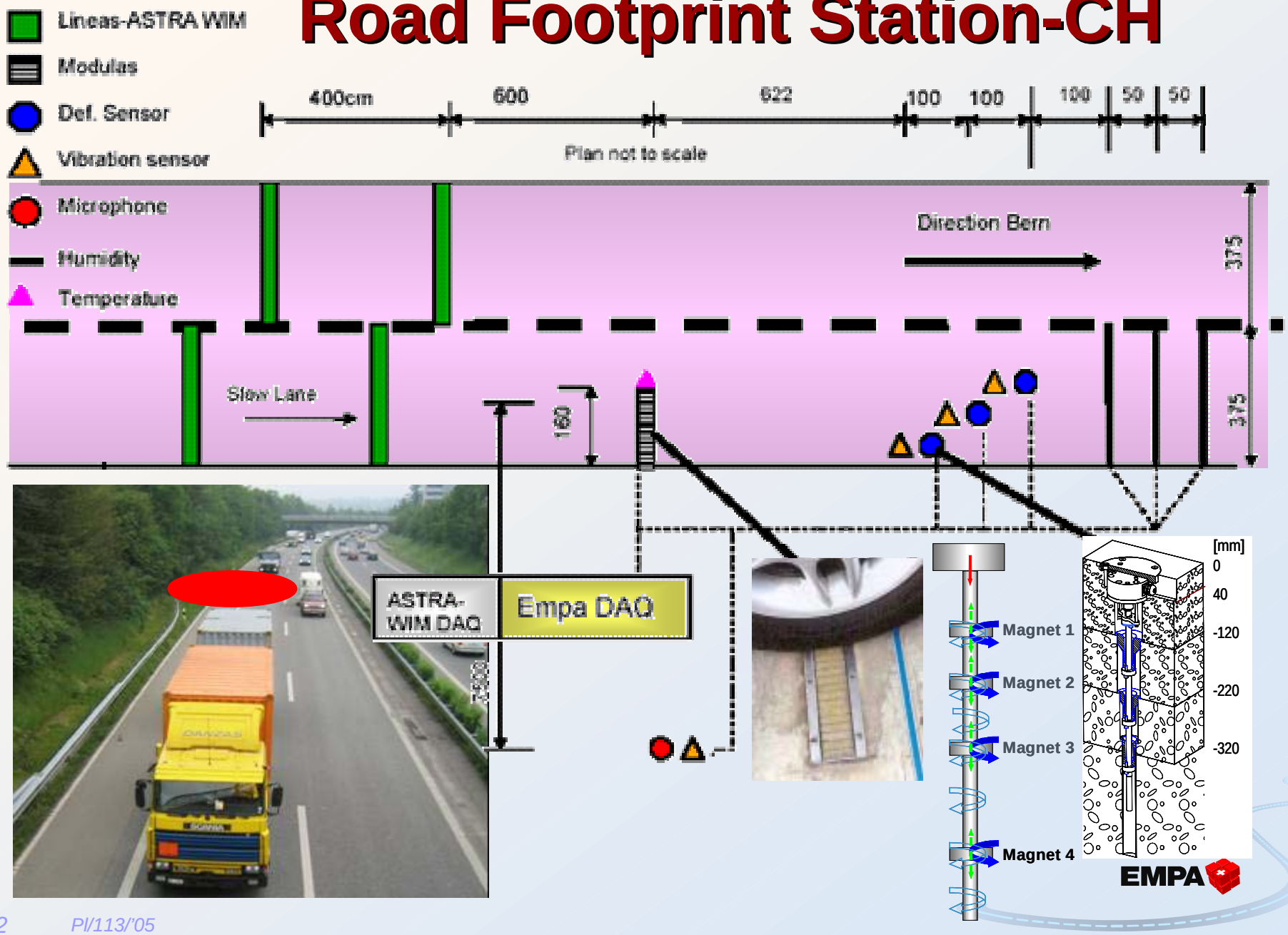


R&D

Ingenieursbureau Coenecoop

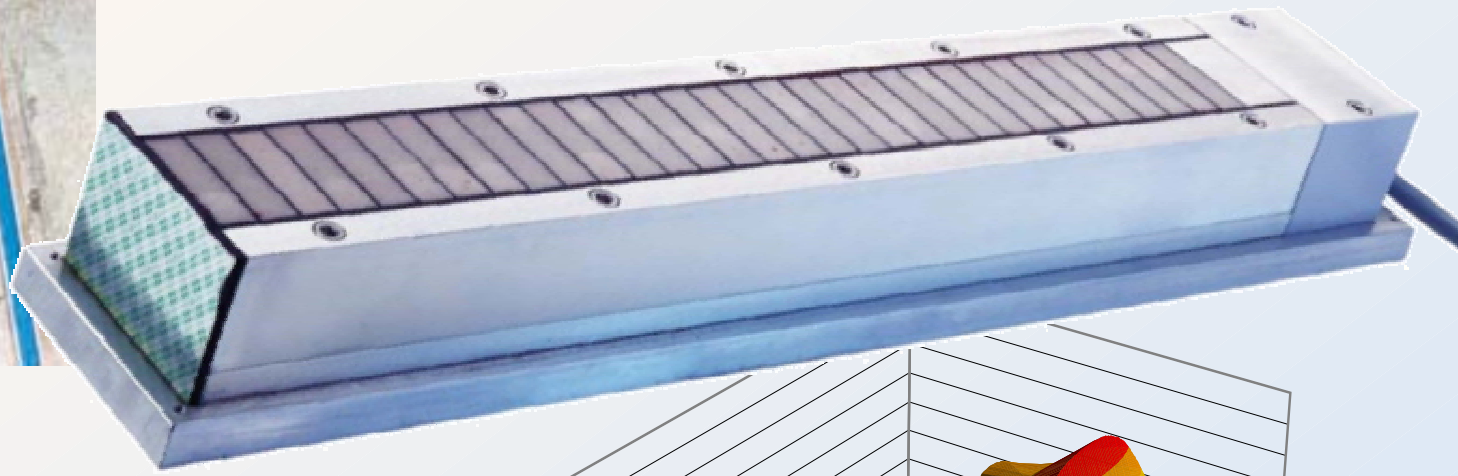
EMPA

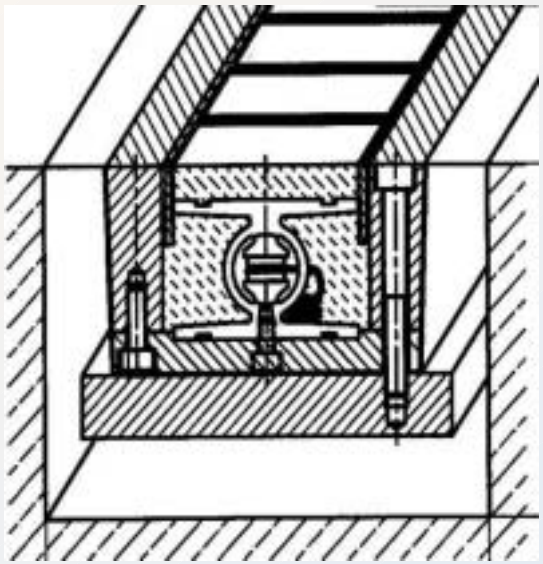
Road Footprint Station-CH

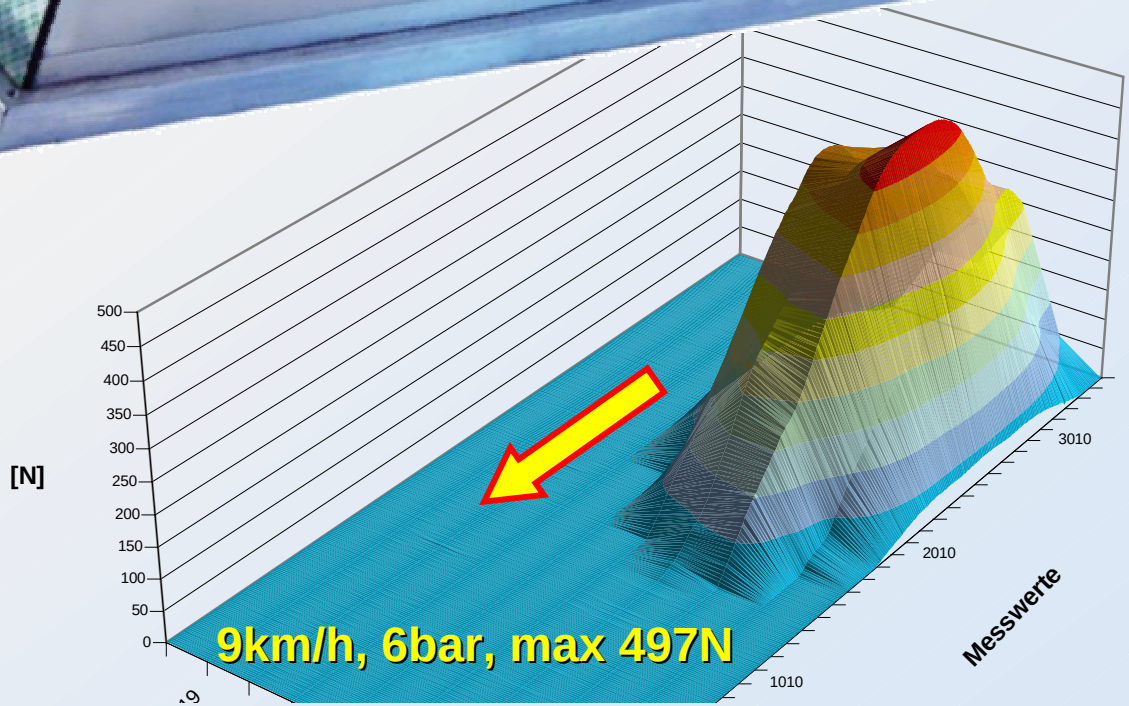


Modulas System by Kistler

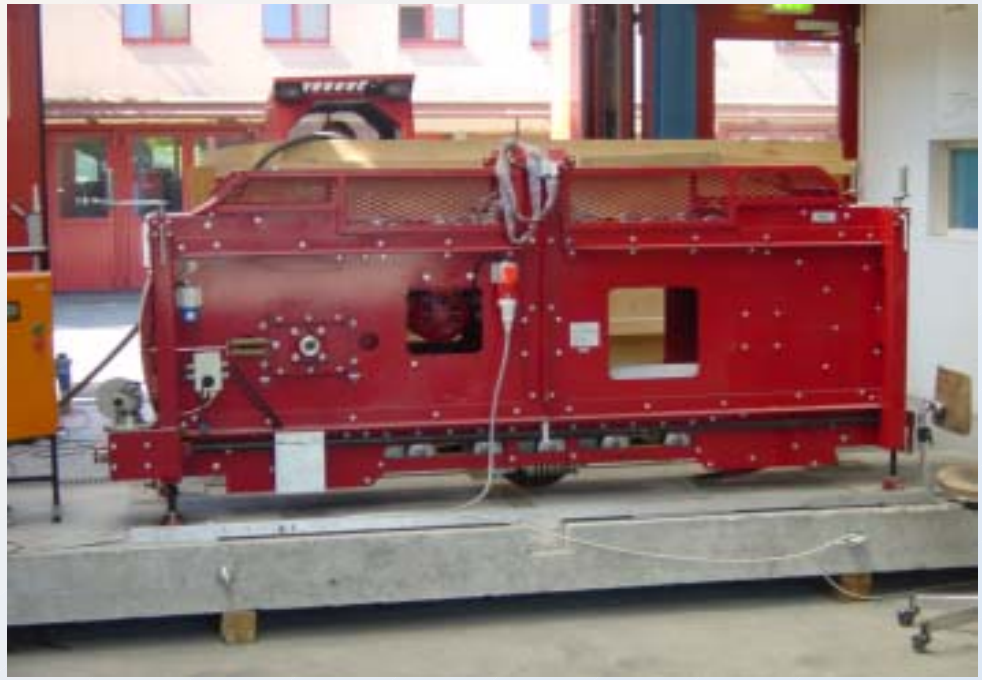
(E. Doupal, R. Calderara Kistler Instr.)







