Concrete Roads

The sustainable choice!

Erik Simonsen, Market Development, Ph.D.
Cementa AB/Heidelberg Cement

Contents:

- The situation in Sweden

- Presentation of a modern concrete road project, E4 Uppsala

- New concept for concrete road building

- Sustainability: Are we focusing on the right things?

  Examples: Fuel efficiency
  Particle emissions
  Lighting energy requirements

- Conclusions

CEMENTA
HEIDELBERGCEMENT Group

The situation in Sweden

Category	Length, km
State roads	98 400
Local roads	46 500
Private roads	200 000
=	344 900
Highways cat A	1 860
Highways cat B	360
=	2 220
Asphalt (cat A)	1793 (~ 96 %)
Concrete (cat A)	67 (~ 4 %)

?

CEMENTA
HEIDELBERGCEMENT Group

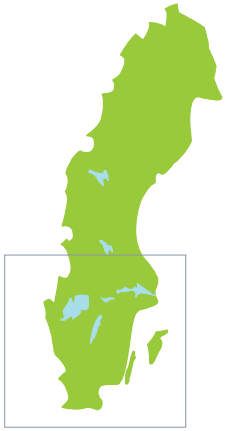
Misconception frequently heard

- Investment cost
- Difficult to construct/lay
- Difficult to maintain
- Energy requirements for cement/concrete
- Concrete is noisy
- etc…..
- etc….
- etc….

However modern concrete technology and life cycle analysis dispute this!

CEMENTA
HEIDELBERGCEMENT Group

Concrete roads in Sweden today



E4
Uppsala-Mehedeby
2006, 23 km

E4.65
Arlandavägen
1990, 2 km

E20
Eskilstuna-Arphus
1999, 14 km

E6/E20
Falkenberg, etapp I
1993, 15 km

Falkenberg, etapp II
1996, 13 km

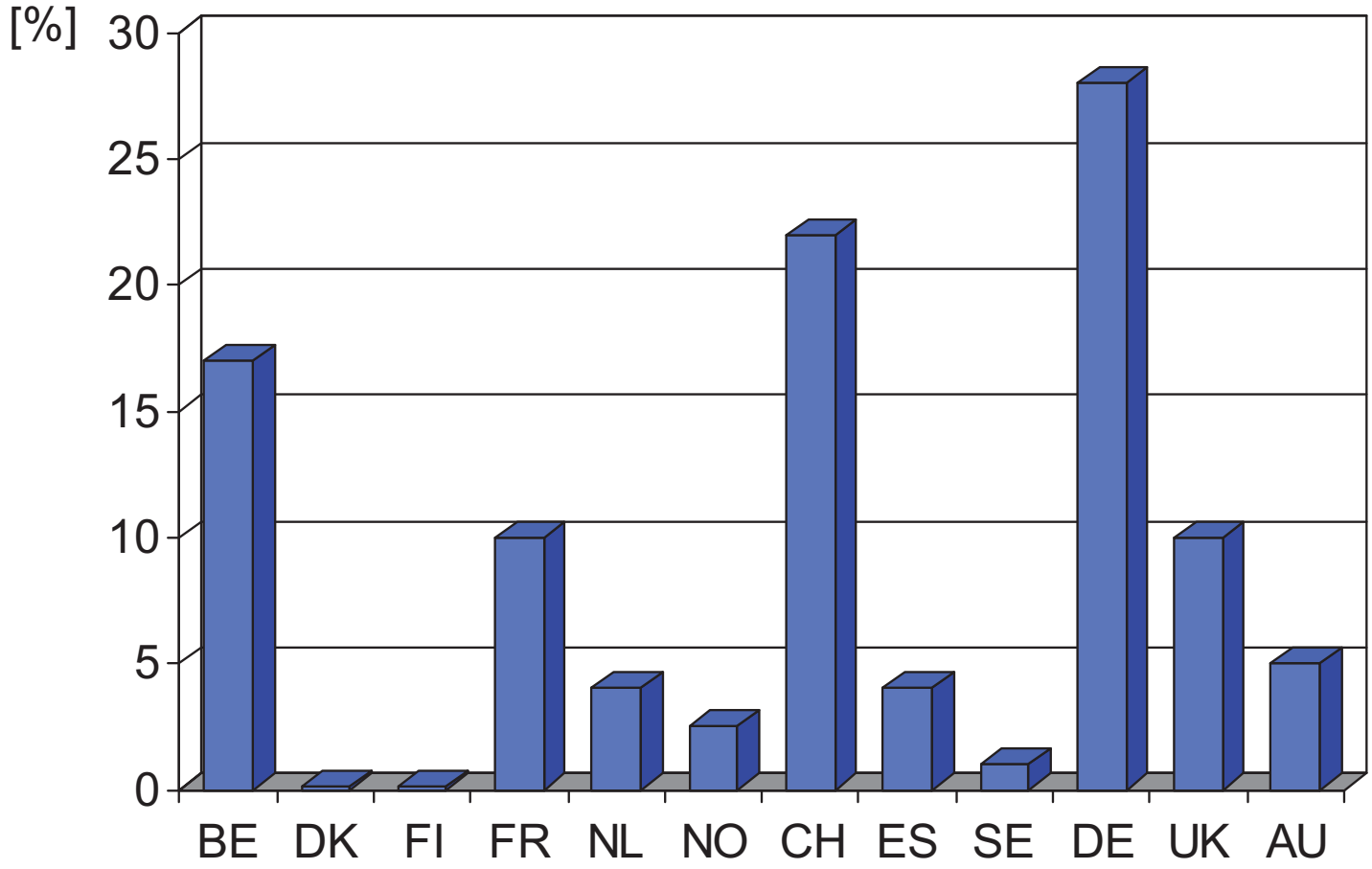
E4
Väla-Hyllinge
1978, 7 km
(Overlay with asphalt 2010)

E6
Malmö-Vellinge
1972, 12 km
(Overlay with asphalt 2009)

Total 86 km
(today 67 km)

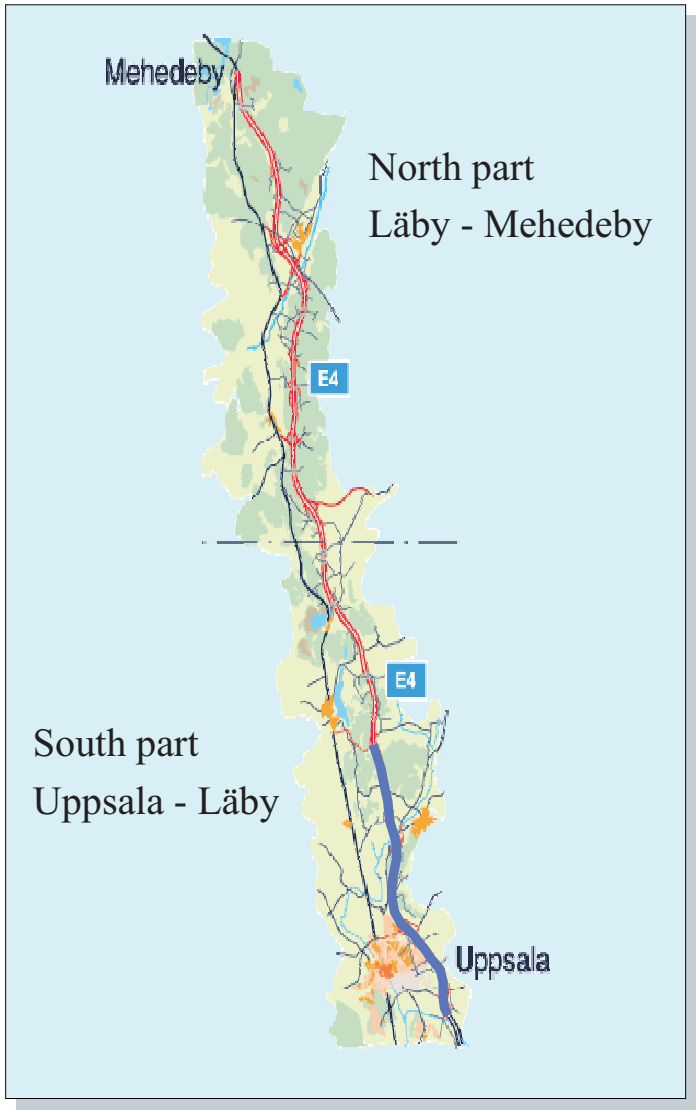
CEMENTA
HEIDELBERGCEMENT Group

“Current“ status of Concrete Pavements



Number of concrete roads in different European countries after European Commission (1999)

