SEMINARIO INTERNACIONAL DE PAVIMENTOS DE HORMIGÓN
24 y 25 DE OCTUBRE 2012 • CIUDAD DE CÓRDOBA - ARGENTINA

Concrete Pavement in Germany – Construction, Surface Texture, Interlayer, Drainage and Base Course

by Stefan Höller

Federal Highway Research Institute
(BASt / Germany)

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1.Introduction

2. Concrete Pavement Construction

3. Concrete Pavement Surface Texture

4.Interlayers, Base Course and Drainage

5.Outlook

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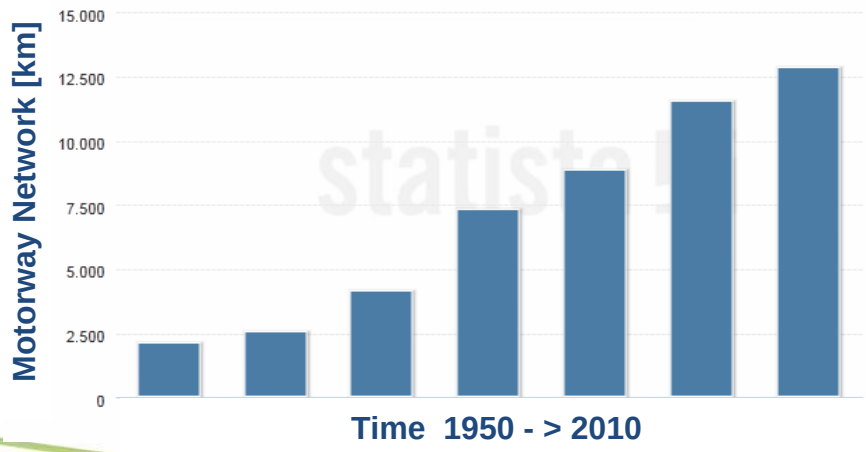
Road Network and Traffic in Germany

Autobahn	meistbefahrener Abschnitt	Verkehrsstärke DTV [Kfz/24h]
100 A 100	Dreieck Funkturm – Kurfürstendamm (Berlin)	186.100
3 A 3	Köln-Dellbrück – Kreuz Köln-Ost (Nordrhein-Westfalen)	157.100
8 A 8	Dreieck Leonberg – Kreuz Stuttgart (Baden-Württemberg)	147.600
9 A 9	Kreuz München-Nord – Garching-Süd (Bayern)	146.200
5 A 5	Frankfurt-Niederrad – Frankfurter Kreuz (Hessen)	145.900
7 A 7	Dreieck Hamburg-Nordwest – Hamburg-Stellingen (Hamburg)	134.300
66 A 66	Frankfurt-Höchst – Eschborner Dreieck (Hessen)	133.200
81 A 81	Ludwigsburg-Nord – Ludwigsburg-Süd (Baden-Württemberg)	129.300
2 A 2	Hannover-Herrenhausen – Dreieck Hannover-West (Niedersachsen)	129.000
99 A 99	Aschheim/Ismaning – Kirchheim bei München (Bayern)	121.200
4 A 4	Kreuz Köln-Süd – Köln-Poll (Nordrhein-Westfalen)	120.500
1 A 1	Kreuz Leverkusen-West – Köln-Niehl (Nordrhein-Westfalen)	119.400
57 A 57	Köln-Bickendorf – Köln-Longerich (Nordrhein-Westfalen)	118.500
40 A 40	Dreieck Essen-Ost – Essen-Frillendorf (Nordrhein-Westfalen)	117.200
661 A 661	Offenbach-Kaiserlei – Frankfurt-Ost (Hessen)	116.800
59 A 59	Dreieck Sankt Augustin-West – Dreieck Bonn-Nordost (Nordrhein-Westfalen)	115.900
111 A 111	Flughafen Tegel – Heckerdamm (Berlin)	114.700
52 A 52	Dreieck Breitscheid – Kreuz Breitscheid (Nordrhein-Westfalen)	111.700
46 A 46	Kreuz Hilden – Hilden (Nordrhein-Westfalen)	111.600
565 A 565	Bonn-Beuel-Nord – Bonn-Auerberg (Nordrhein-Westfalen)	106.500



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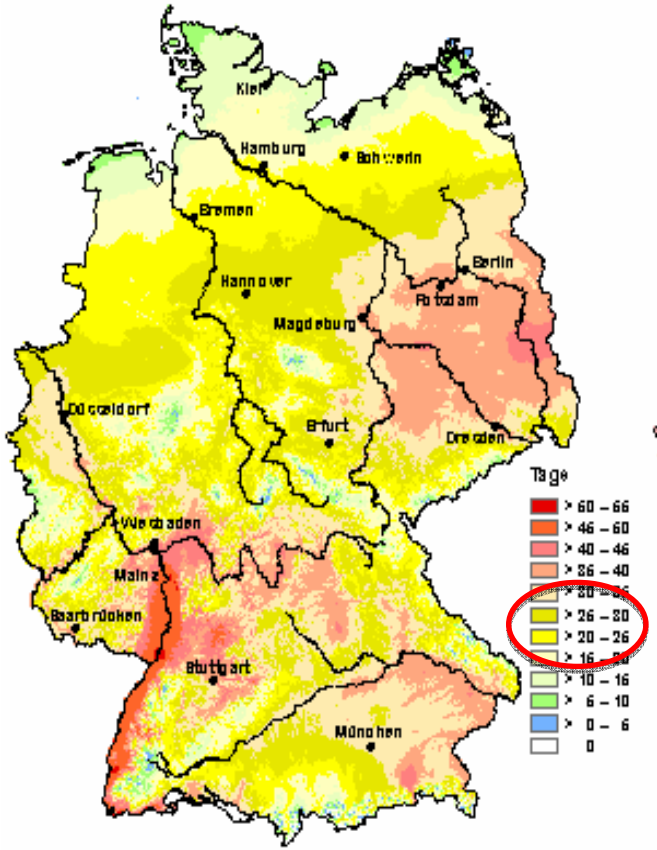
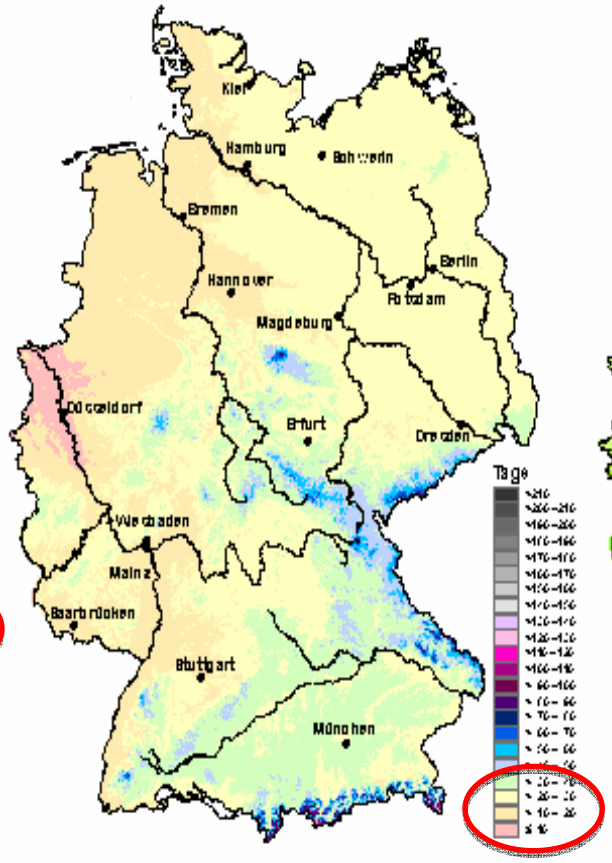
DE PAVIMENTOS DE HORMIGÓN