Modulas Preparation, MMLS



p=560..800kPa
v=2.5m/s, 9km/h
N=7200 cycles/h
l=2400mm
Axel load=1.9… 2.7kN

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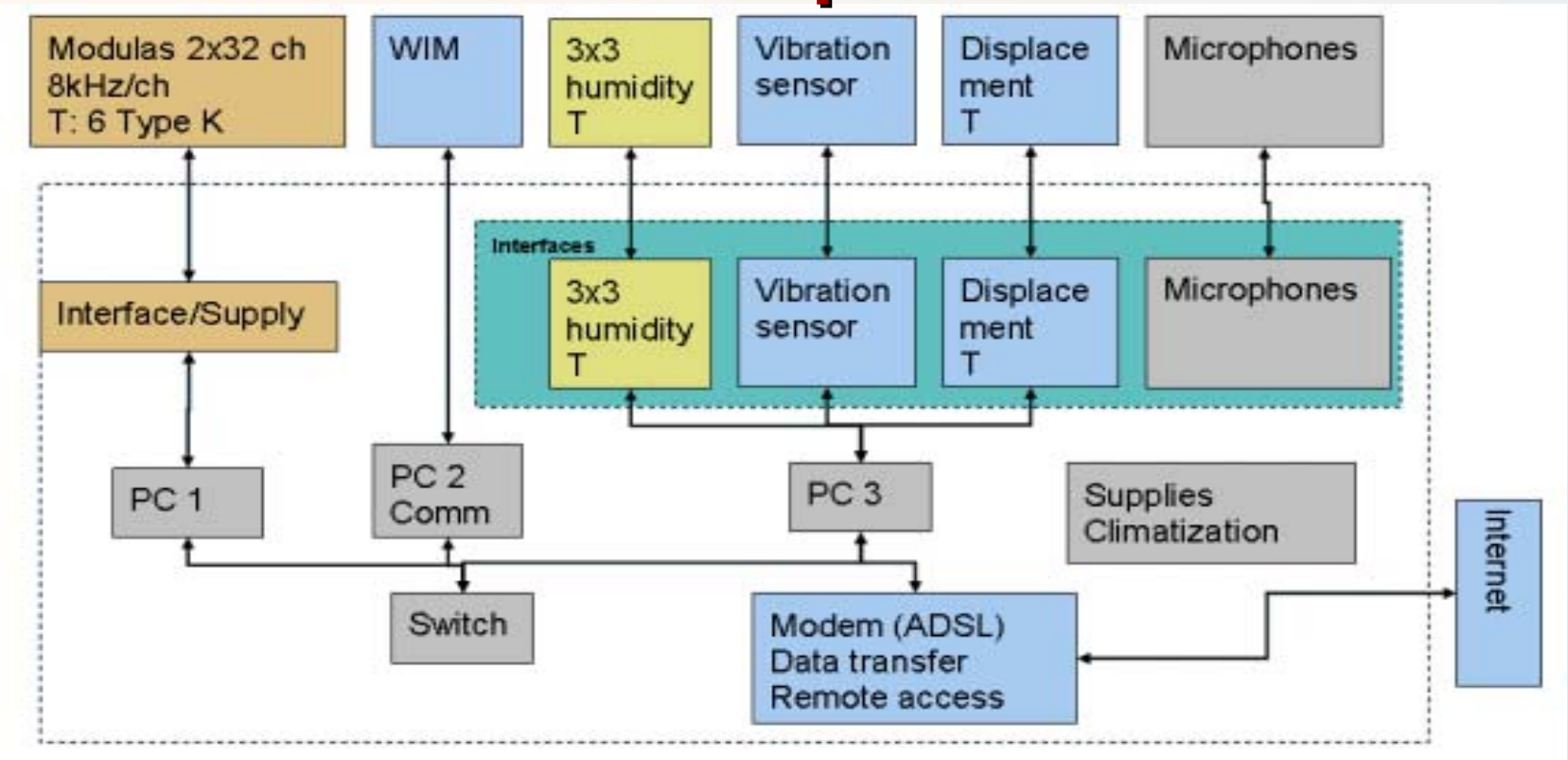
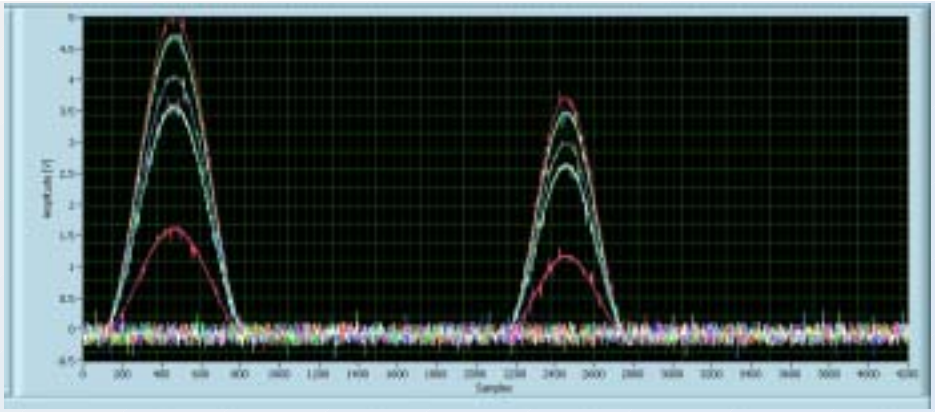
Data Acquisition

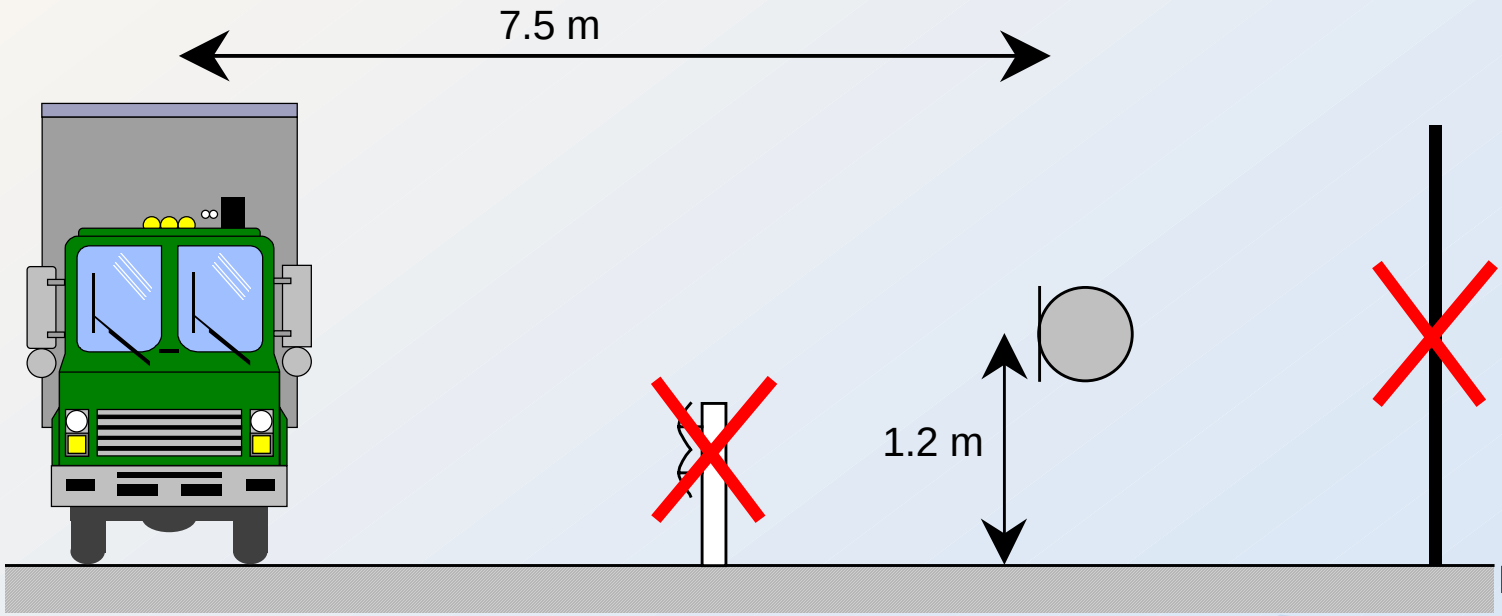




Acoustic Measurements: Goal

Kurt Heutschi, EMPA, Acoustics (177)