CEMENTA
HEIDELBERGCEMENT Group



Road E4 Uppsala – Mehedeby

Facts about the project:

Schedule: sep -2002 -- okt -2007

Road section: Motorway

Road length: 78 km (Concrete 23 km/Asphalt 55 km)

Concrete: 23 000 – 15 000 vehicles/day

Asphalt: 15 000 – 12 000 vehicles/day

Bridges: 102 st

Contractor:

- South part, Veidekke ASA
- North part, PEAB AB

Subcontractor for concrete, Eurovia Beton GmbH

CEMENTA
HEIDELBERGCEMENT Group

Facts about the concrete

E4 Uppsala - Mehedeby:

- Time: June – October 2006
- Concrete i both directions: 23 km
- Width: 9 m
- Thickness: 200 mm
- Speed capacity: 1,0-1,4 m/min
- Total surface: ca 420 000 m^2
- Concrete volume: ca 85 000 m^3

CEMENTA
HEIDELBERGCEMENT Group

Laying technology

Slipform paving and treatment of the road surface

Concrete surface

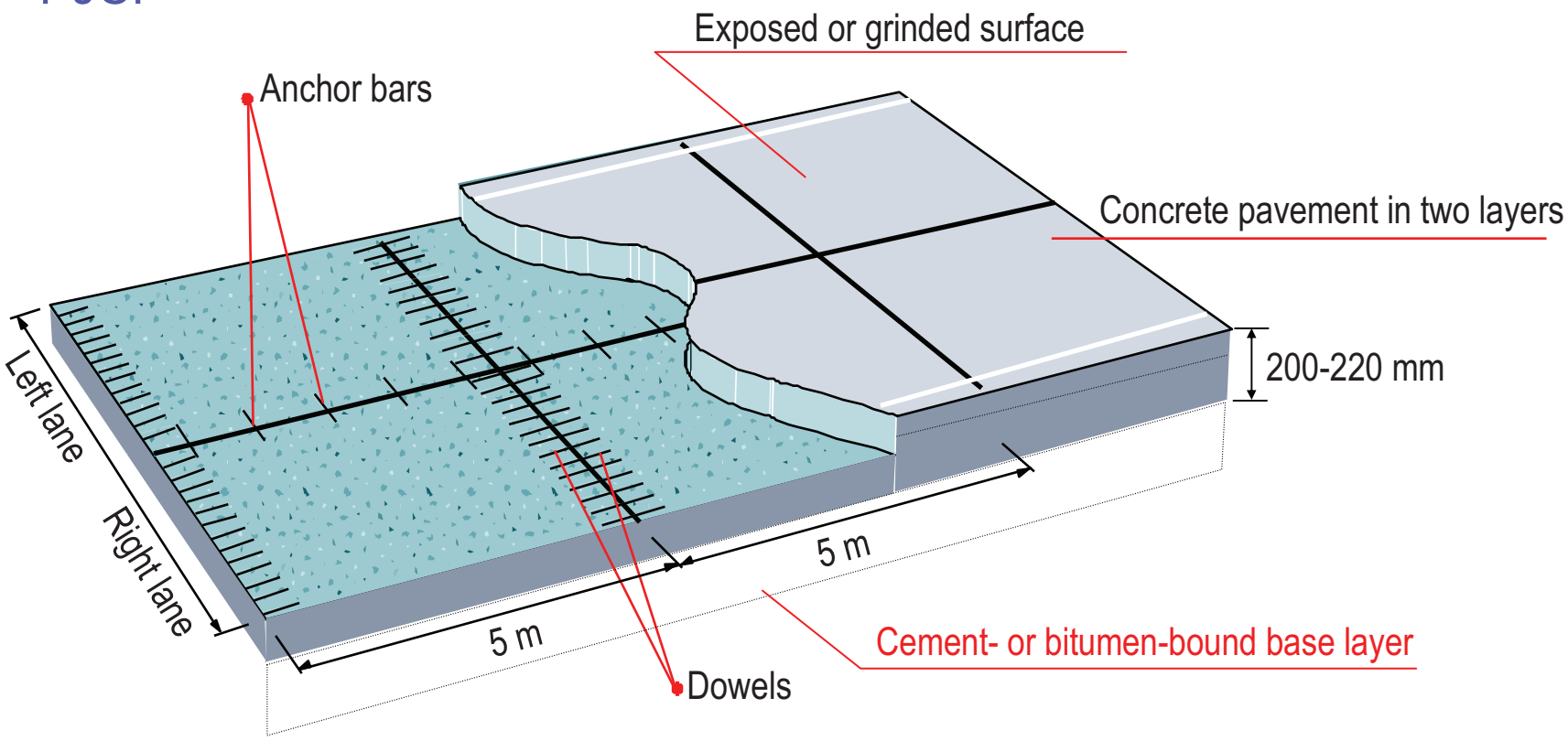
Exposed aggregate

Diamond grinded

CEMENTA
HEIDELBERGCEMENT Group

Concrete Roads in Sweden today

PJCP



CEMENTA
HEIDELBERGCEMENT Group

The situation for concrete roads in Sweden today.

- What type of concrete roads will be construced in the future?
- Where are our focus today?

CEMENTA
HEIDELBERGCEMENT Group

The traffic on Swedish motorways

75 - 95% of all traffic in right lane

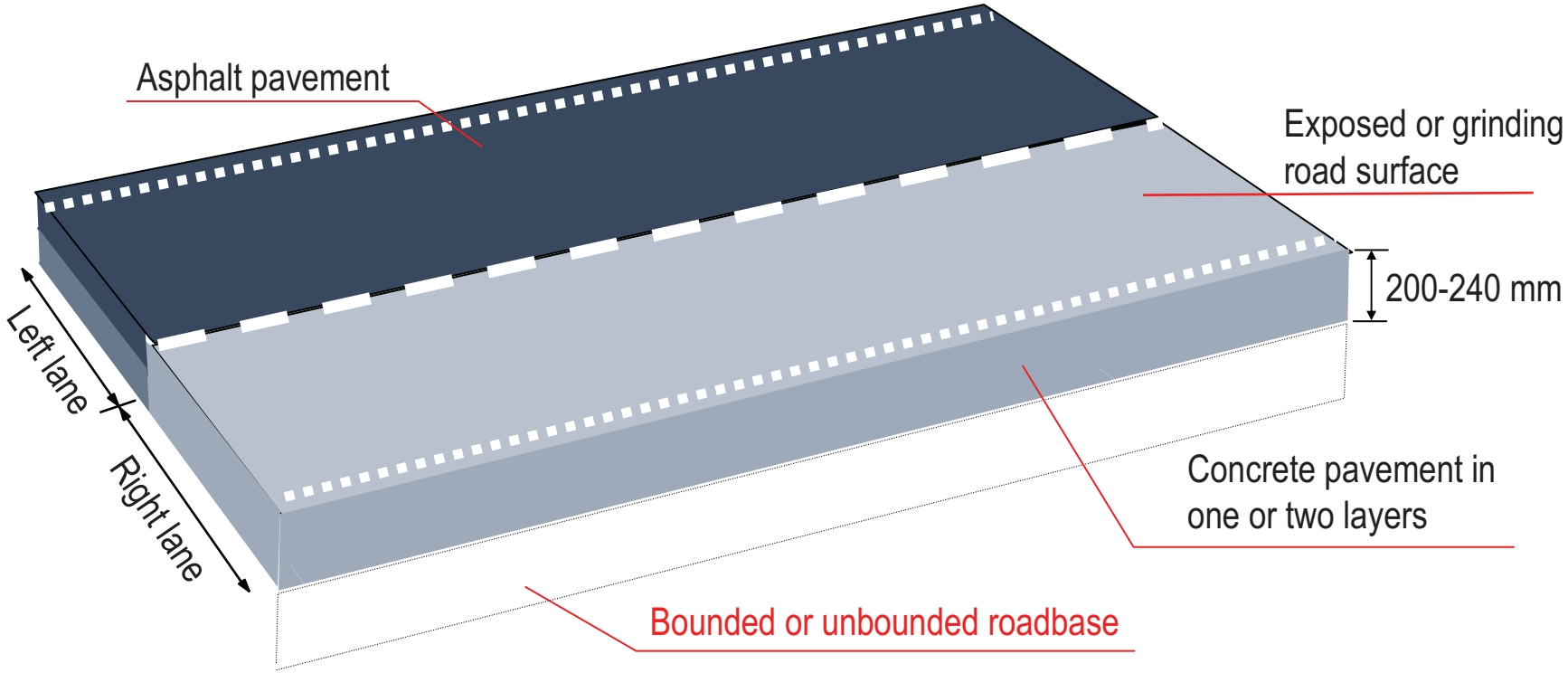
95 -100% of all heavy traffic in right lane

