High Performance – What Does that Mean?

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High Performance Means:

- Safe
  - Layout & Geometry of Road
  - Skid Resistance
  - Splash & Spray
  - Surface Damage
    - Ruts
    - Loose Stones
    - Potholes
  - Ice-Phobic
  - Visibility
    - Glow in the Dark
    - Reflective in the Dark
    - Glare Dimming
  - Non Hazardous During
    - Use
    - Construction
    - Maintenance
    - Demolition
    - Recycling
    - Disposal
High Performance Means:

- Leave NO Problems!
- Saving Material Resources
  - Recycling (RAP)
  - Marginal Materials
  - Re-Use of Post-Consumer Mater.
  - Substitutes of components

High performance only possible if:

- **Description & understanding** of materials is clear
- Components are **reproducible**, i.e. RAP ≠ RAP, Tire Rub. ≠ Tire Rub. !!
- **Interaction** between all components is understood (Chem & Phys.)
- **Lab tests & assumptions** are really relevant for new mixture (**Don't Extrapolate !!!**)
- **Statistical validation & error analysis** are made
- **Range of application** is known.
- Lab performance **validated** w. field performance (long term!!)
  Lab-Field Dilemma ➔ APT (Load, Weather, Aging)
Lab-Field RAP-Validation

ACT16/AC11S: 600k loads (4.3Mio ESALs), RAP-pavm. more cracks & rutting than control
ACT22S: 400k loads (2.8Mio ESALs), RAP-pavm. more cracks & slightly more rutting

High Performance Means

Safe

Sustainable

Recycling (RAP) Pitfalls:

Multiple Recycling:
Example 60% RAP: 13% of 1st RAP is left after 4th Cycle!

100% Recycling:
- Don't expect performance identical to original mixture! \( \Rightarrow \) Material change!

Rejuvenation:
- Don't expect mixture identical to the original one! \( \Rightarrow \) Material change!

Reproduce RAP in the Lab:
- Mineral aggregates damage by milling/crushing difficult to simulate in the laboratory
- Aging in the field takes too much time
  \( \Rightarrow \) Lab simulation ignores effect of moisture, frost, UV, diffusion, mechanical loading
High Performance Means

- Safe
- Sustainable

Saving Material Resources

- Recycling
- Marginal Materials
- Re-Use of Post-Consumer Materials
- Substitutes

Post-Consumer Materials: "Waste"

- Roofing Shingles
- Tire Scraps
- Glass

But Be Careful:

Roads are no Dumping Place for Waste!
Linear Landfill = High Risk & Risk for RAP Quality!!
Use Non-Recyclables only to Improve Roads!
High Performance Means

- Saving Material Resources
  - Recycling
  - Marginal Materials
  - Re-Use of Non-Recyclables
  - Substitutes

- Saving Energy
  - Cold/Warm (e.g. Foam Bit, Emuls)
  - Local Materials (Short Distances)

- No Greenhouse Gases (CO₂,..)

- Durable
  - Rutting
  - Cracking
  - Wear
  - Water, Weather & Climate
  - Chemicals
  - Aging, Degradation
  - Maturing, Curing

- Renaturable (Leave No Waste !)

**Safe**

**Sustainable**

Histograms: Bubble Size Distribution


Other Approaches

Foam w. Particles & other Agents NaHCO₃ (Baking Powder)

Pickering Emuls.

Foam Agent Bit

H₂O

Bit

Other Approaches

- Foam w. Particles & other Agents NaHCO₃
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- Pickering Emuls.

- Foam Agent Bit

- H₂O

- Bit
High Performance Means

- Safe
- Sustainable
- Affordable

During Whole Life Cycle
- Planning
- Construction
- Maintenance
- Rehabilitation
- Renaturation

Competitive to Alternatives
- Other Road Concepts
- Other Mobility Carriers (Intermodality)
- Other Social Needs
High Performance Means

- **Safe**
- **Sustainable**
- **Affordable**
- **Efficient**

- **Traffic Capacity**
- **Maintenance & Repair**
  - Fast
  - Local Materials
  - Few & Simple Machinery
  - **Induction Heating**
  - 0-Maintenance

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High Performance Means

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Traffic Capacity
- Fast
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- Induction Heating
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Construction
- All-Weather
- Error Tolerant
- Self Compaction
- Pre-Fabrication
- Robots

Robotic 3D-Reinforcement of Pavements

Displacement (mm)

0 10 20 30 40 50 60

Cycles

0 3000 6000

16-22mm Stones

Cyclic Tests

1Hz ±3kN
±2kN const.

No String

With String

Robotic 3D-Reinforcement of Pavements

"Jamming" Concept

Project leader Empa: Dr. Martin Arraigada, M., Abbasion ,S.
https://www.aramis.admin.ch/Gru nddaten/?ProjectID=40744&Sprache=de-CH
High Performance Means

- Safe
- Sustainable
- Affordable
- Efficient
- Adaptive, Smart

Intrinsic "Self"-…
- Deicing
- Opto-Active
  - Night-Shining
  - Sun-Glare Dimming
- Monitoring
- Healing regain functionality (after damage)
  - Cohesion
  - Adhesion
  - Rejuvenating
  - Re-Assembling
High Performance Means

- Road **condition** (rain, ice, snow, temperature)
- Road **over-stressing** & **over-straining**
  Road cries when suffering!!

**Adaptive, Smart**

- **Intrinsic "Self"**-…
  - Deicing
  - Opto-Active
    - Night-Shining
    - Sun-Glare Dimming
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  - Healing **regain functionality** (after damage)
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**"Spongy" Capsules**
- Trigger Particles for Release?

**Bi-Layer Capsules**
- RFID-MEMS

High Performance Means


Microcapsules μPCM-21:
Tetradecane C_{14}H_{30}
MeltingPt: 4 to 6°C
Melamine-Formaldehyde Shell

Adaptive, Smart

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- Monitoring
- Healing regain functionality (after damage)
  - Cohesion
  - Adhesion
  - Rejuvenating
  - Re-Assembling
- Adjusting Strength
  - Temp: PCM Phase Change Materials
  - Traffic (e.g. Platooning): Self-Reinforcing & EAM Electroactive Mat. (DEA Dielec. Elastomer Acutators)
High Performance Means

- Safe
- Sustainable
- Affordable
- Efficient
- Adaptive, Smart
- Multifunctional
- Resilient

- Energy Harvesting
- Climate Regulation
  - UHI Urban Heat Island (Evaporation, Water Circulation)
  - Rain Retention
- Cleaning Environment (Water Filter, NOX, CO₂ Absorption)
- Noise Reduction
- Protection (Waterproofing)
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- Flooding
- Rockfall
- Explosives
- Fire
Conclusions

Is High Performance of Materials Allone Enough?

No !!

The best performing Asphalt Material (in the lab) is useless, if it is

- a wrong conceptual choice
- based on unrealistic material design
- part of a poor structural concept
- not compatible with lower layers
- poorly placed & compacted
- not durable & not climate/weather resistant
- difficult to maintain
- not recyclable
- hazardous & fostering global warming
- jeopardizing driving safety
- not affordable & not available
- …

What counts is not only performance of "Asphalt Material" but of the "Whole Pavement"!!!
Thank You

High Performance on Asphalt Materials in Ottawa