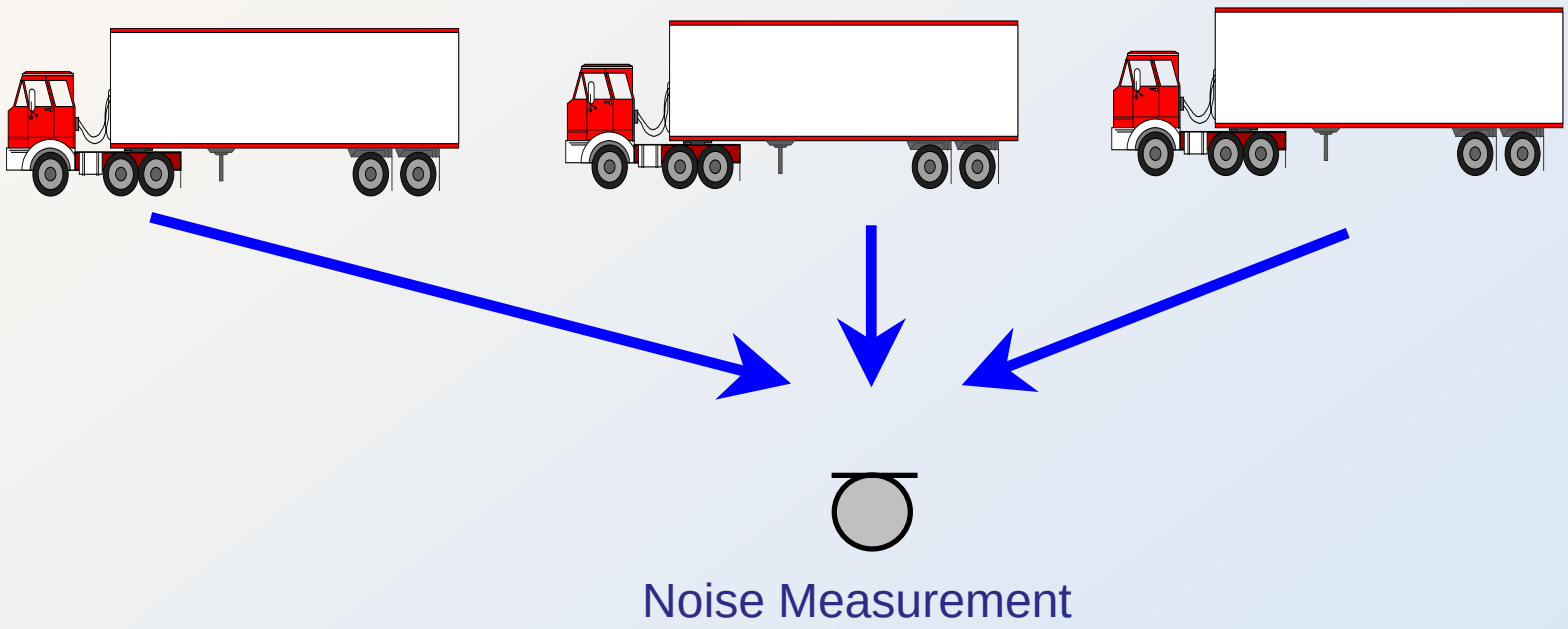
- **Detect** Single Truck Passings
  - Geometrie: EN ISO 11819-1 Acoustics – Meas. of influence of road surfaces on traffic noise – Part 1: Statistical Pass-By method, 1997.
  - Signal characteristic: max. passing level
- **Statistical** study of meas. data as function of traffic (6 dB-down rule).
- **Verification** of the 6 dB-down rule (simulation)



Challenge: Single Truck Passings

Kurt Heutschi, EMPA, Acoustics (177)

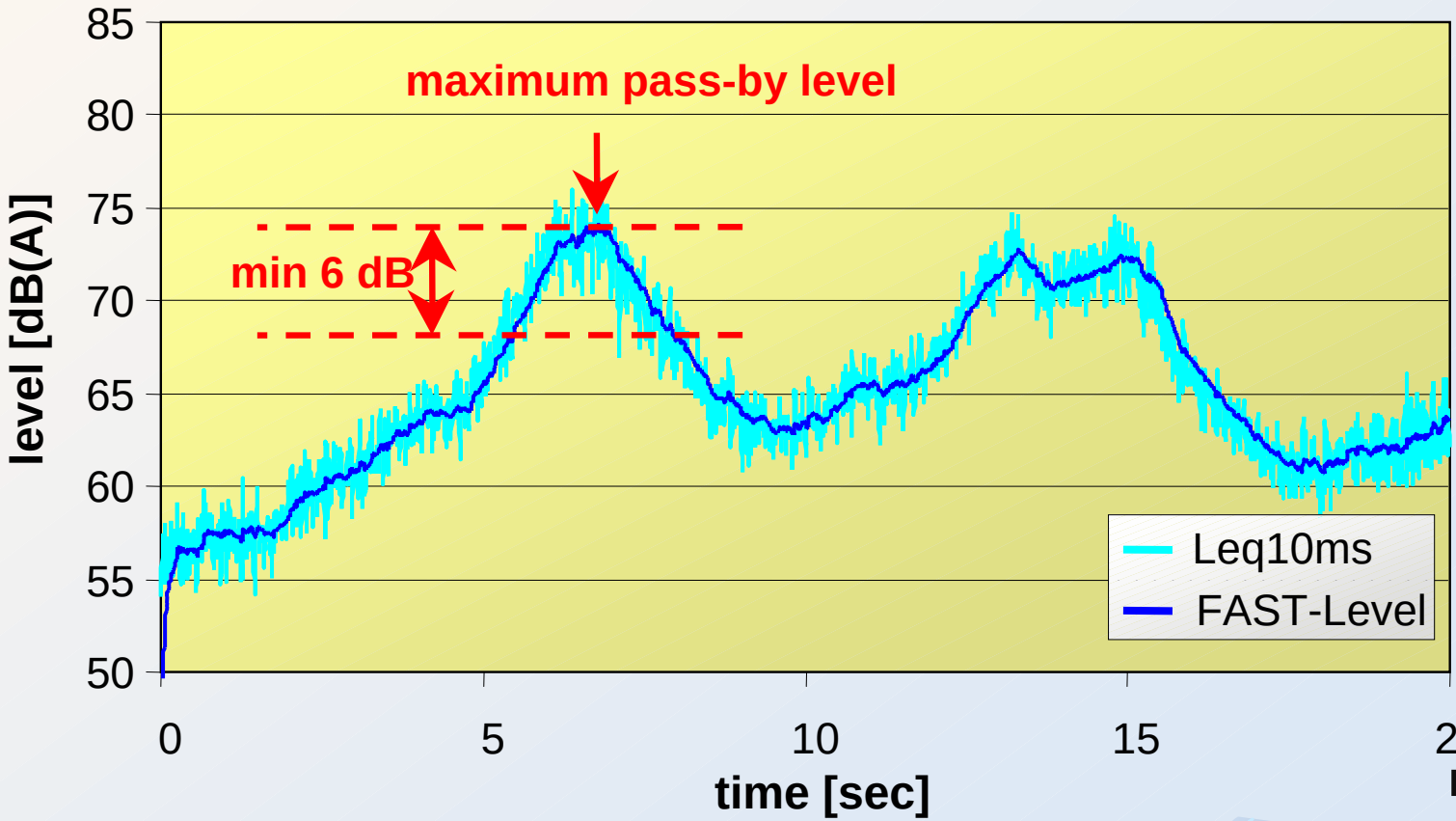
- Acoustic „disturbance“ of measurement by other trucks



6dB down-Rule EN ISO 11819-1

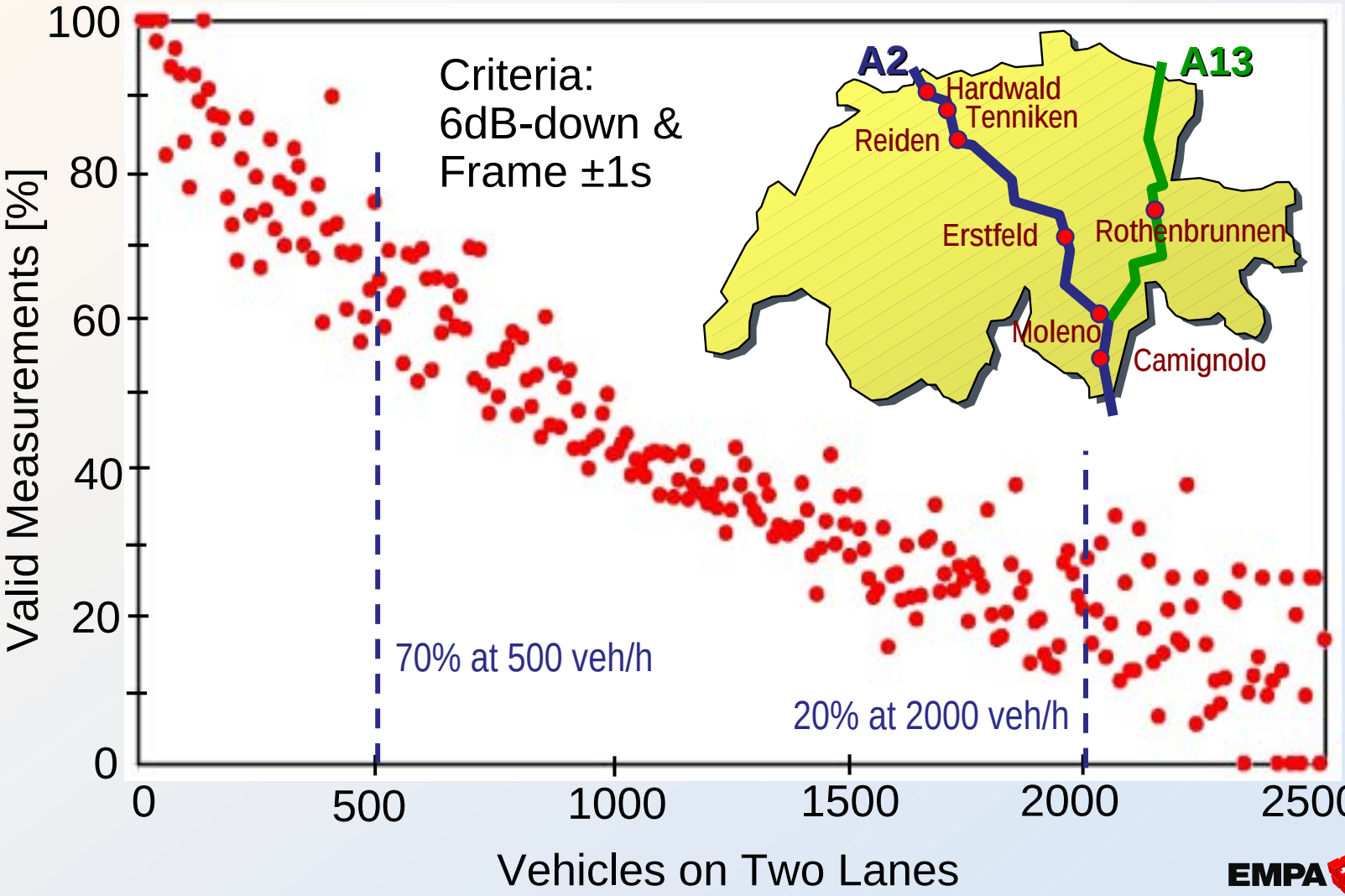
Kurt Heutschi, EMPA, Acoustics (177)