CEMENTA
HEIDELBERGCEMENT Group

Highways: A new concept for Sweden?

PJCP or CRCP?

Motorway



CEMENTA
HEIDELBERGCEMENT Group

Experience from other countrys

CEMENTA
HEIDELBERGCEMENT Group

Experience from other countrys

CEMENTA
HEIDELBERGCEMENT Group

Pilot project in Sweden 1988

E4 Södertälje

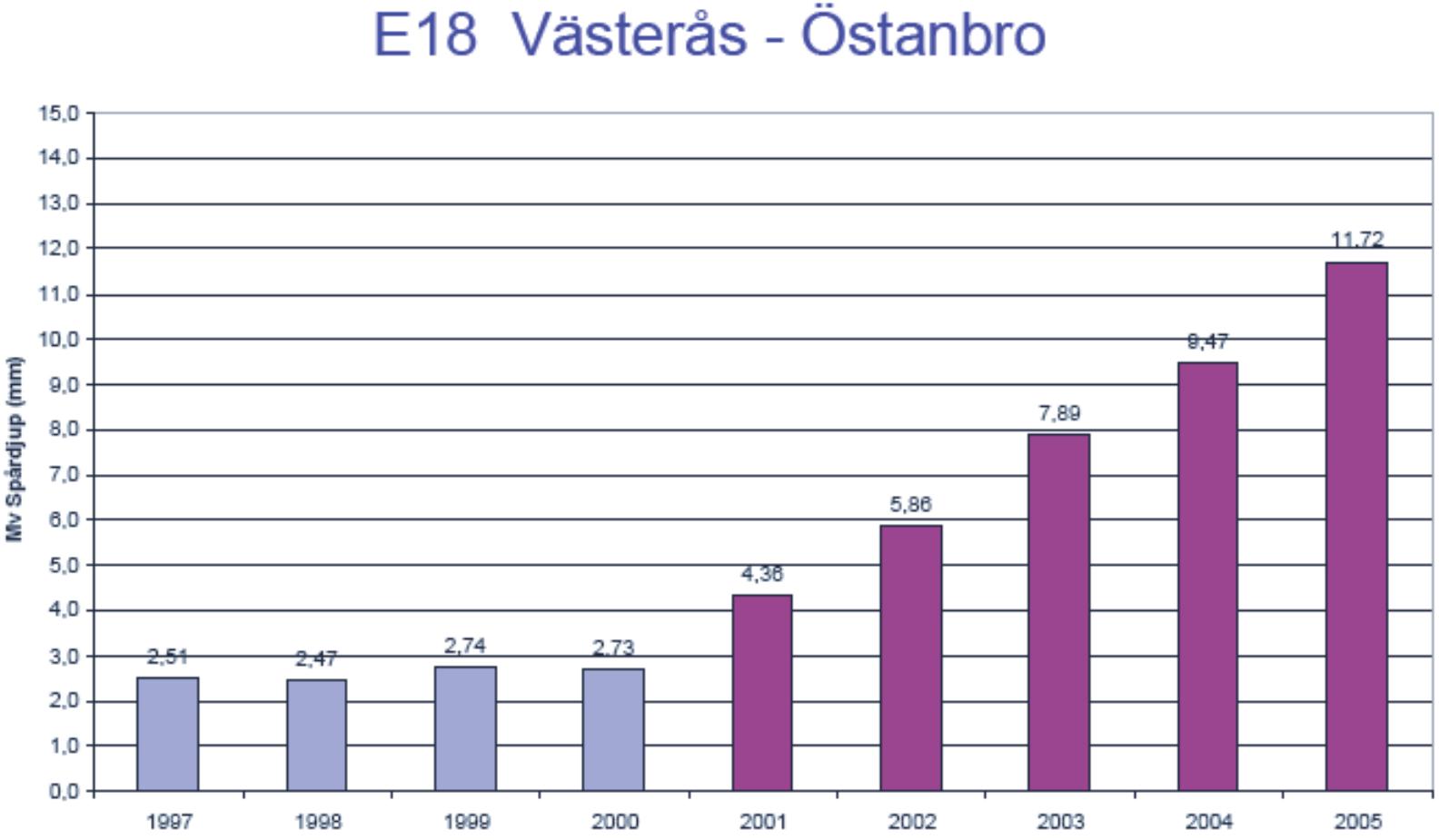
CEMENTA
HEIDELBERGCEMENT Group

Old 2 road lanes rebuilt to 2+1 road lanes

The effect of old pavement design and narrow traffic lanes!