Climate in Germany

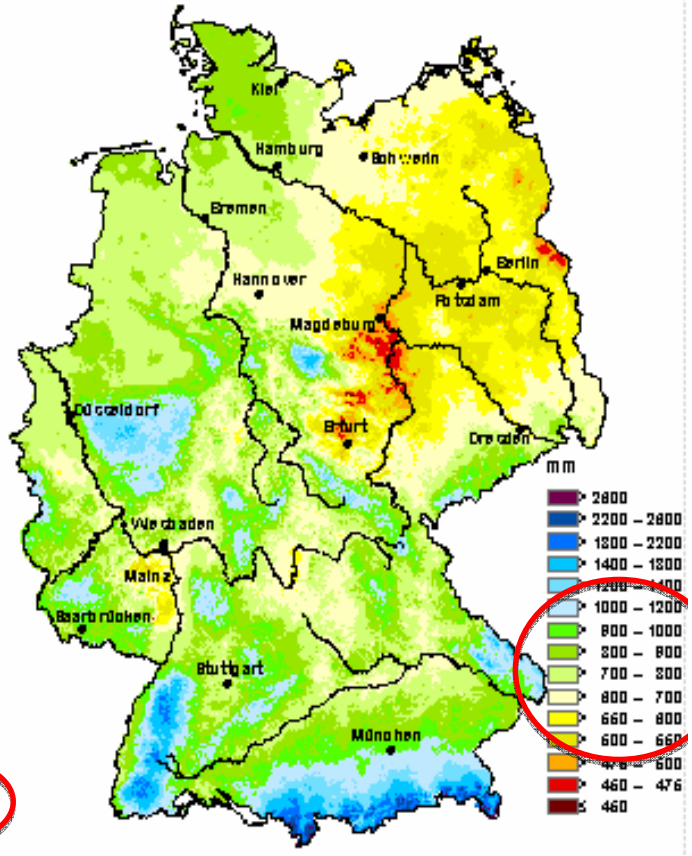
Summer Days
[Days min. + 25°C/Year



Ice Days
[Days max. 0°C/Year]



Precipitation
[mm/m²/Year]



Why Concrete Pavement?

- High Durability

- Light Surface
  (Traffic Safety)

and

- National Raw Material

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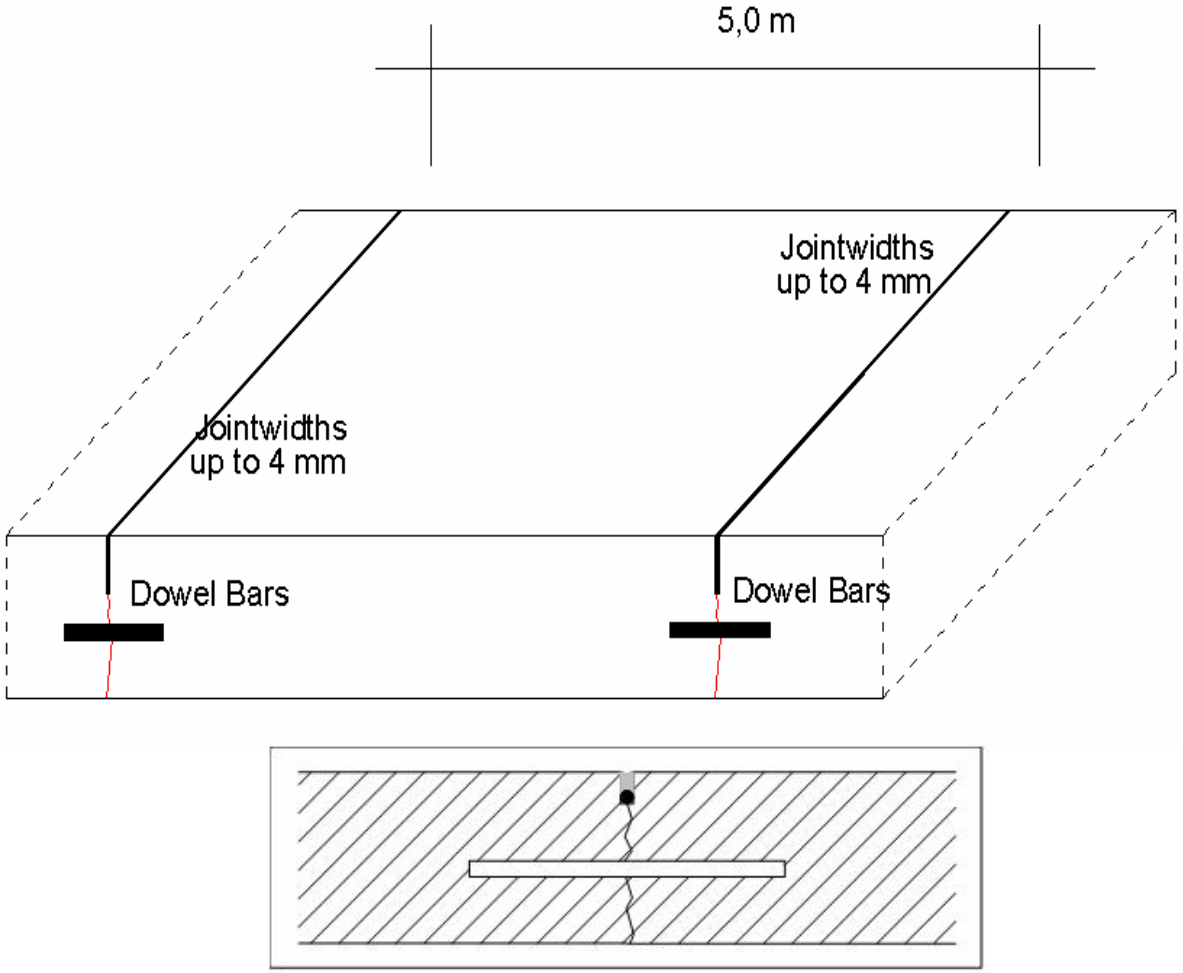
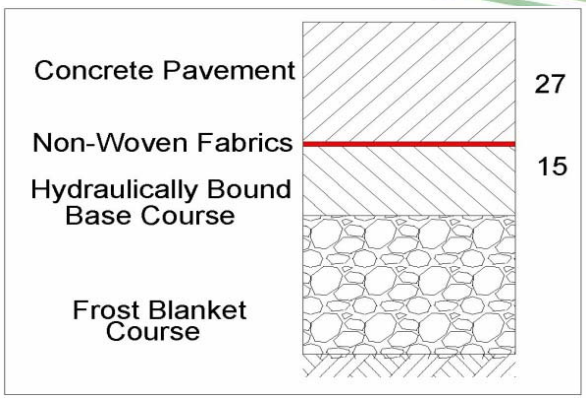
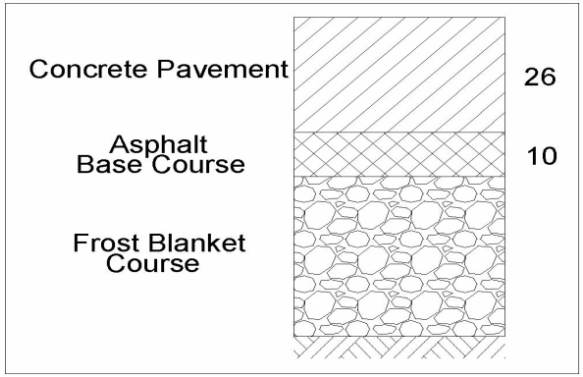
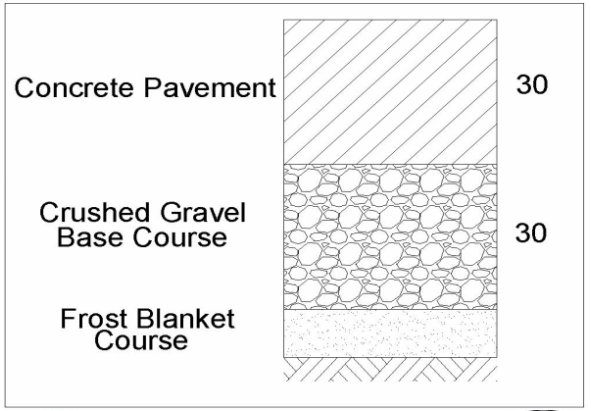
Jointed Plain Concrete Pavement, (unreinforced slabs) JPCP