- Problem: Not a 100% guarantee that each vehicle will be measured



SAEFL Noise Monitoring Project

Kurt Heutschi, EMPA, Acoustics (177), Irène Schlachter (SAEFL)

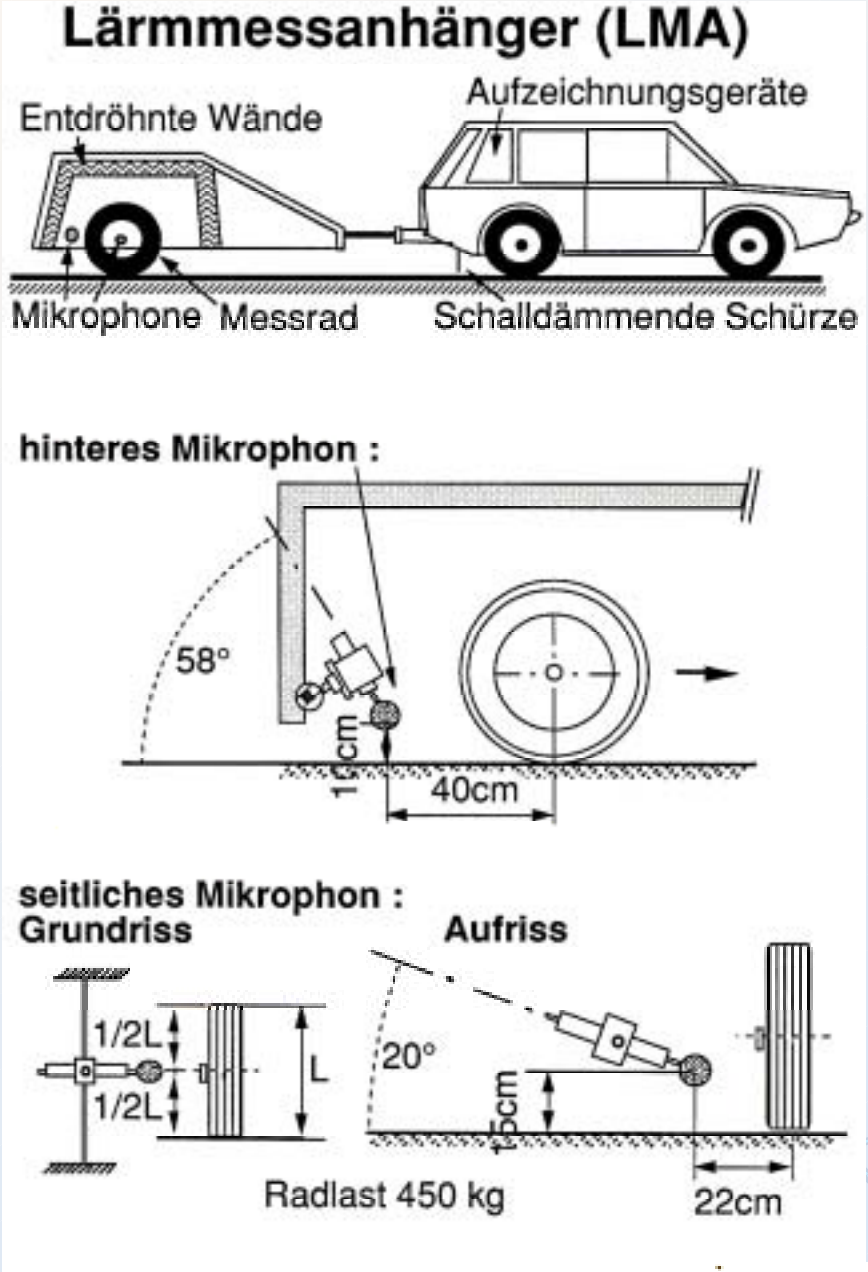


Porous Asphalt

Noise properties of different Pavement Surfaces (Lärmverhalten verschiedener Belagsoberflächen)

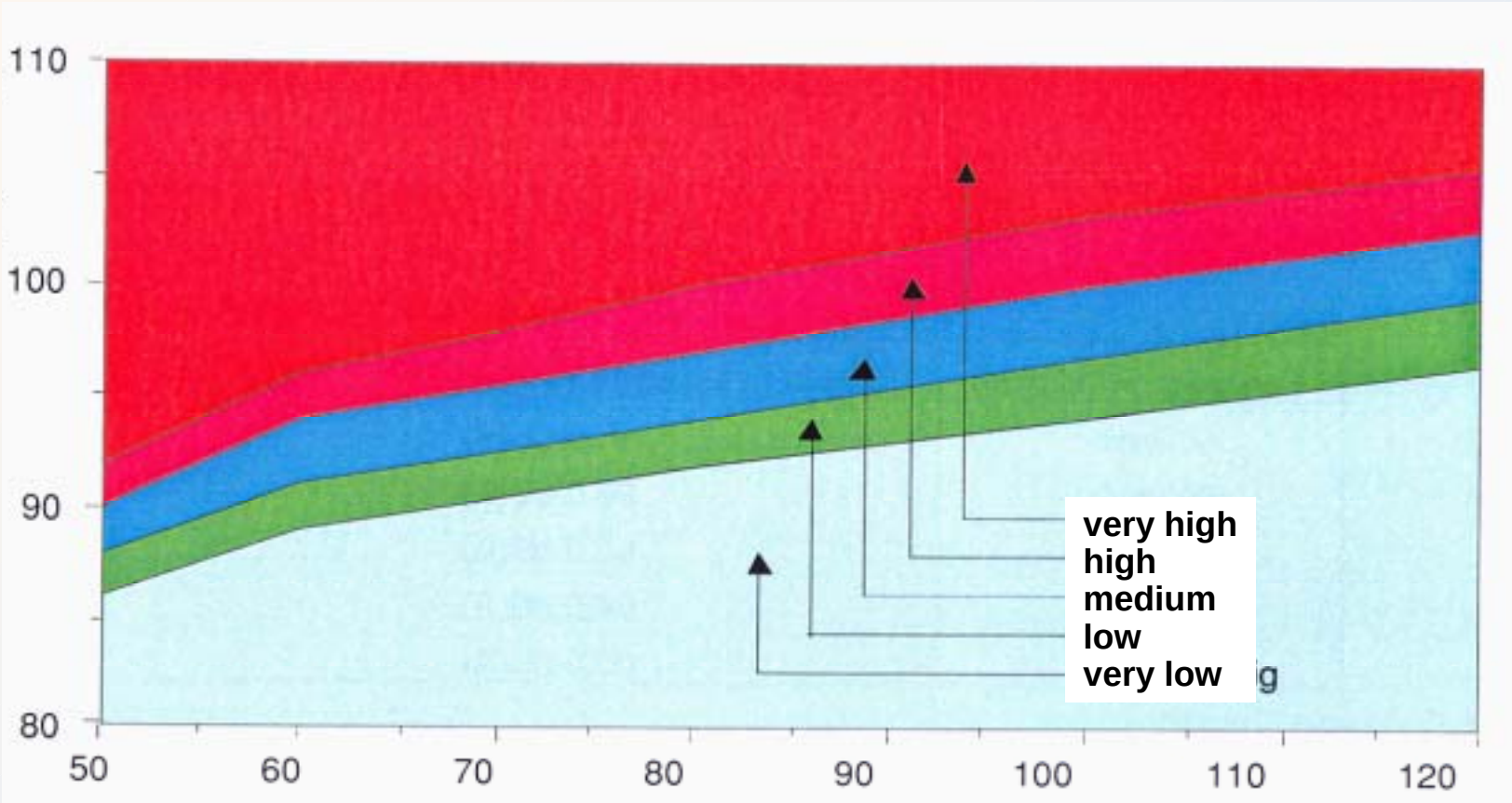
Shojaati, M.; Blötz, A.; Horat, M.; Caprez, M. (2000)

20 different pavements.
Standardized European PIARC/AIPCR-Tire (4 Length Threads);
Wheel Load ca. 450 kg and Tire Pressure 2.3bar.