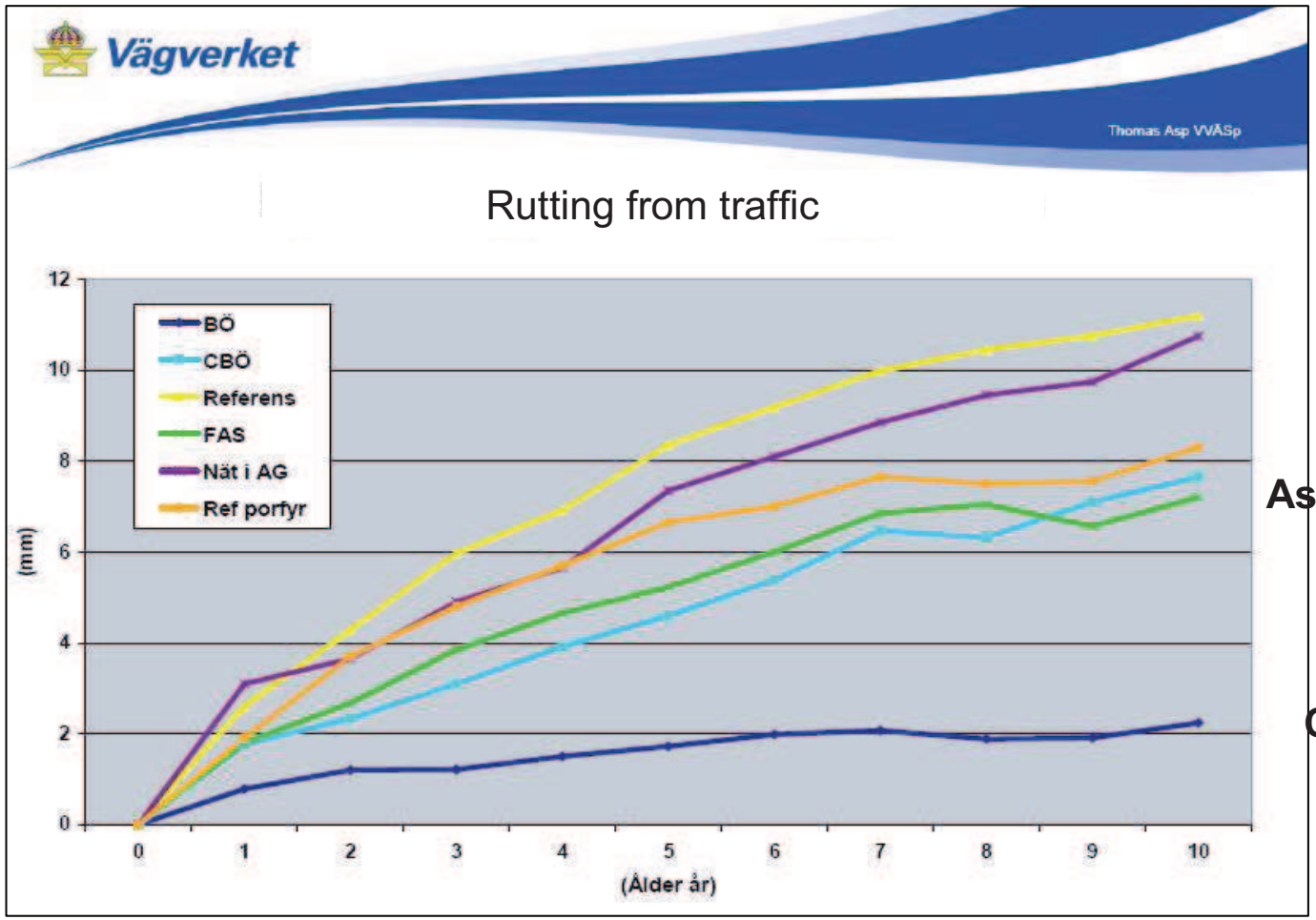
CEMENTA
HEIDELBERGCEMENT Group

Rut depth development after conversion to 2+1



CEMENTA
HEIDELBERGCEMENT Group

10-years experience of different pavement in Sweden from test on E6 Fastarp - Heberg



Asphalt SOA

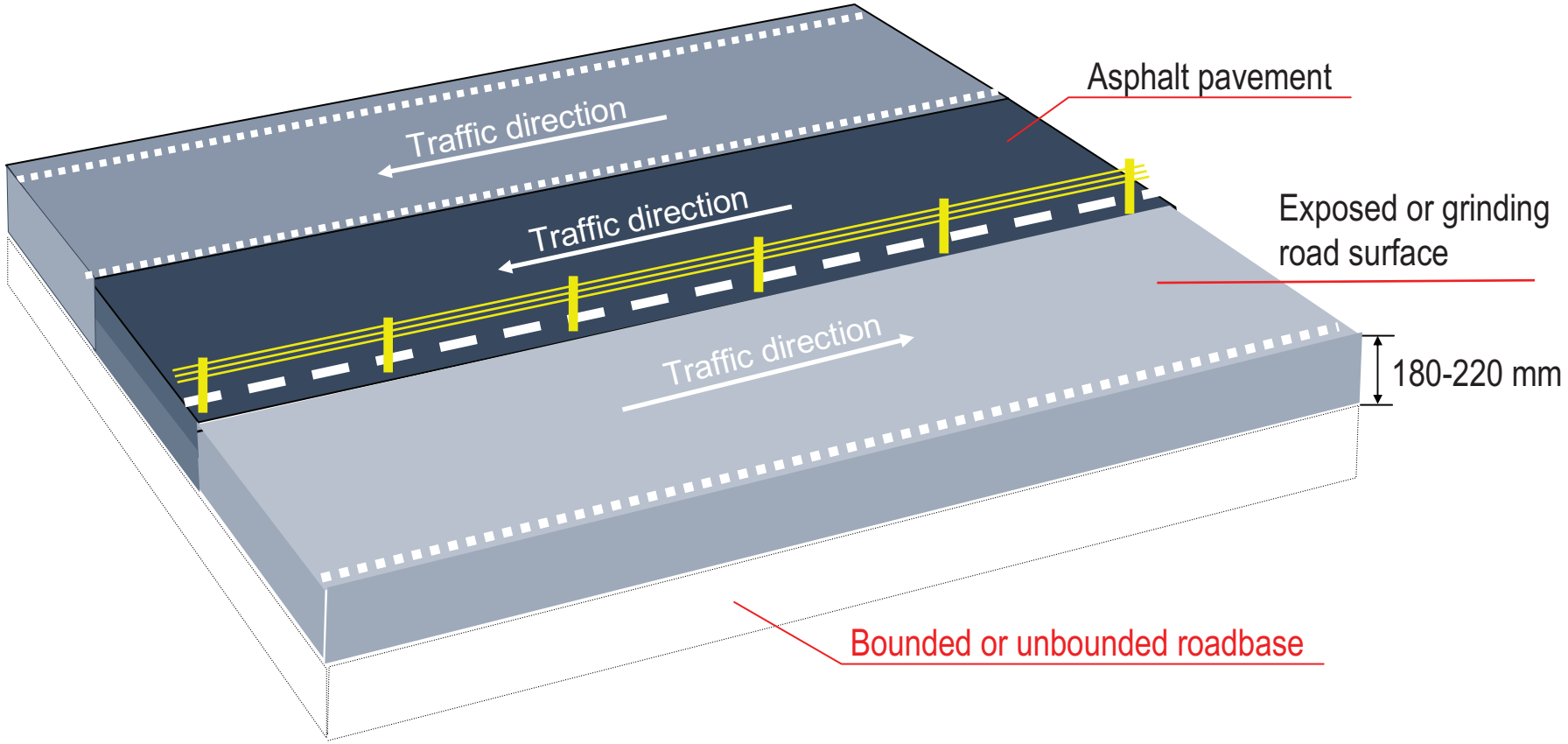
Concrete

CEMENTA
HEIDELBERGCEMENT Group

Another type of concrete roads?

2+1 road lane

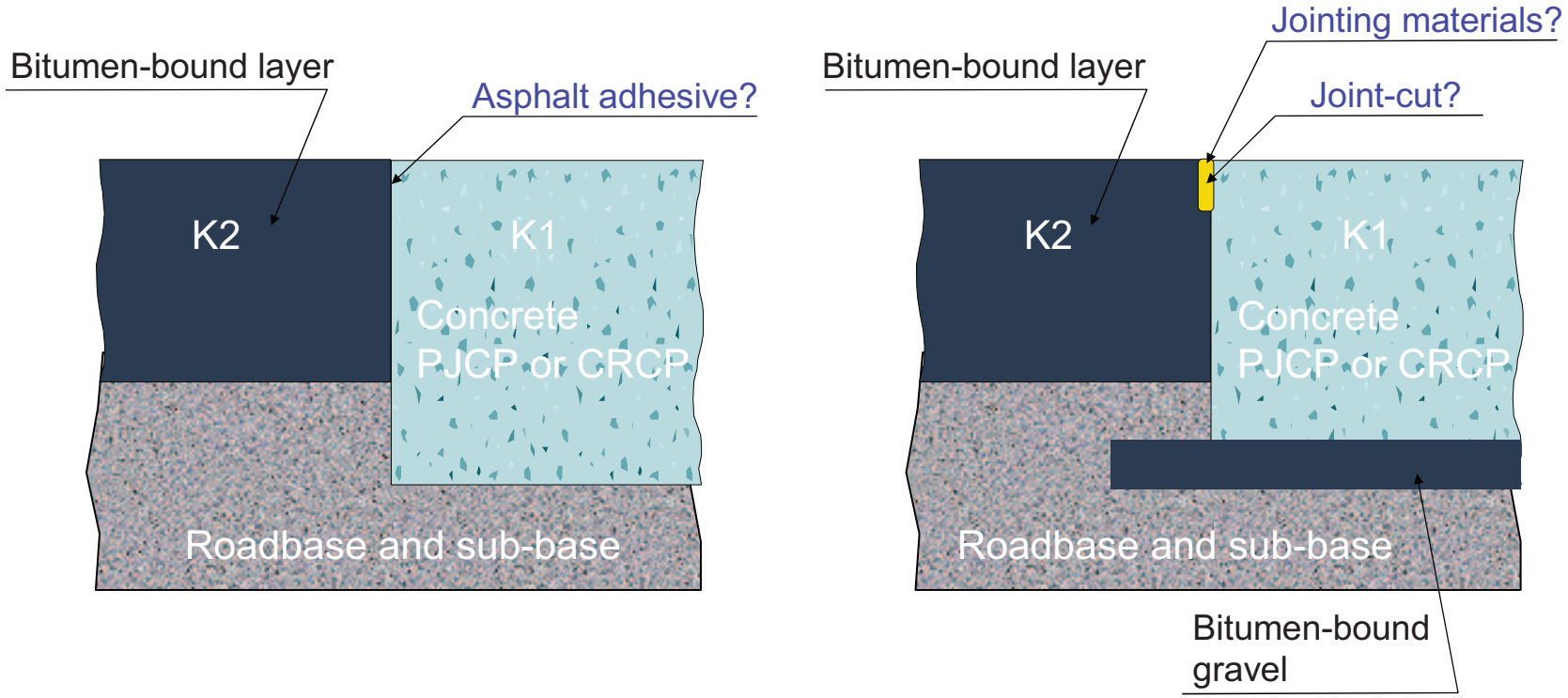
PJCP or CRCP?