Concrete Mixing Plant

Important:

- Continuous Delivery of Cement and Aggregates

- Adequate Mixing Capacity

- Adequate Transport Capacity

- Short Distance to Construction Site

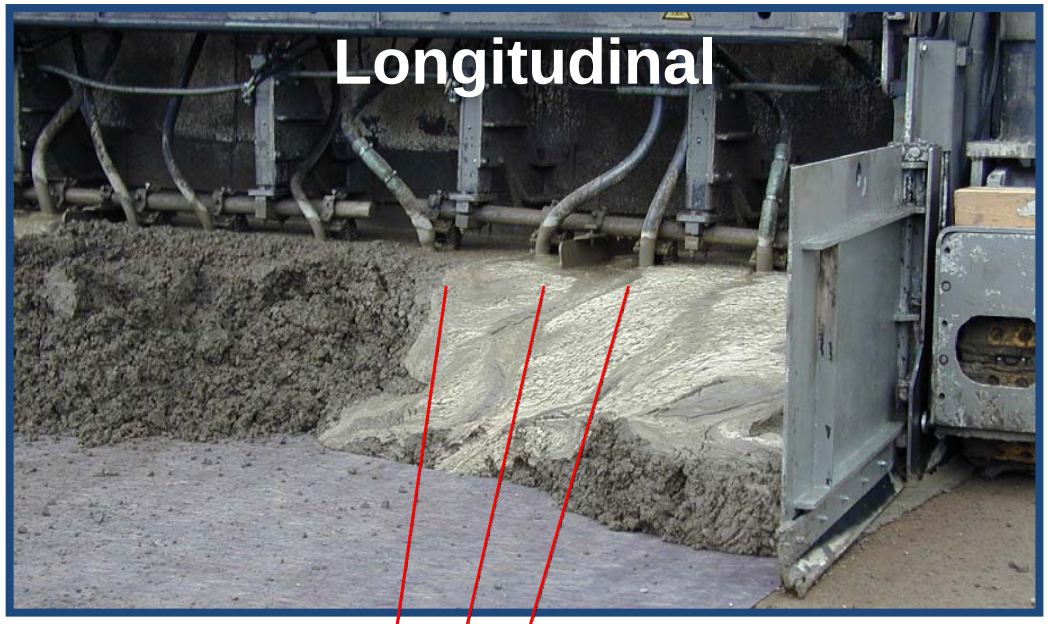
- Experienced Operators

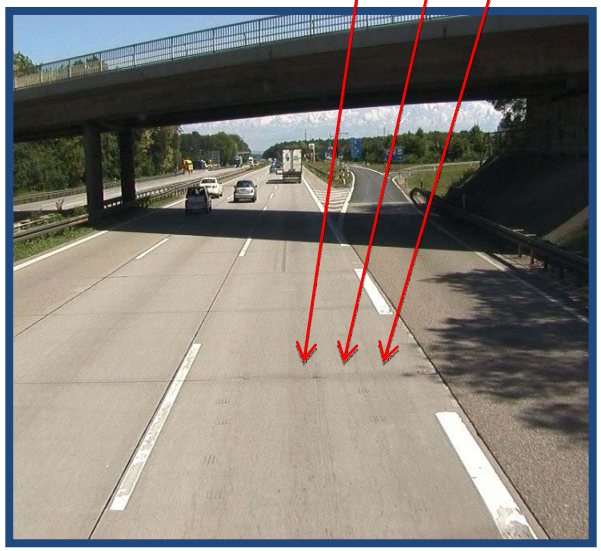
Concrete Pavement -
- Mix Design -

Property		Requirement
Compressive Strength	Class	C 30N/mm² / 37 N/mm²
Flexural Strength		4,5 N/mm²
Aggregates	top layer:	0-8 mm; 0-16 mm; 0-22 mm
	bottom layer	exposed aggregate only 0-8mm
		0-16 mm; 0-22mm; 0-32 mm
	layer thickness	min. 3 x aggregate size
Cement	Portland Cement	(CEM I)
	Composite Cement	(CEM II)
		(Portland in combination with
		slag ashes, limestone, blast furnace)
Cement Content		min. 340 kg/m³
	exposed aggregate:	min. 420 kg/m³
W/C - Ratio		max. 0,45
Air Void Content	aggr. size 0-8mm:	5,50%
	aggr. size 0-16mm:	4,50%
	aggr. size 0-22mm	4,00%
	aggr. size 0-32mm	4,00%

Examples of Slip Form Paver

Concrete Compaction by Poker Vibrator





Transversal

Concentration of Cement Paste and Fines => Cracks?

Construction Site

Property	Requirement
Air Temperature	+5°C - +25°C
Concrete Temperature	+5°C - +30°C
Higher / lower Temperatures:	special actions required
	- heated Mixing Water
	- heated Aggregates
	- higher Cement Content
Curing	- Parafin Based Curing (early stage)
	- Curing with Water (later on)
	- Plastic Sheets / Tents (optional)

Concrete – Aluminium - Reaction

Fresh Concrete in Touch with Aluminium

=> Gas Decompression

Transport of Aggregates and Concrete to the Construction Site

Steel: Yes

Aluminium: No

Variable Lane Width

Transportation of Slip Form Paver

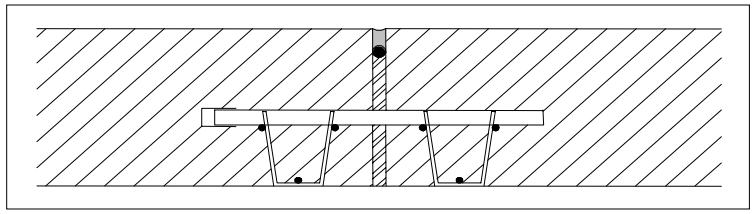
„Manual Paving“ for smaller Sites

Dowels and Tie Bars

- Expansion Joints -

Positive:

- **Position of Dowels and Tie Bars fixed by wooden inlays**



- **no influence of Compaction Energy on Position of Dowels and Tie Bars**

Negative:

- **Delievery of fresh Concrete limited**

- **Man Power intensive**

Dowels and Tie Bars

- Contraction Joints / Baskets -

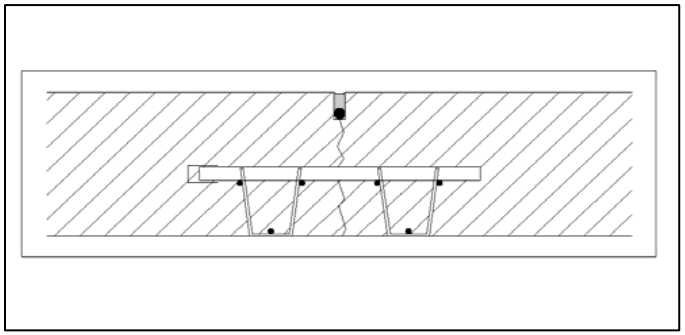
Positive:

- Position of Dowels and Tie Bars fixed by Baskets
- no influence of Compaction Energy on Position of Dowels and Tie Bars

Negative:

-Delievery of fresh Concrete limited

- Man Power intensive



Dowels and Tie Bars

- Contraction Joints / Installation by Vibration Devices -

Positive:

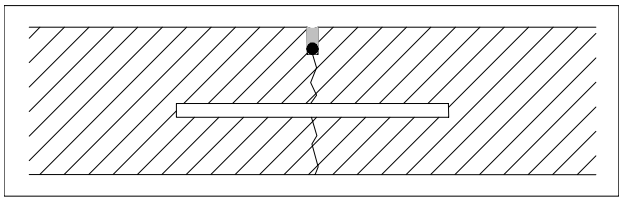
- Less Man Power

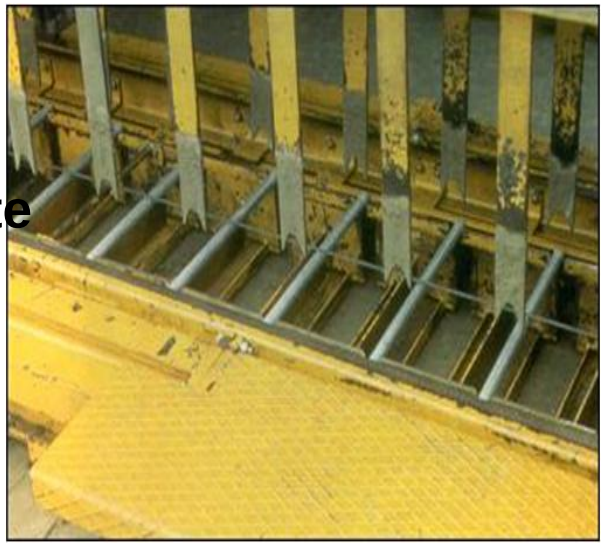
-Delievery of fresh Concrete not limited

Negative:

-influence of Compaction Energy on Position of Dowels and Tie Bars

Position always correct?





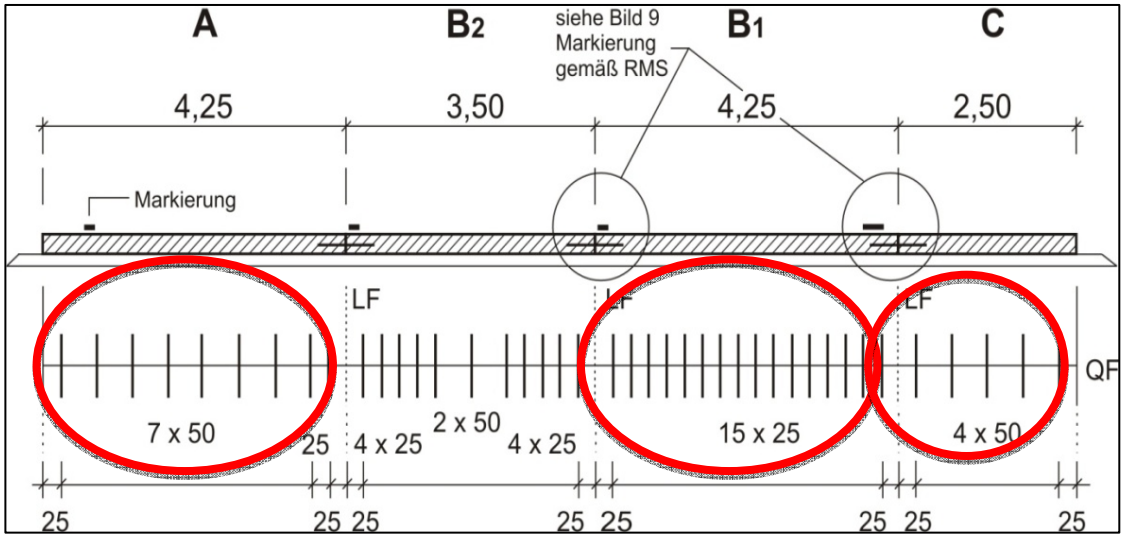
Dowels and Tie Bars

- Requirements -

- **Dowel Dimension**
  25mm x 500mm

-**Smooth Round Steel**

- **Plastic Coating 0,3 mm**

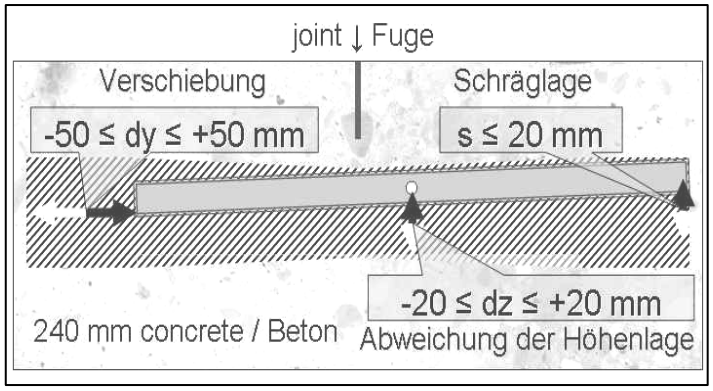


-<u>Tolerances</u>:

Horizontal Shift : +/- 50 mm

Inclined Position: < 20 mm

Vertical Shift: +/- 20 mm



Dowels and Tie Bars

- Position extremly wrong -

Damages appear quickly

Dowels and Tie Bars

- Measurement of Position -

<u>Core Samples</u>

Type of Measurement: destructive

effort: high

Quality of Result: high

Dowels and Tie Bars
- Measurement of Position -

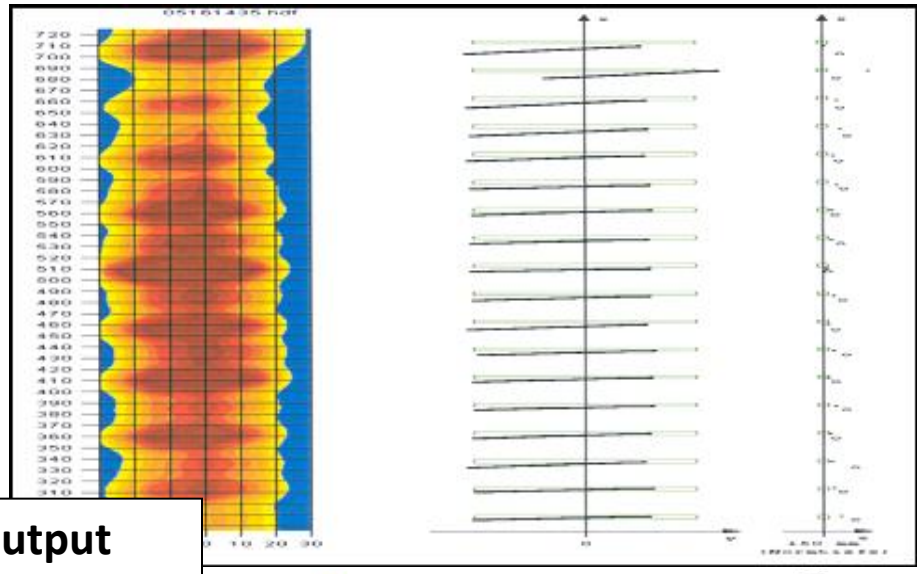
Measuring Device

Puls Induction Measurement

Type of Measurement: non destructive

effort: low

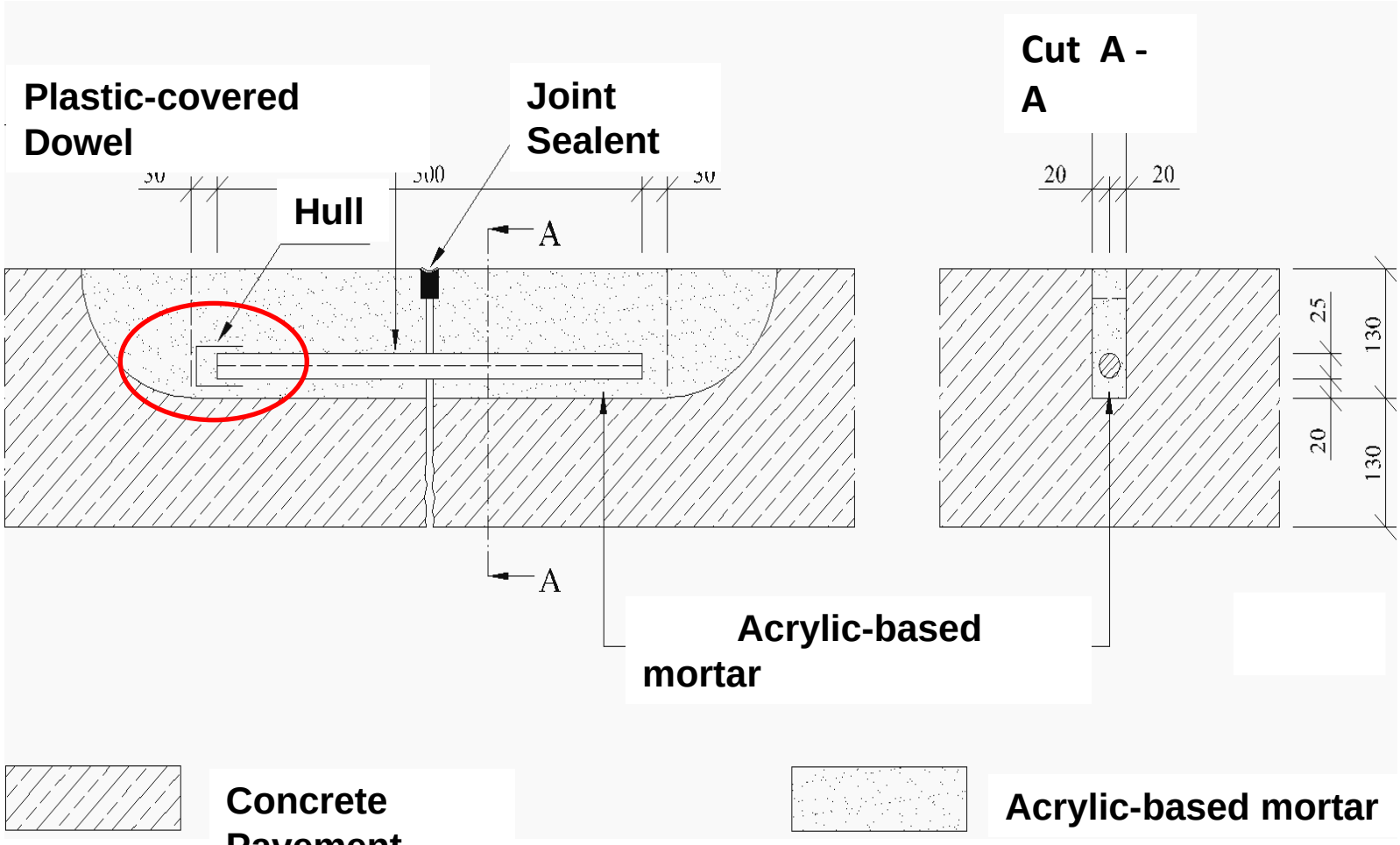
Quality of Result: medium



Output of the Results

Dowels and Tie Bars

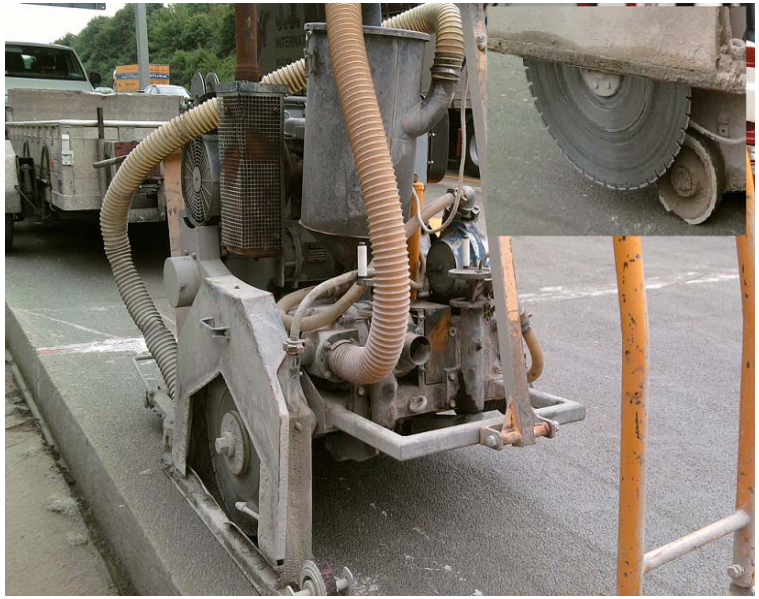
- Retrofit of Dowels -



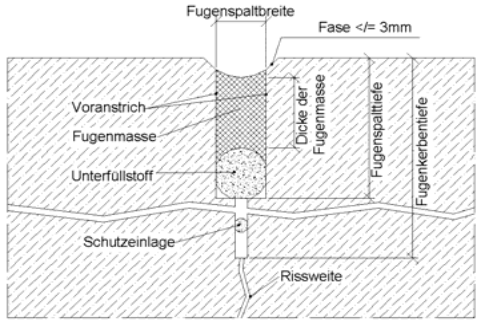
Dowels and Tie Bars

- Retrofit of Tie Bars -

Joints (longitudinal and transversal)
- Saw Cutting -

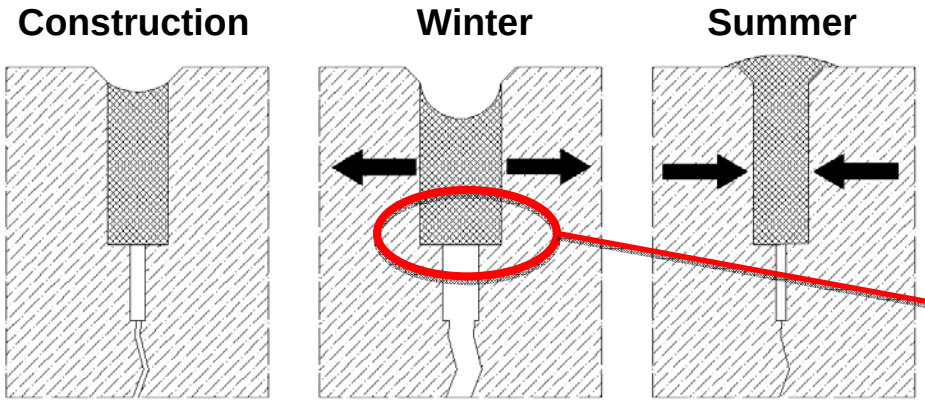


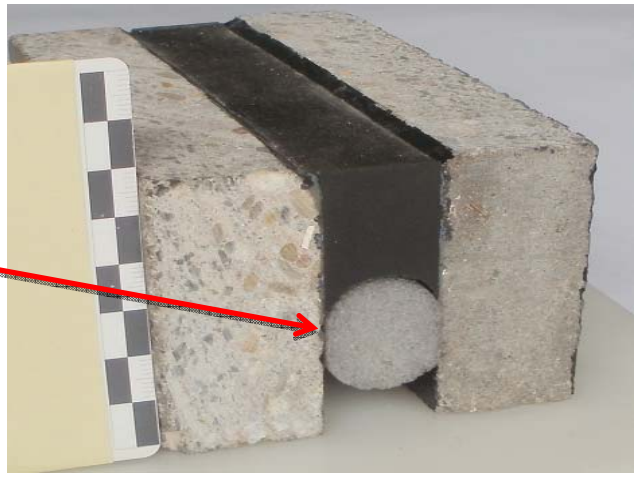
complete Transversal Joint



Joints (longitudinal and transversal)
- Saw Cutting -

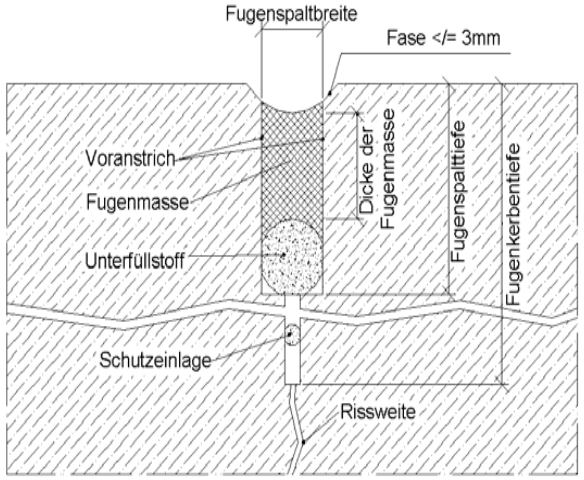
Joints (longitudinal and transversal)
- Hot Bitumen Joint Sealing -