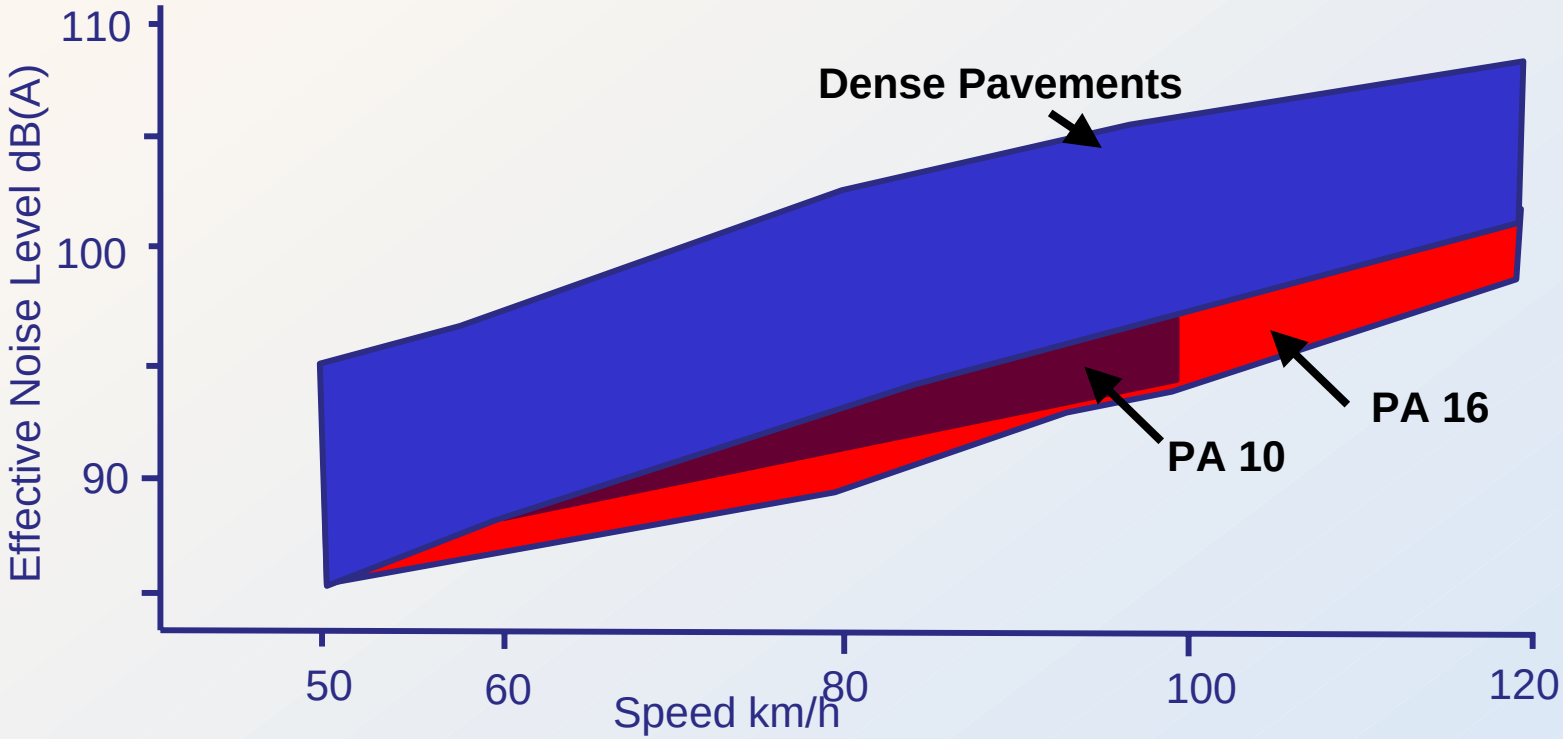
Empirical Noise-Assessment Scheme

M. Horat, IVT, ETH, 1990



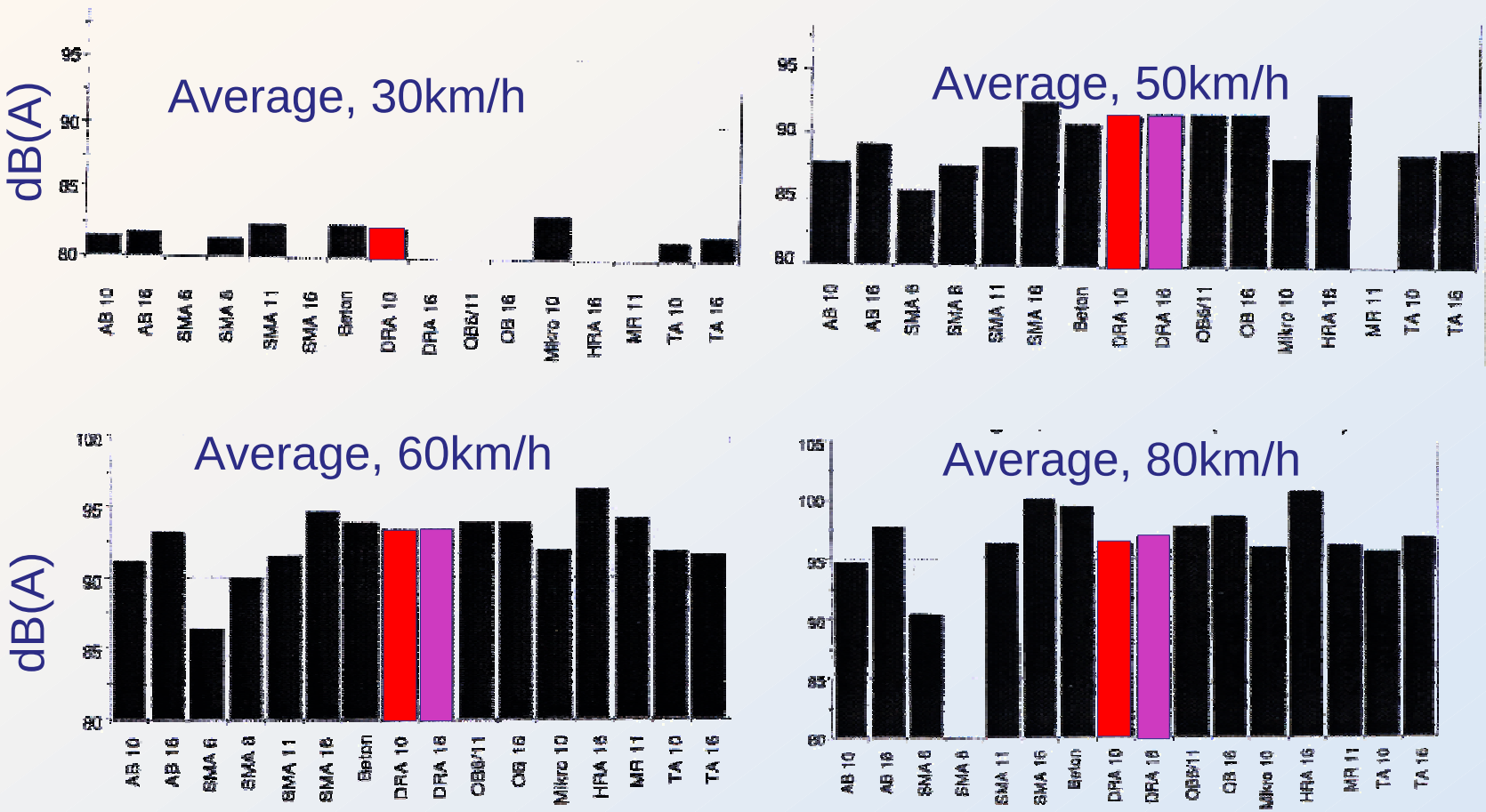
Influence of Speed

Köster, H., Isenring, T. (1990)



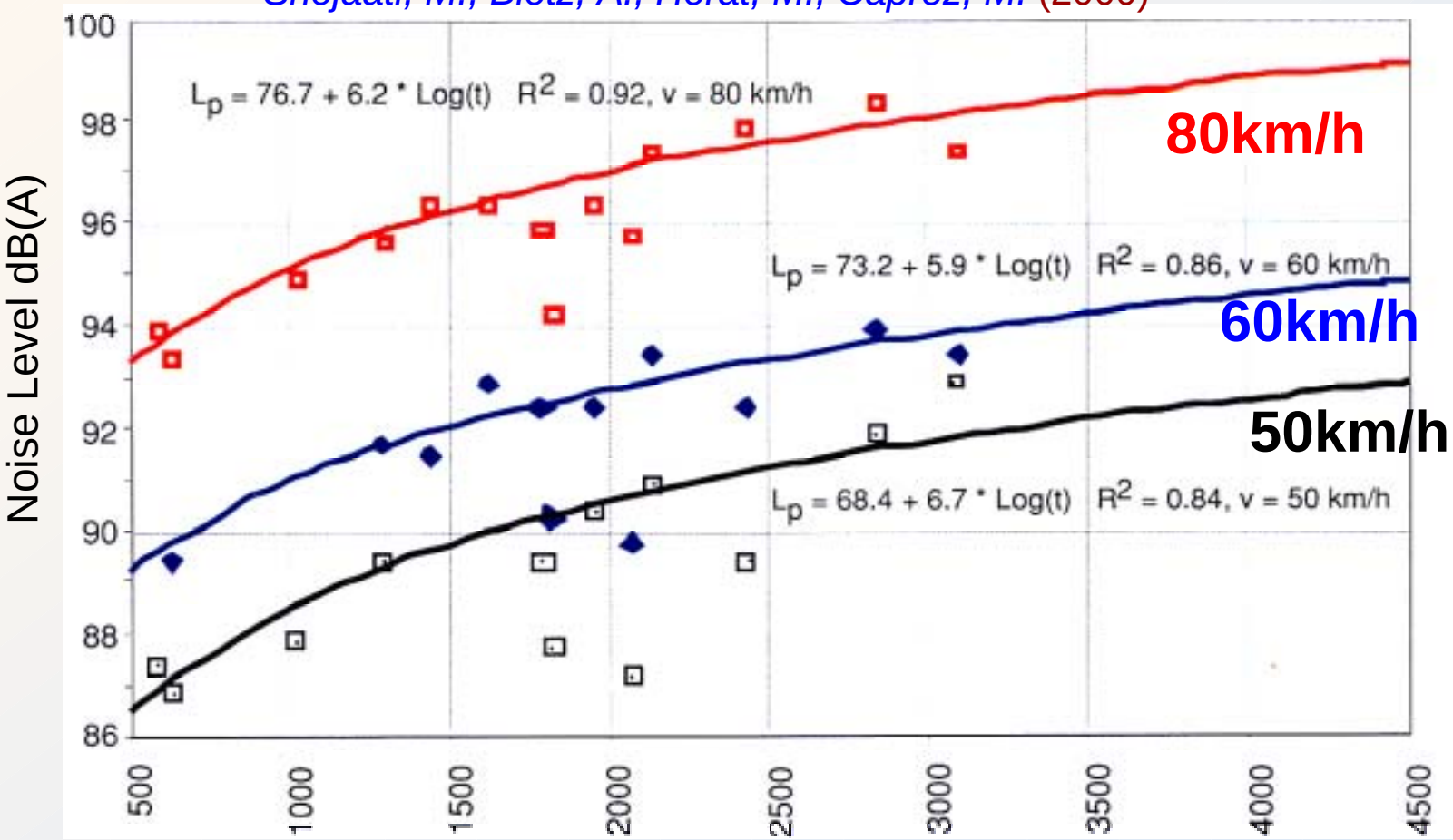
Influence of Speed

Shojaati, M.; Blötz, A.; Horat, M.; Caprez, M. (2000)