CEMENTA
HEIDELBERGCEMENT Group

Design of longitudinal joint between concrete and asphalt in traffic lane

Example



CEMENTA
HEIDELBERGCEMENT Group

Sustainability and Pavements: Are We Focusing on the Right Things?

11th International Symposium
on Concrete Roads
13-15 October , 2010
Seville, Spain

Leif G. Wathne, P.E.
American Concrete Pavement Association

Sustainability

- Highway Engineer will focus o
  - Structural design
  - Pavement materials
  - Construction
- Items such as:
  - Recycling
  - Industrial byproducts
  - Resource conservation

Are we missing significant opportunities?

Are we missing the target?

CEMENTA
HEIDELBERGCEMENT Group

Sustainability? ***YES!***

- Opportunities are missed by ignoring the operational or use-phase of the pavement!
- Research suggests the long-term, cumulative benefits are staggering (…*Europe and North America*).
- Mostly relates to fuel use and surface reflectivity
- So, central question for engineers/administrators: In the context of sustainable practices…

  Are we focusing on the right things?

CEMENTA
HEIDELBERGCEMENT Group

Sustainability and Roadways…

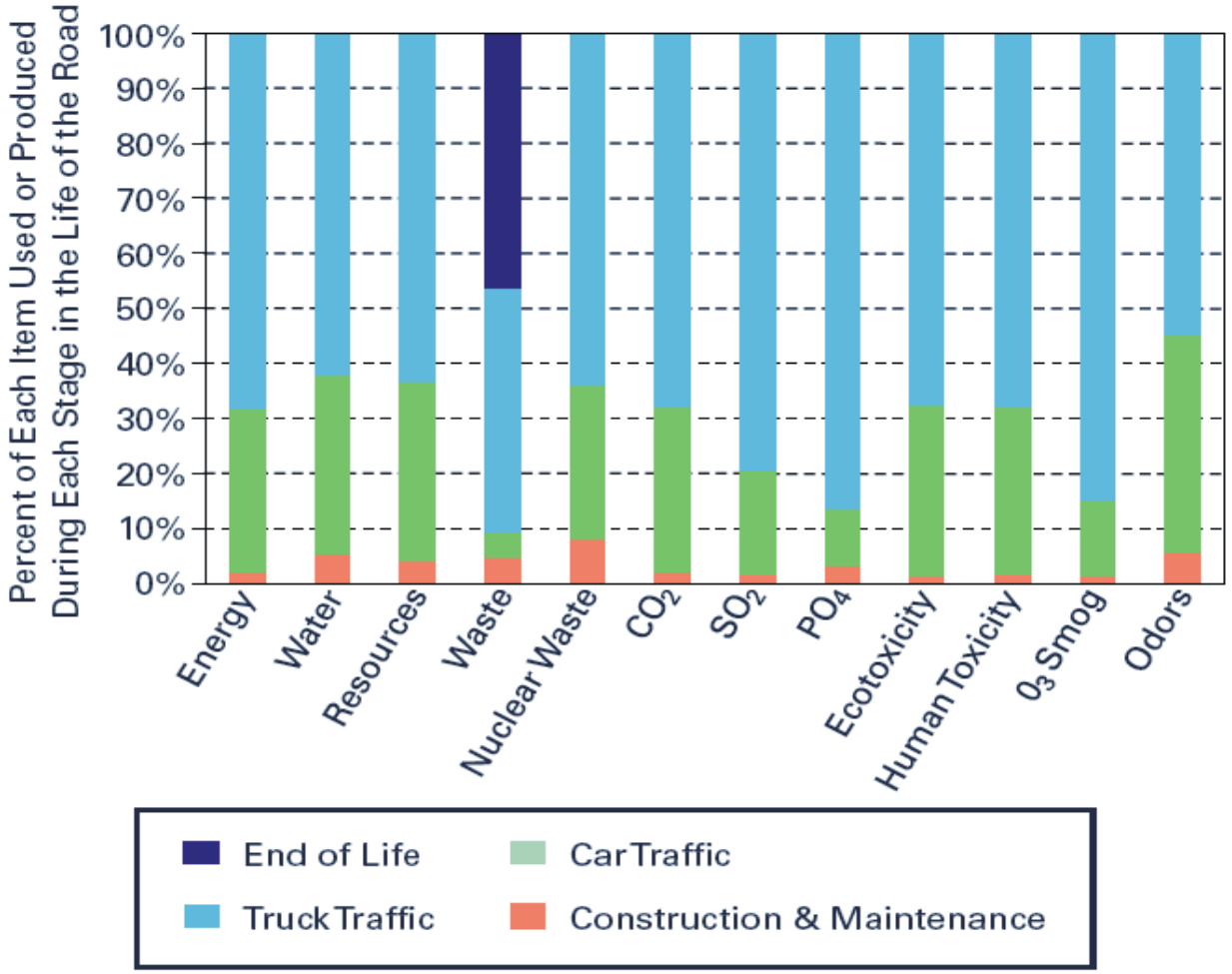
What to make of all these opportunities?

- ***Cradle-to-grave*** or ***end-to-end*** analysis has emerged…
- Life Cycle Assessment (LCA)
- Involves a "***cumulative analysis of impacts throughout <u>all</u> stages of the life cycle***"

CEMENTA
HEIDELBERGCEMENT Group

What should we be doing?

Ecoprofile of different life cycle stages



[Centre d'Energetique de l'Ecole des Mines de Paris]

CEMENTA
HEIDELBERGCEMENT Group

What should we be doing?

- From this LCA we see:
  - Overall impacts from use-phase dwarfs impacts from ALL other phases of the roadway life cycle
  - From energy perspective… construction and maintenance accounts for less than 2% of the entire energy footprint *[EAPA 2004]*
- Therefore (as an example):
  - Just a 3% improvement in the truck/car portion of the ecoprofile would offset the entire construction and maintenance ecoprofile!

CEMENTA
HEIDELBERGCEMENT Group

What should we be doing?

- From this LCA we see:
  - Overall impacts from use-phase dwarfs impacts from ALL other phases of the roadway life cycle
  - From energy perspective… construction and maintenance accounts for less than 2% of the entire energy footprint *[EAPA 2004]*
- Therefore (as an example):
  - Just a 3% improvement in the truck/car portion of the ecoprofile would offset the entire construction and maintenance ecoprofile!

CEMENTA
HEIDELBERGCEMENT Group

What should we be doing?

What are these use/operational-phase impacts?