Primer

Application

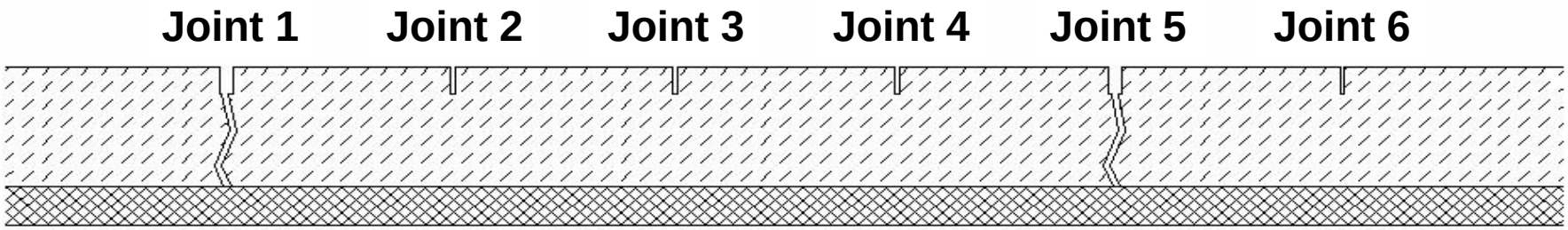


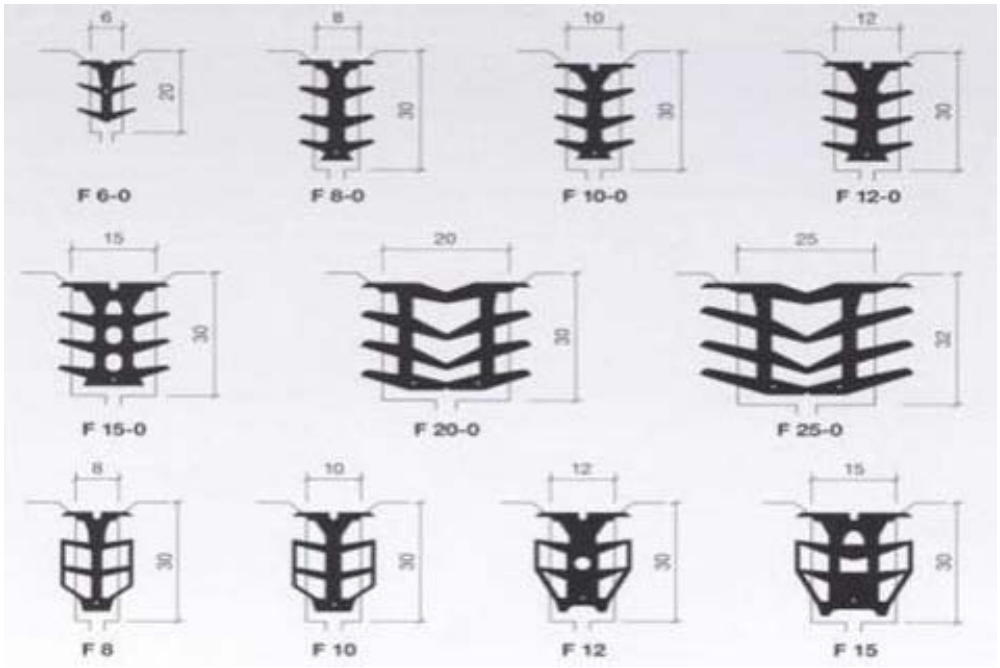
Joints (longitudinal and transversal)
- Plastic Profile Joint Sealing -

Installation at any Weather Condition

Joints (longitudinal and transversal)
- Plastic Profile Joint Sealing -

„Package Cracking“ in the Early Stage





Choose the right size!

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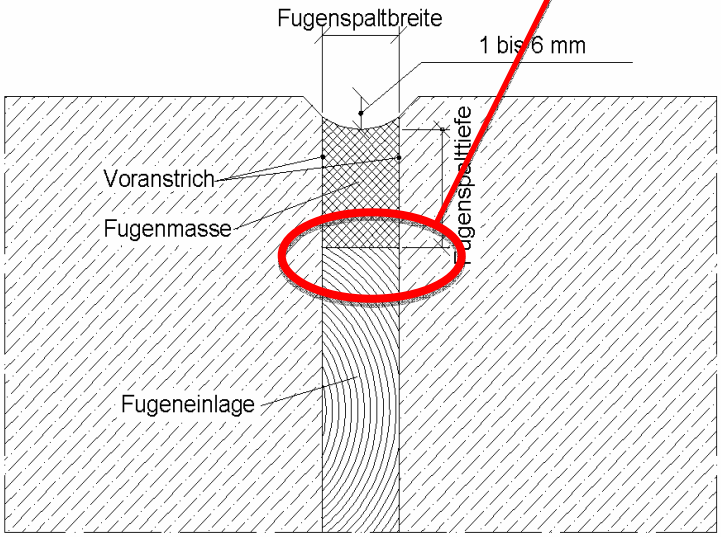
Joints (longitudinal and transversal)

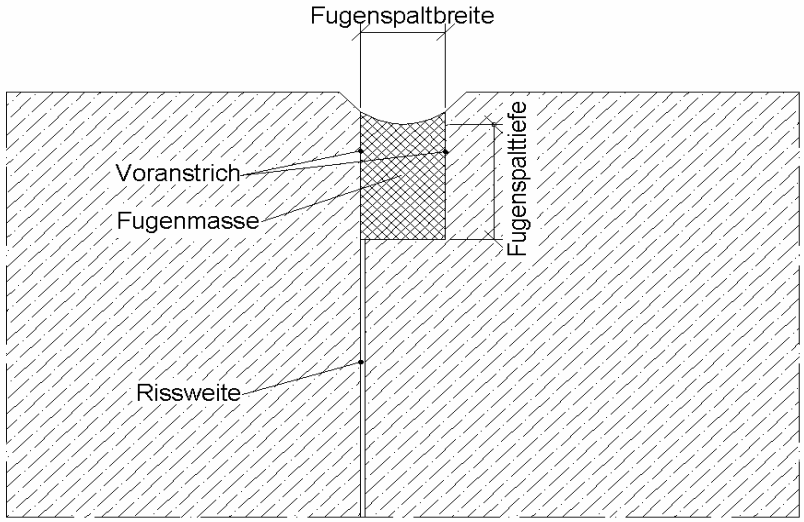
- Sealing of Expansion and Butt Joints -

Wooden Inlay



Expansion Joint

Butt Joint



End Areas, to avoid horizontal Movements

Reinforced End Anchoir

Unreinforced „Double Concrete Slab“

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Concrete Pavement

Surface Texture (1938)