Noise Level vs. Age for DRA16

Shojaati, M.; Blötz, A.; Horat, M.; Caprez, M. (2000)



80 km/h: Lp = 76.7 + 6.2*Log(t) ; R^2=0.92
60 km/h: Lp = 73.2 + 5.9*Log(t) ; R^2=0.86
50 km/h: Lp = 68.4 + 6.7*Log(t) ; R^2=0.84 (t in days)

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Influence of Temperature

Shojaati, M.; Blötz, A.; Horat, M.; Caprez, M. (2000)

$$P(T)=P(0°C) + a\,T$$

P(T): Noise Level at Temp. T in dB(A)
P(0°C): Noise Level at °=C in dB(A)
a: Temperature Coefficient in dB(A)/°C
T: Reference Temp. in the Sun

Pavement Type	Temp. Coefficient dB(A)/°C
AC10 new	0.06
AC10 old	0.03
SMA neu	0.08
HRA old	0.02
DRA 10 old	0.08
DRA 16 old	0.06
Concrete old	0.03

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Summary of Some Results

Shojaati, M.; Blötz, A.; Horat, M.; Caprez, M. (2000)

- Relevant Rolling noise: Private cars 40..50km/h; Trucks 60..70km/h
- Rolling noise increases logarithmic with vehicle speed
- Aggregate size: The smaller the aggregate the lower the rolling noise (not so much for D>11mm)
- Porous asphalt reduces noise, but there is clogging etc
- Increasing temp reduces noise. Porous asphalt reacts stonger on tmperatures. The older the pavements the less influnce has temperature

Noise Reduction after Installation Canton Vaud (VD)

B. Graf, E. Simond

Measured in houses in a distance of 20 to 150 m of the motorway (from 5 to 10 measurement points per construction site)

Date de pose	Lieu	Atténuation du bruit après la pose du DRA [dBA]
1991	Pertit	4.1 ... 6.2
1993	Morges	5.4 ... 8.6
1999	Lonay	6.2 ... 8.4
1999	Bex	4.5 ... 6.0 *

Twin Layer between Vevey and Glion (A9) in 2000

B. Graf, E. Simond

5 cm DRAT22 (Bind. Cont: 3.9%) and 2.5 cm DRA8 (Bind. Cont: 5.0%) paved hot on hot.

Observations

- Drainage capability increased by 25..30%
- Noise reduction by ~1dB (compared to single layer)

Conclusions Porous Asphalt VD

B. Graf, E. Simond

- Generally positive **15 year experience.** Will be further used for roads below **600m** above sea level
- People react very positive and communities ask more and more porous asphalt
- Noise reduction on motorways **(~6 dBA**), improvement can be maintained during **9** years.
- Porous asphalt ca be used on **bridges** without reduction of safety. there was no accident after more than 12 years on 17 bridges which could be attributed to the pavement.
- To avoid **loss of aggregate** one should not under-compact porous asphalt and not use Trinidad instead of PmB.

Heavy Duty Noise Reducing Aphaltic Plug Joints

Contact

Sivotha Hean

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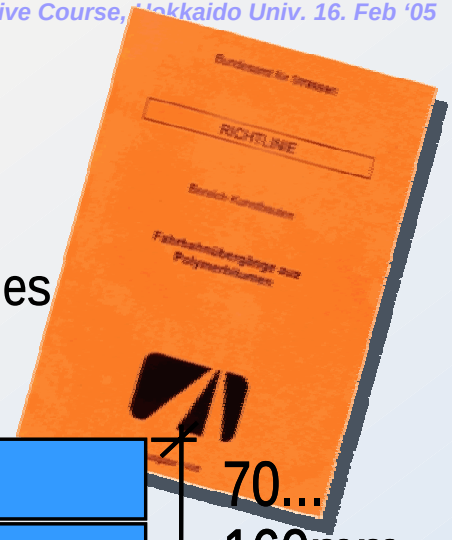
EMPA

Asphaltic Plug Joints APJ



ASTRA Guidelines

EMPA

General APJ Requirements

- **Durable** (e.g. Temperature Resistant)
- **Waterproof** (Structure Protection)
- **Quasi-Static Dilatations** & **Dynamic Traffic Loads** without
  - Loss of Adhesion
  - Low Temperature & Fatigue Cracks
  - Loss of Stability in Summer
- **Economics** & **Easy Application**

APJ Damage Examples

Displacements: Summer

Aggregate Loss

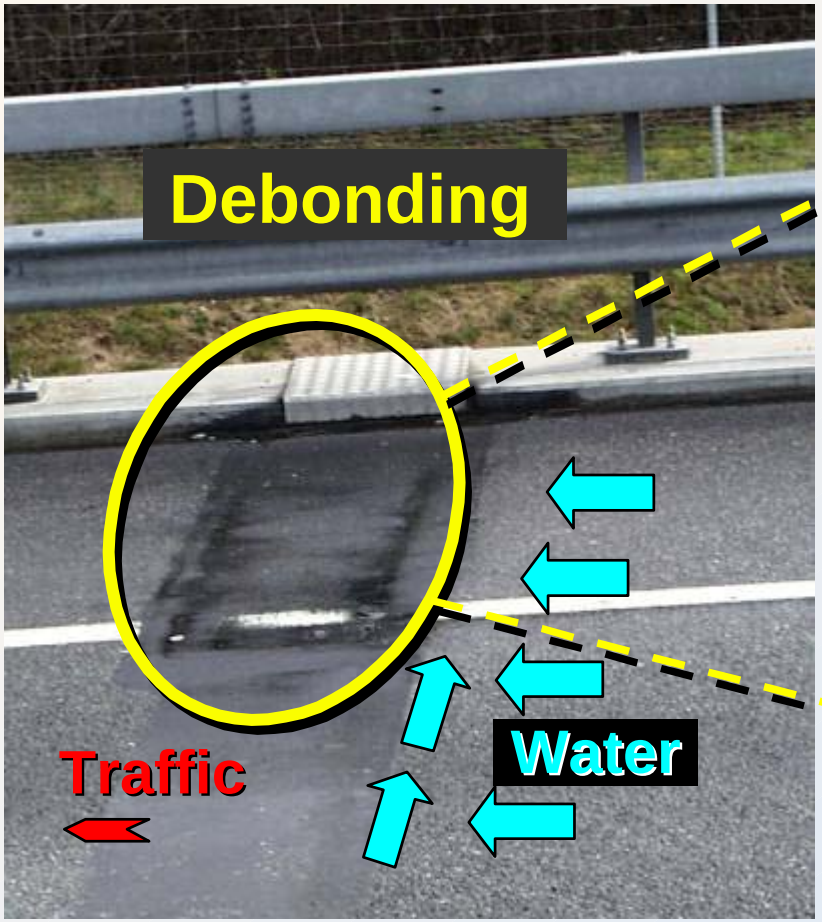
Crack: Winter

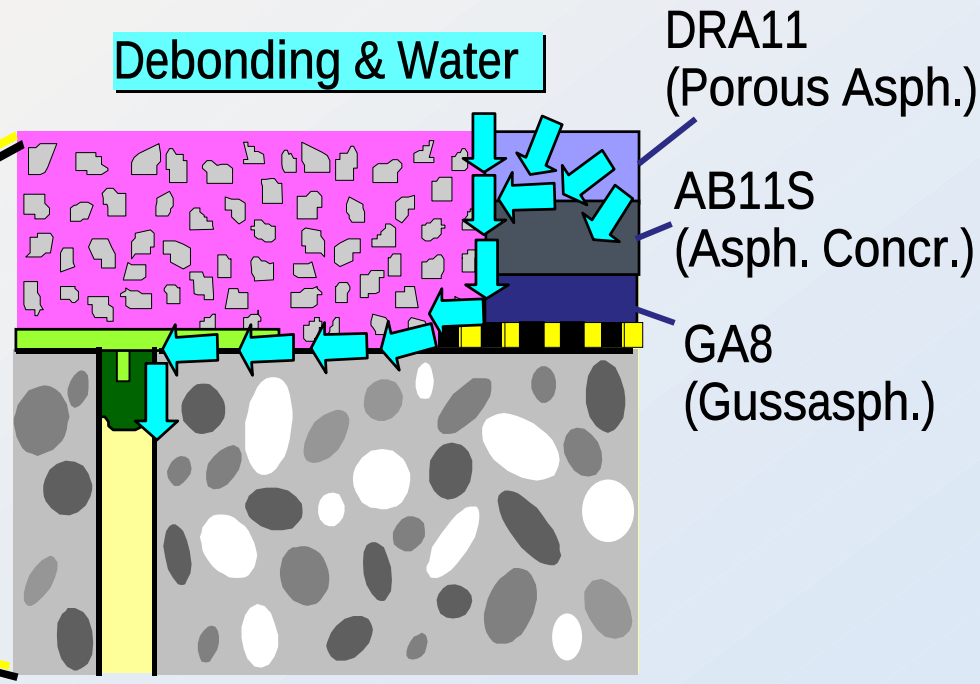
Debonding: Winter →

APJ/Pavement Interface Requirements (ASTRA Guide Line) to prevent Water Penetration