- **Vehicle fuel consumption rates**
  - Pavement rigidity
  - Pavement smoothness
- **Pavement surface reflectivity (albedo)**
  - Urban heat island mitigation
  - Lighting need
  - Global cooling potential
- **Particle emissions**

CEMENTA
HEIDELBERGCEMENT Group

Measurement of Fuel Consumption

- **Introduction:**

- **Road E4 at Uppsala in Sweden**
- **Asphalt and Concrete Pavement**
- **Car Fuel Measurements**
- **- June 2008 (24 + 24 measurements, two nights)**
- **- June 2010 (24 + 24 measurements, two nights)**
- **Fuel Measurements, Heavy Duty Vehicle**
- **- July 2009 (12 measurements, a hot summerday)**
- **- July 2010 (12 measurements, a hot summerday)**

CEMENTA
HEIDELBERGCEMENT Group

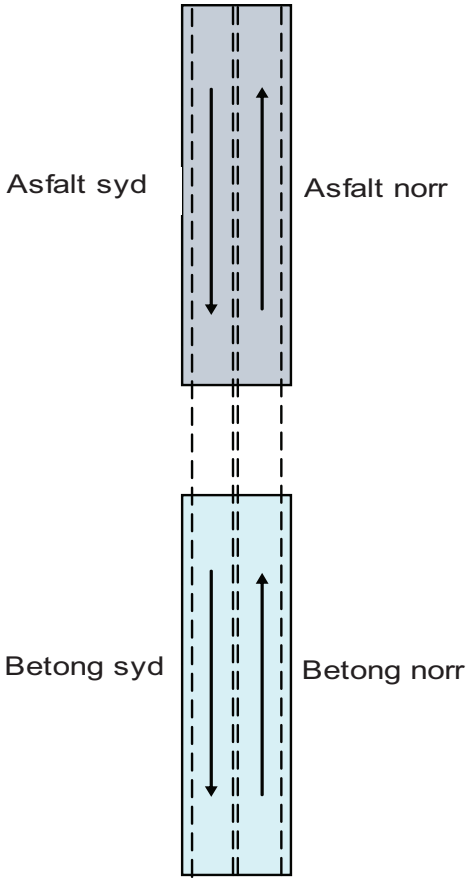
Car Fuel Measurement
Measurement Vehicle
VOLVO 940 (1992)

Parameters measured

- Time
  - Road distance
- Speed
- Fuel Consumption
- Fuel Temperature

CEMENTA
HEIDELBERGCEMENT Group

Description of Measured Road Sections
Asphalt and Concrete (Car measurement)



- **Each section 1 km**
- **Distance between sections 4 km**
- **Stone Mastic Asphalt, SMA**
- **Exposed aggregate in the**
- **concrete surface**
- **Aggregate size 16 mm**
- **Road Geometry –**
- **as equal as possible**
- **RST-vehicle measurement:**

Horizontal and vertical alignments surface characteristics

CEMENTA
HEIDELBERGCEMENT Group

Measured Road Sections

Concrete

Asphalt

CEMENTA
HEIDELBERGCEMENT Group

Surface Chatracteristics

Parameter	Concrete North	Concrete South	Asphalt North	Asphalt South
Rut depth (mm)	**2.4**	**2.6**	**3.2**	**3.1**
Evenness IRI (mm/m)	**1.22**	**1.17**	**0.79**	**0.67**
Texture MPD (mm)	**0.48**	**0.51**	**0.99**	**0.86**
Gradient (%)	**-0.27**	**+0.43**	**-0.28**	**+0.44**

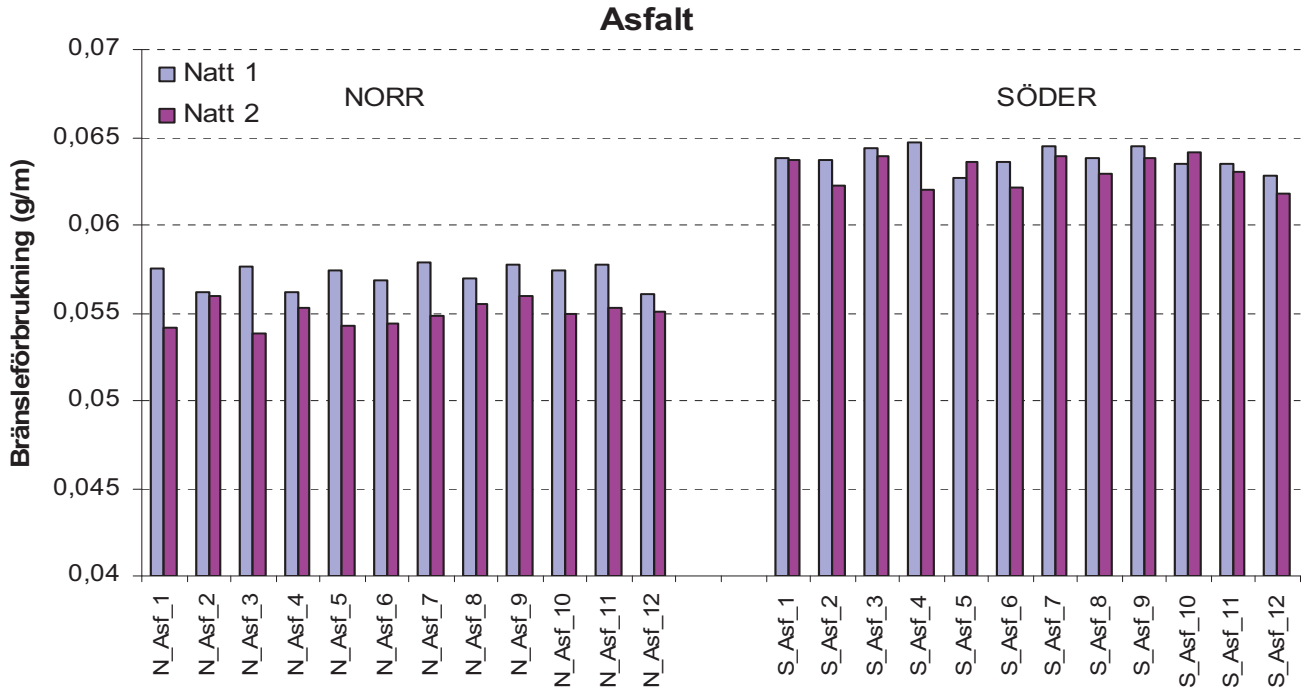
CEMENTA
HEIDELBERGCEMENT Group

Weather Conditions 2008

	First Night 3 Jun-4 Jun	**Second Night 4 Jun-5 Jun**
Air Temperature (C)	**4.6**	**9.0**
Surface Temperature (C)	**13.0**	**16.0**
Wind Direction	**N-W-S**	**NW-NE-SE**
Wind Speed (m/s)	**0.1**	**0.4**

CEMENTA
HEIDELBERGCEMENT Group

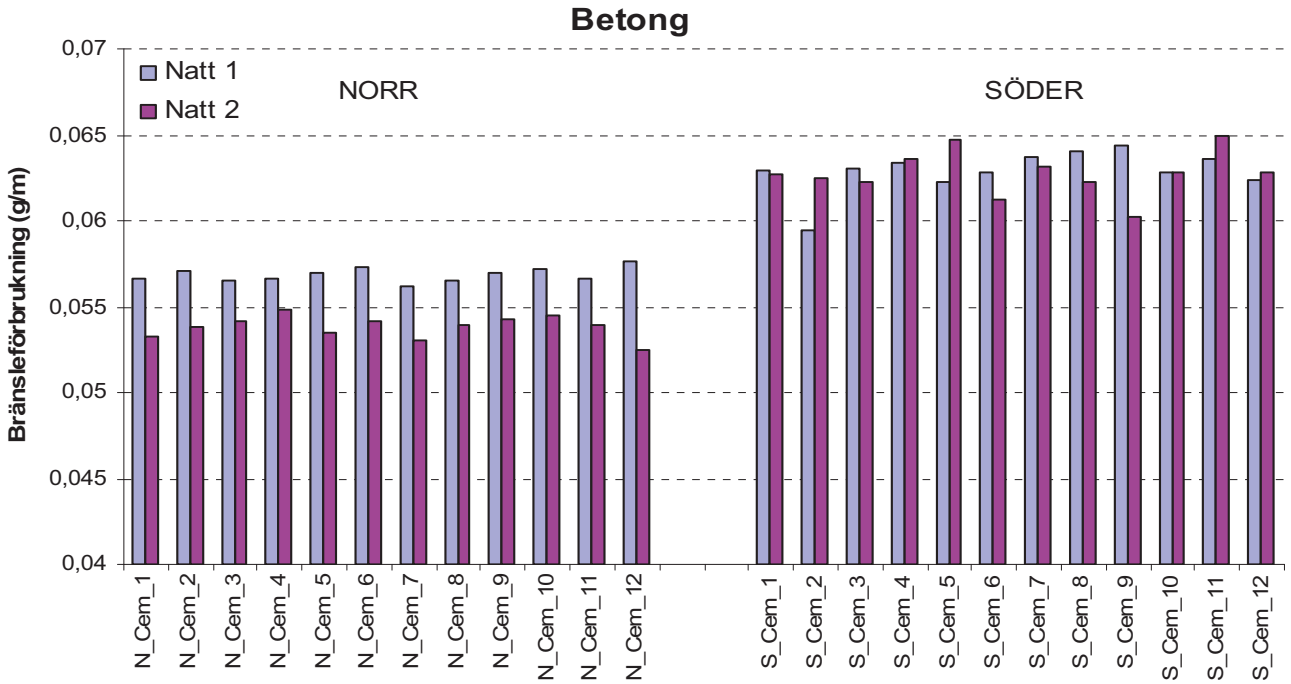
Fuel Consumption
Results Asphalt Pavement 2008