1 cm

Traffic in Germany / Europe

Traffic Volume 1960

Traffic Volume 2010

Traffic in Germany / Europe

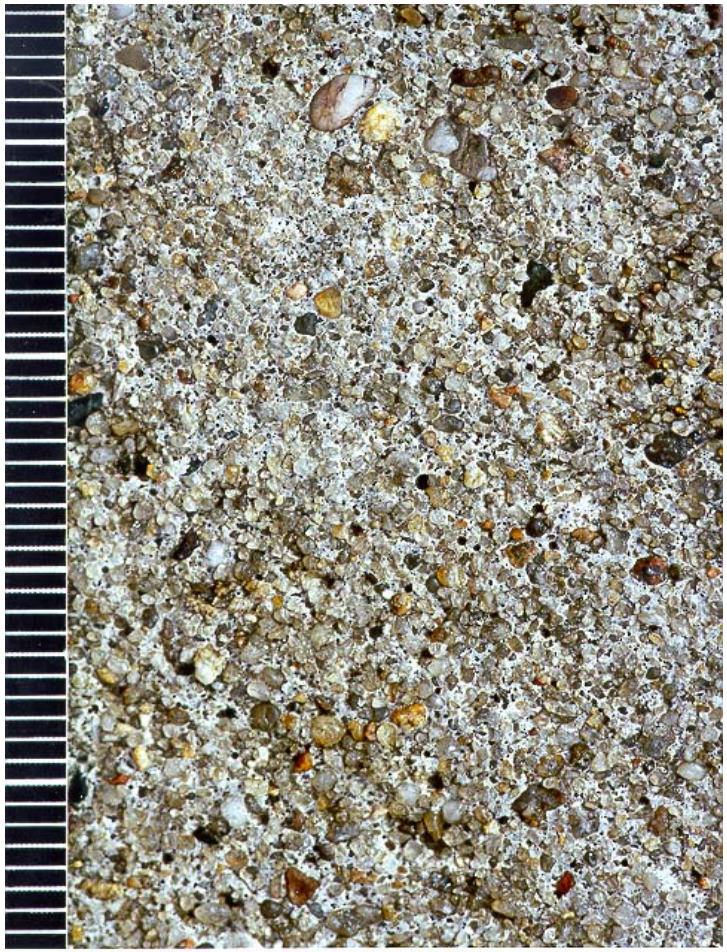
„Average“ Car in 1950

„Average“ Car in 2010

Concrete Pavement

Surface Textures (1972)

-Soft Brush - transversal –



1 cm

Surface Textures for (1978)

- Steel Brush - transversal -

1 cm

Surface Textures (1978)

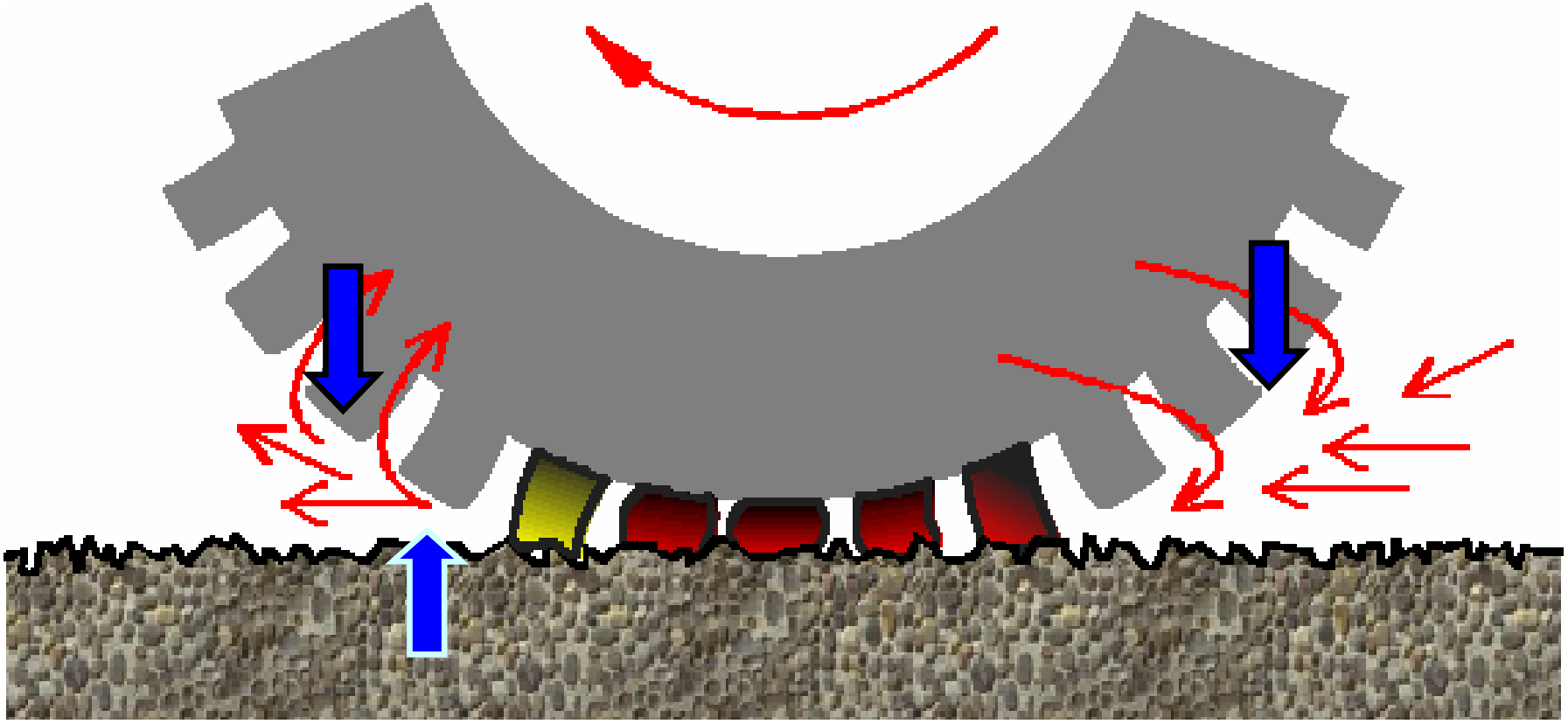
- Hard Plastic Brush - longitudinal -

Surface Textures (1991)