Adhesion Strength [MPa]:	no req. yet
Air Void Content of Adjacent Pavement [Vol-%]:	<6
Otherwise add Pavement Patch (e.g. GA) of Width [m]:	1

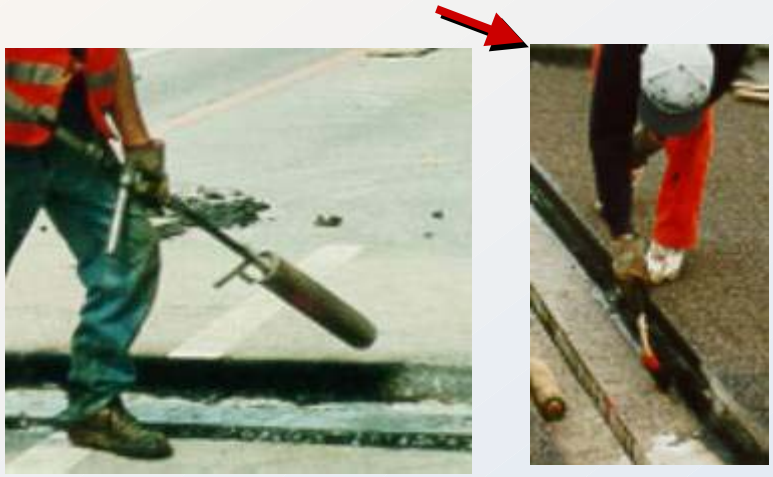
Debonding APJ - Porous Asphalt

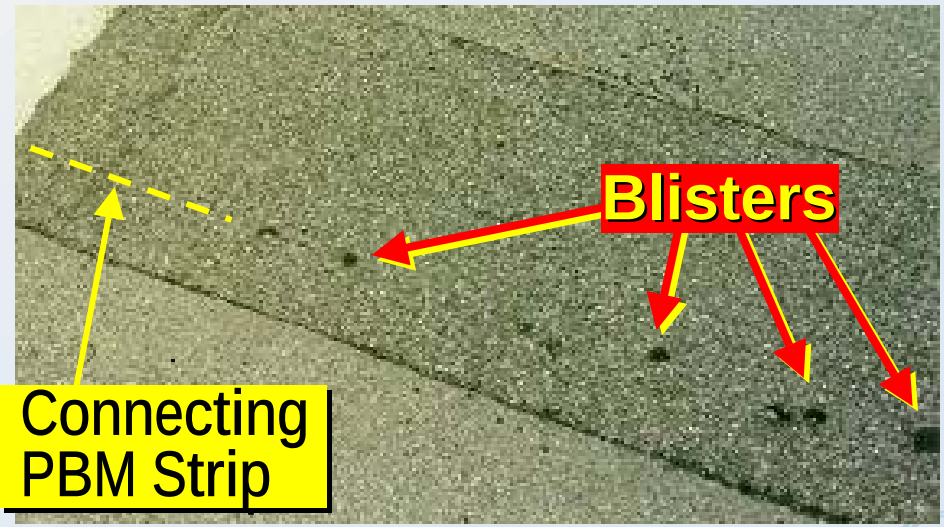




APJ/GA Contact Surface Activation

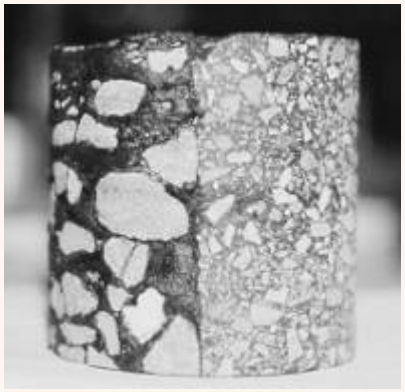
- Pre-heating is important
- Use hot-air fan (blows away weak zones)
- Don't overheat or burn connecting PBM-strip
- Don't drain away the PBM binder
- Don't use bonding agents with solvents

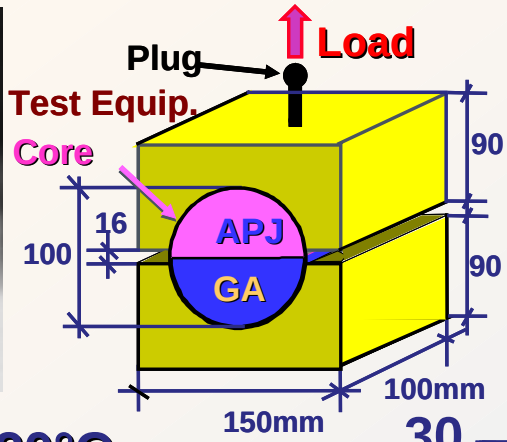




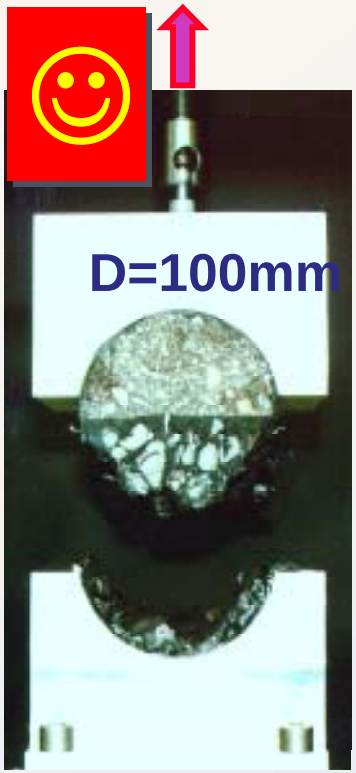
Debonding...Water Penetration...Blisters