- **North and south direction**
- **Blue is the first night, red is the second night**

CEMENTA
HEIDELBERGCEMENT Group

Fuel Consumption
Results Concrete Pavement 2008



- **North and south direction**
- **Blue is the first night, red is the second night**

CEMENTA
HEIDELBERGCEMENT Group

Average Fuel Consumption 2008
Car measurement

Fuel Consumption	Asphalt	Concrete
Average (g/m)	0.0597	0.0591
Standard Deviation	0.0039	0.0041
Average (l/10 km)	0.807	0.798

Difference in fuel consumption

1.1 % lower on concrete surfacing

Statistically significant difference (t-test)

CEMENTA
HEIDELBERGCEMENT Group

Average Fuel Consumption 2010
Car measurement

Fuel Consumption	Asphalt	Concrete
Average (g/m)	0.0597	0.0591
Standard Deviation	0.0033	0.0031
Average (l/10 km)	0.807	0.798

Difference in fuel consumption

1.1 % lower on concrete surfacing

Statistically significant differense (t-test)

CEMENTA
HEIDELBERGCEMENT Group

Fuel Measurement with a HGV Heavy Duty Vehicle

Scania R500 (2008 model)

- **Vehicle + trailer 60 tons**
- **500 hp V8 engine**
- **Manual gearbox (12 gears)**
- **Cruise control speed 80 km/h**
- **Rpm 1400 in gear 12**
- **Air pressure in tyres:**
  vehicle 0.7 MPa, trailer 0.9 MPa
- **Computer system for parameters:**
  speed, road distance, rpm and fuel consumption

CEMENTA
HEIDELBERGCEMENT Group

Resume of fuel consumption 2009
Heavy Goods Vehicle, HGV

Fuel Consumption	Asphalt l/10 km	Concrete l/10 km	Difference	Difference %
Northbound Avarage	4.19	4.05	0.14	3.3
Southbound Avarage	3.97	3.57	0.40	10.0

Difference in fuel consumption on a hot summerday
Avarage value
6.7 % lower on concrete surfacing

Statistically significant difference

•

CEMENTA
HEIDELBERGCEMENT Group

Resume of fuel consumption 2010
Heavy Goods Vehicle, HGV

Fuel Consumption	Asphalt l/10 km	Concrete l/10 km	Difference	Difference
Northbound Average	4.08	3.97	0.11	2.7
Southbound Average	4.56	4.23	0.33	7.2

Difference in fuel consumption on a hot summerday

Average value

5.0 % lower on concrete surfacing

Statistically significant difference

CEMENTA
HEIDELBERGCEMENT Group

Conclusions

- **Car measurement**
  - 1.1 % less fuel consumption on the concrete pavement (statistically significant)
  - attributed to difference in macro texture
  - good correlation with VETO fuel model

- **HDV measurement on a hot summerday**
  - 5-7 % less fuel consumption on the concrete pavement (statistically significant)
  - attributed to less rolling resistance of the concrete pavement (differences in macro texture and pavement stiffness)

CEMENTA
HEIDELBERGCEMENT Group

Example:

70 km concrete vs asphalt
20 000 vehicles/day
15 % HDV
Fuel consumption:
Car: 1.1 l/10 km (80 km/h)
HDV: 4.0 l/10 km (80 km/h)
Consumer fuel cost: 13 SEK/l (1.36 euro)

⇨ **Reduced consumer/industry cost:**

12 000 000 kr/year
1 260 000 euro/year

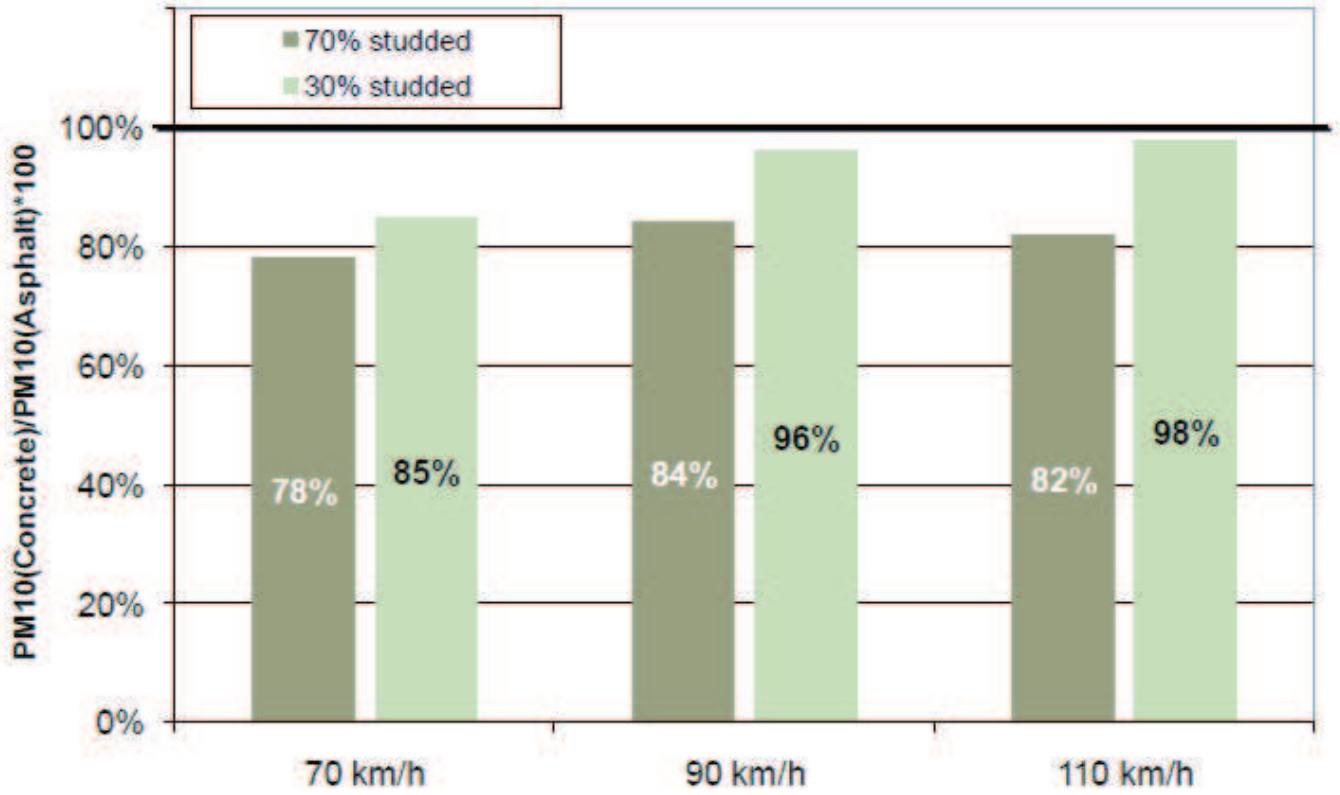
= 3 000 ton CO2/year

E4 Uppsala – Mehedeby öppnad för trafik 2006

CEMENTA
HEIDELBERGCEMENT Group

Particle emission from concrete pavements In relation to asphalt pavements

Conclusions:

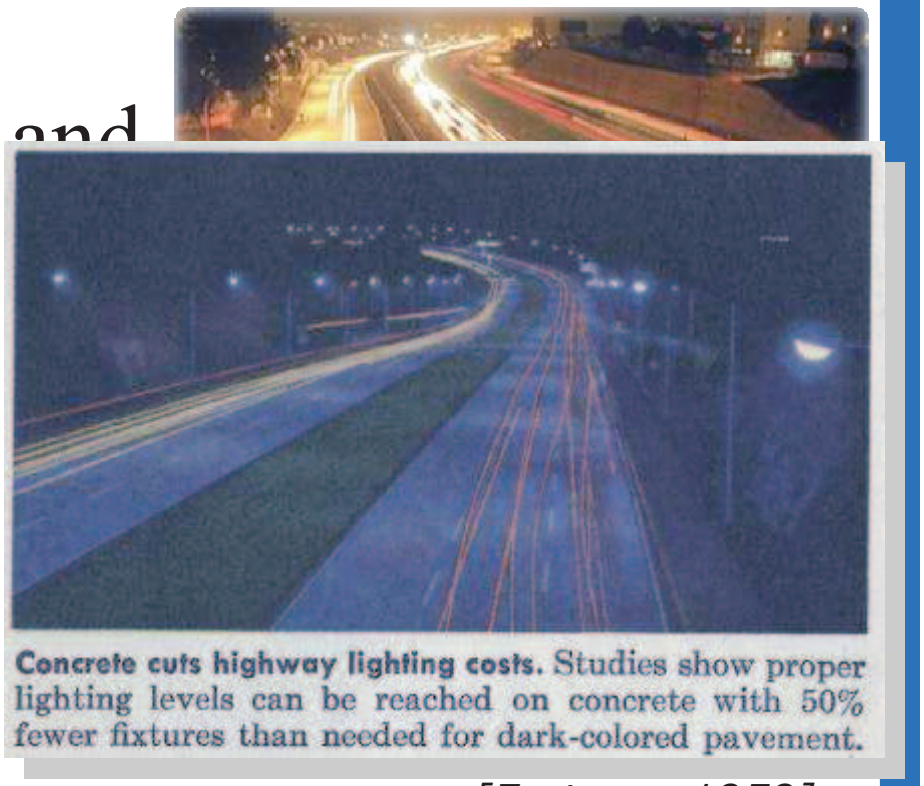


CEMENTA
HEIDELBERGCEMENT Group

Surface Reflectivity - Lighting

Enhanced Nighttime Visibility:

- Improved pedestrian and vehicle safety
- Reduced lighting & energy requirement:
  - Less fixtures/watts
  - Up to 33% reduction
  - AASHTO - 40% lower
  - Huge budget impact!



Concrete cuts highway lighting costs. Studies show proper lighting levels can be reached on concrete with 50% fewer fixtures than needed for dark-colored pavement.

[Fortune, 1959]

CEMENTA
HEIDELBERGCEMENT Group

Conclusions*:

Functional property	Asphalt	Concrete
Investment cost	+	
Maintenance		+
Accidents (maintenance)		+
Evenness	=	=
Polishing	=	=
Noise	=	=
Logistics (during const.)	=	=
Abrasion resistance		+
Plastic deformation		+
Particle emissions		+
Fuel consumption (user cost)		+
CO2 (environment)		+
Brightness/reflection		+
Friction	+	
Repair (flexibility)	+	
Fire (in tunnels)		+

*** According to the Swedish National Road administration**

CEMENTA
HEIDELBERGCEMENT Group

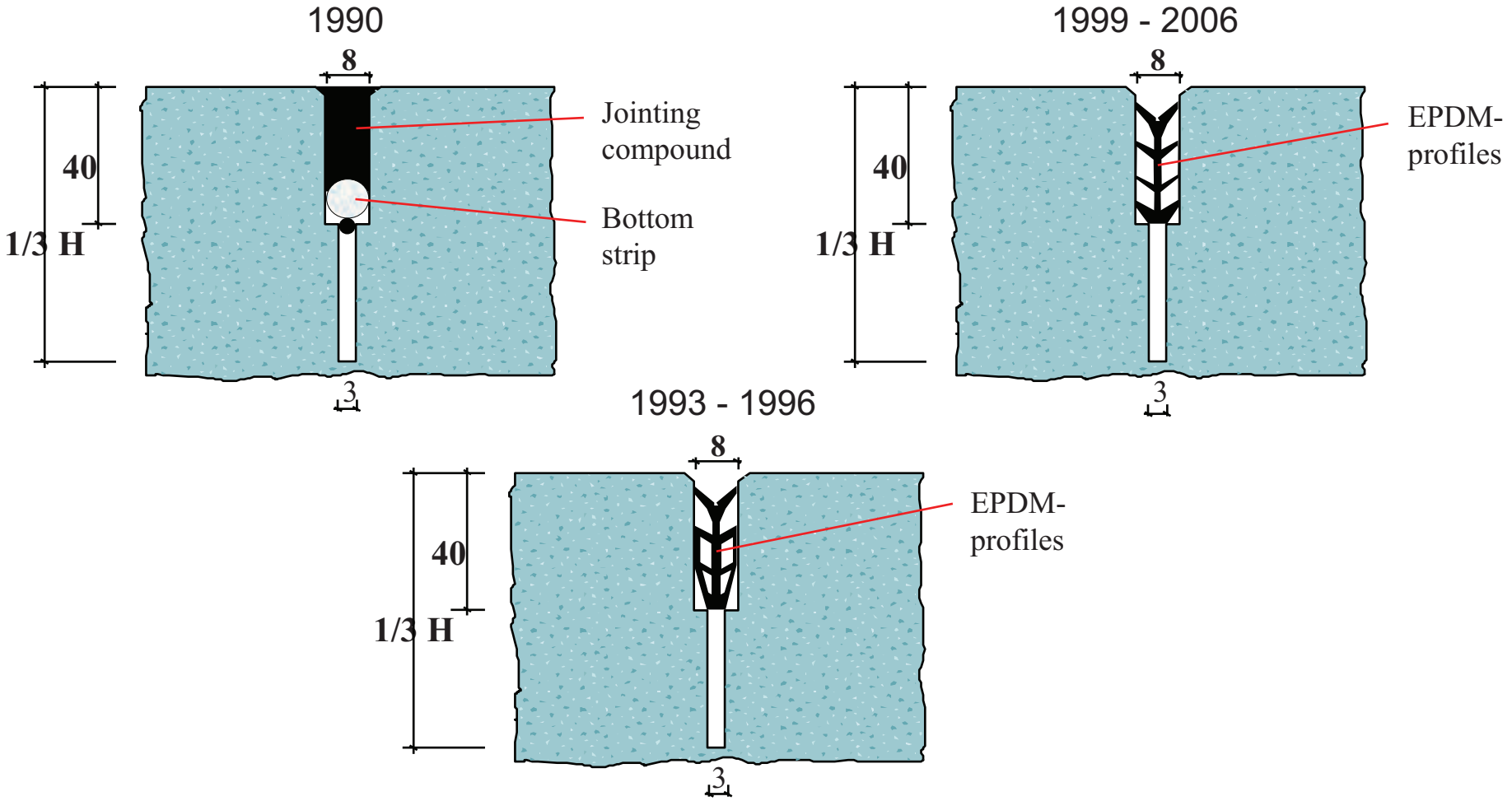

Thank you!
New concrete road
E4 by-pass Uppsala
opened dec 21, 2006

Extras

CEMENTA
HEIDELBERGCEMENT Group

CEMENTA
HEIDELBERGCEMENT Group

Design of transverse joints in concrete roads in Sweden



CEMENTA
HEIDELBERGCEMENT Group

Design of transverse joints in new construction of concrete roads?

After 2010 -