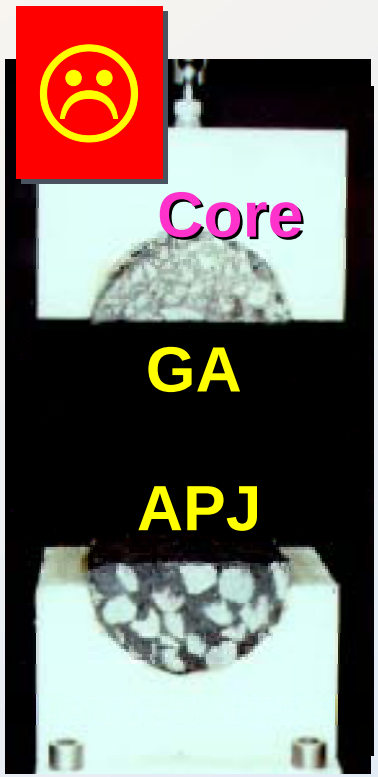
Adhesion Testing

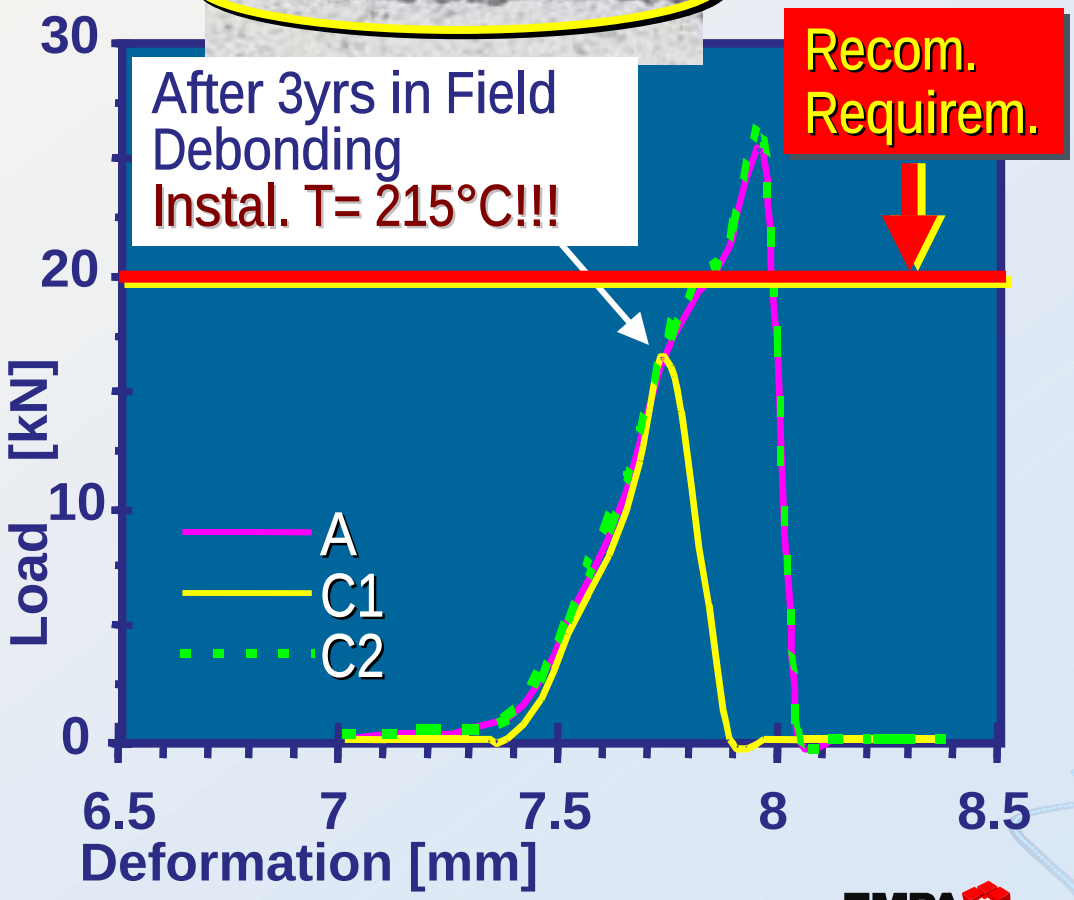




Test Temp.: -20°C
Speed: 10mm/min

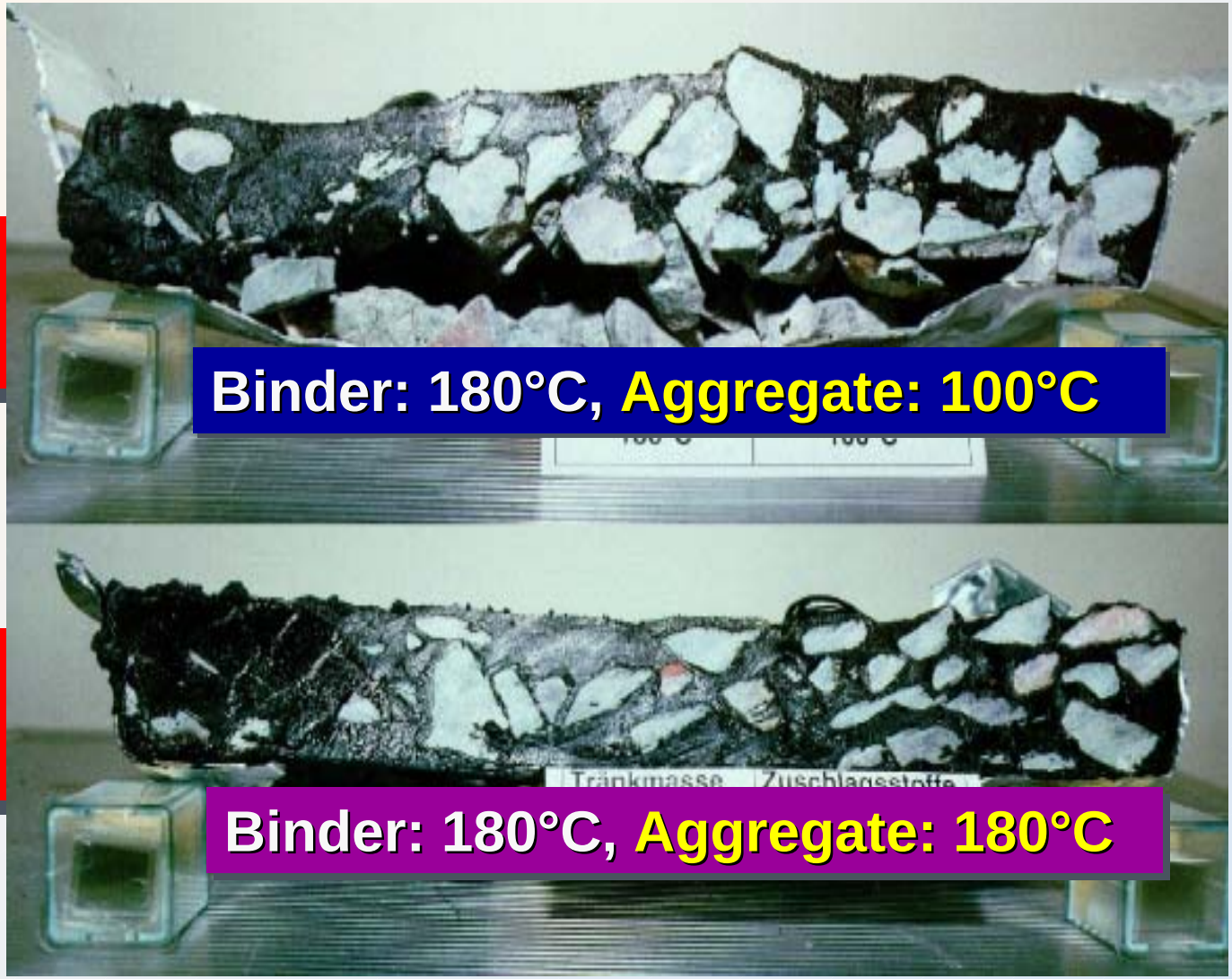






EMPA

Adhesion: Binder/Aggregate

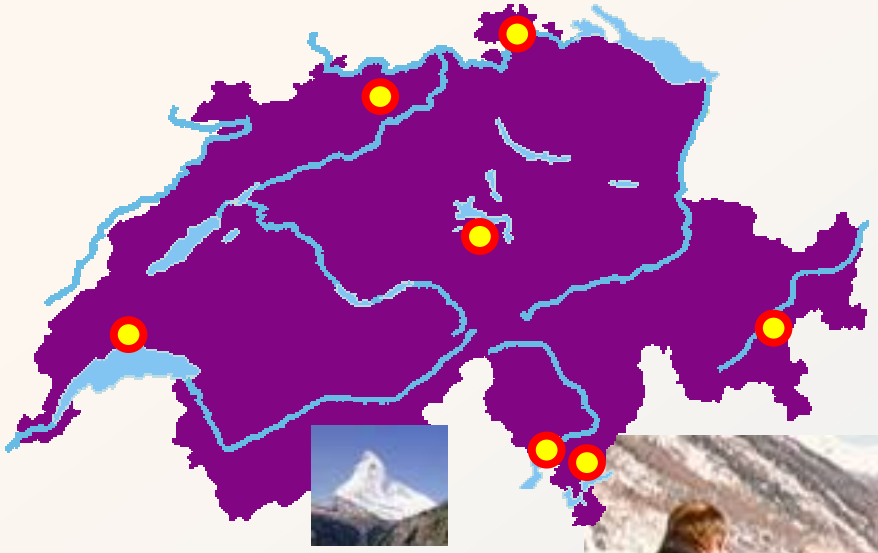


Heating the binder

Overheating the binder led to a drastic degradation of the polymer

- Don't use the heater without oil jacket or temperature and stirrer control !!!

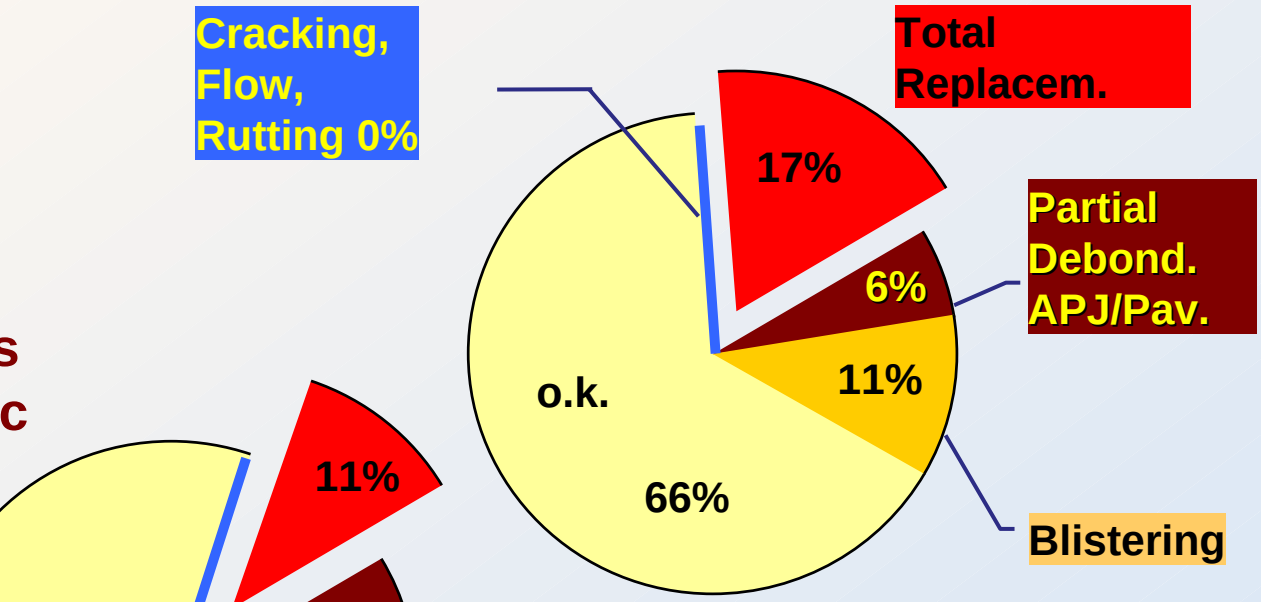
APJ Visual Inspect. @ 2&5 yrs



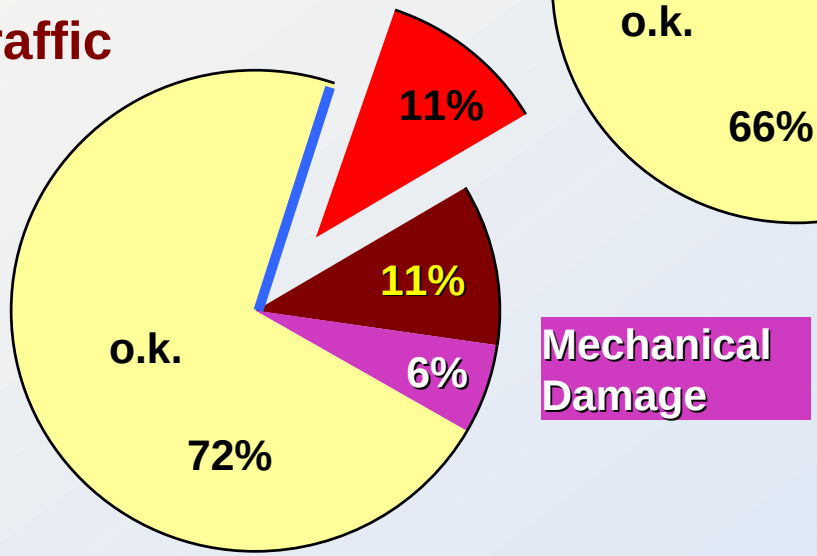
Bridges:	**7**
APJ:	**18**
APJ-Systems:	**4**

Results Inspections after 2 years

APJ Distress on the Sidewalk



APJ Distress on the Traffic Lanes



Findings

- **Swiss ASTRA Guidelines** are suited to detect and eliminate inadequate materials and systems
- **Lateral water accumulation** can destroy APJ / GA adhesion in summer and promote ice-induced debonding in winter
- **Adhesion strength** at –20°C according to ASTRA-guidelines should exceed 2.0 N/mm^2
- **Bonding agents** with organic solvents do not improve adhesion; evaporation may promote debonding and blistering
- Don't use **the heater** without oil jacket or temperature and stirrer control
- **Optimal installation temperature:** Binder 180°C and aggregates 180...190°C

Thank You

2008 ISAP Conference
Asphalt Pavements & Environment, Zurich

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