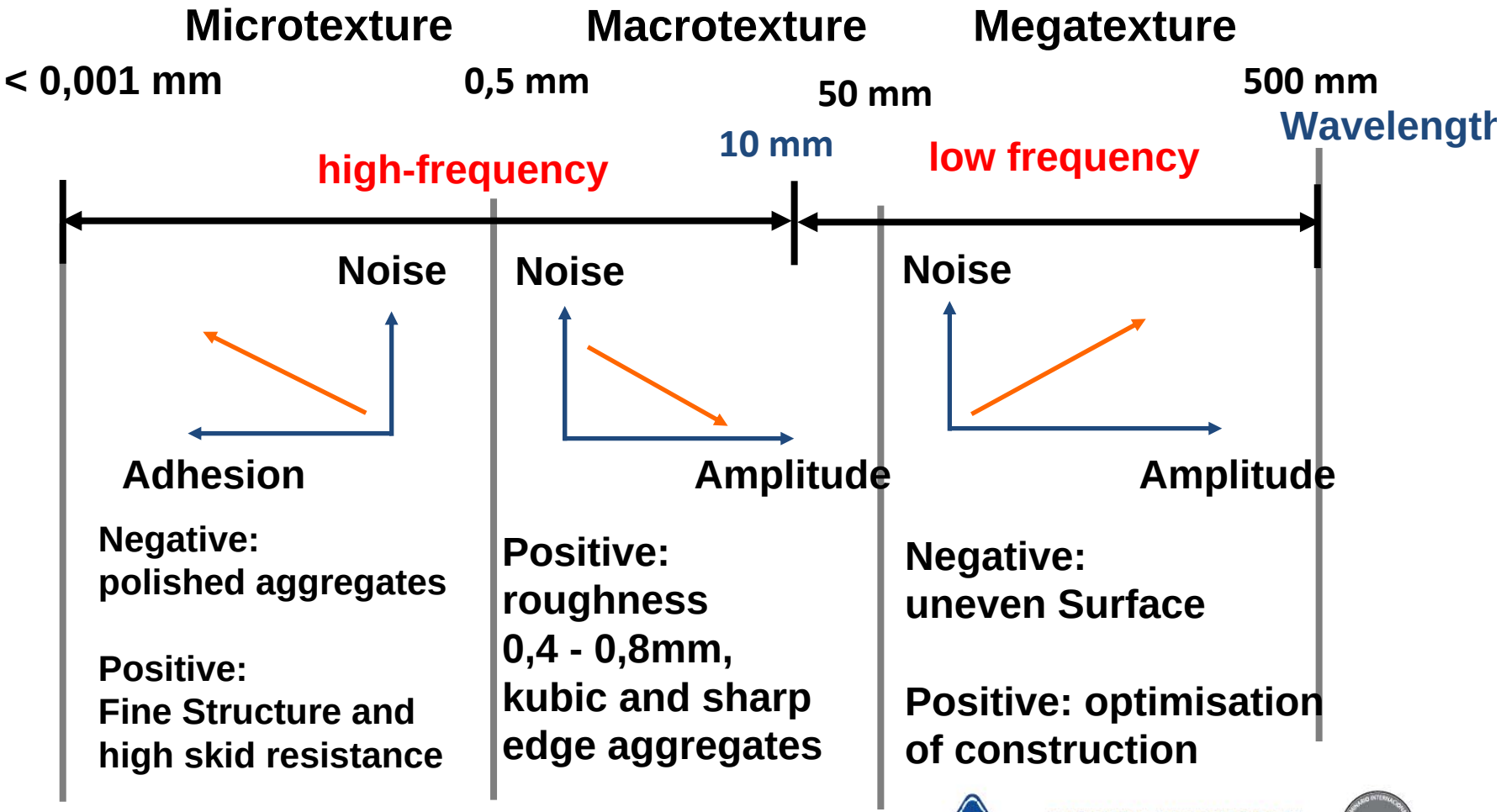
- Slipform Paver + Super Smoother -

+ Burlap - longitudinal

Surface Textures
- Analysis of the Tyre – Road - Noise -

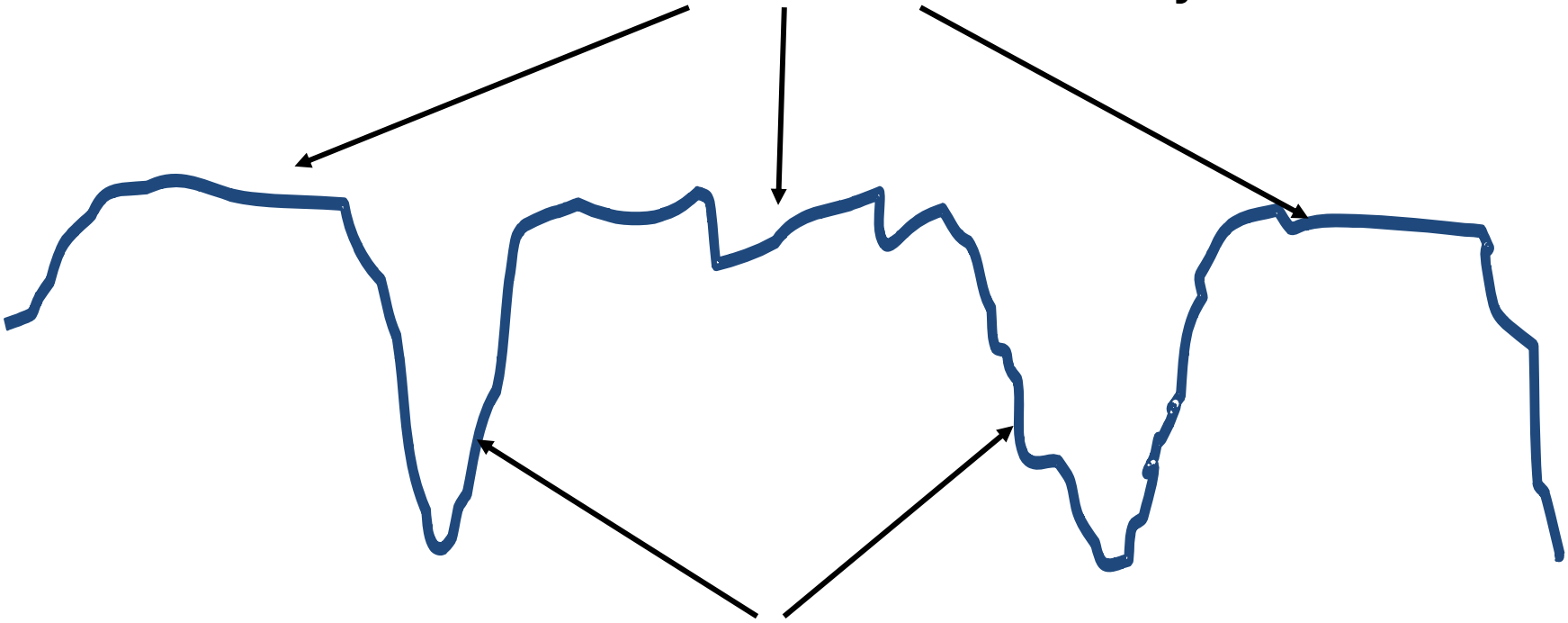


Surface Textures
- Analysis of the Tyre – Road - Noise -



Surface Textures
- The Ideal -

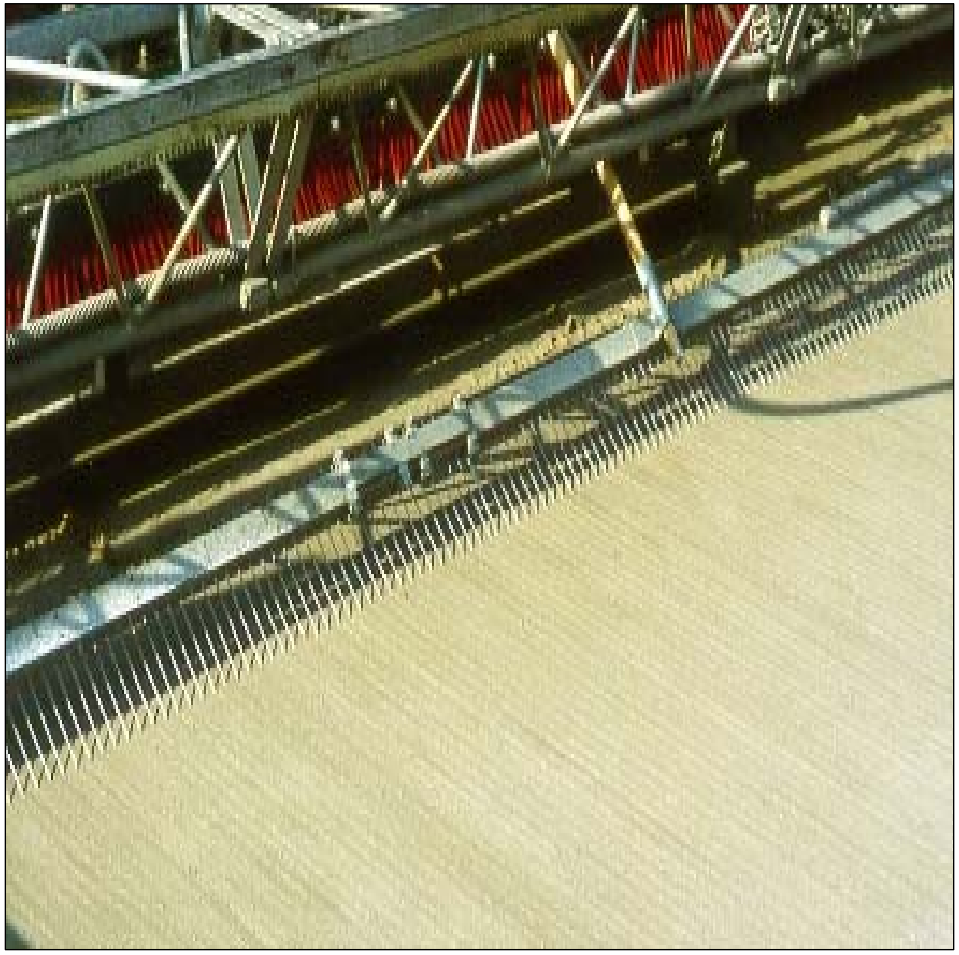
Fine Microstructure
No Mechanical Stimulation of the Tyre



Medium Macrotexture (Gaps)
For Water Evacuation and Air Ventilation

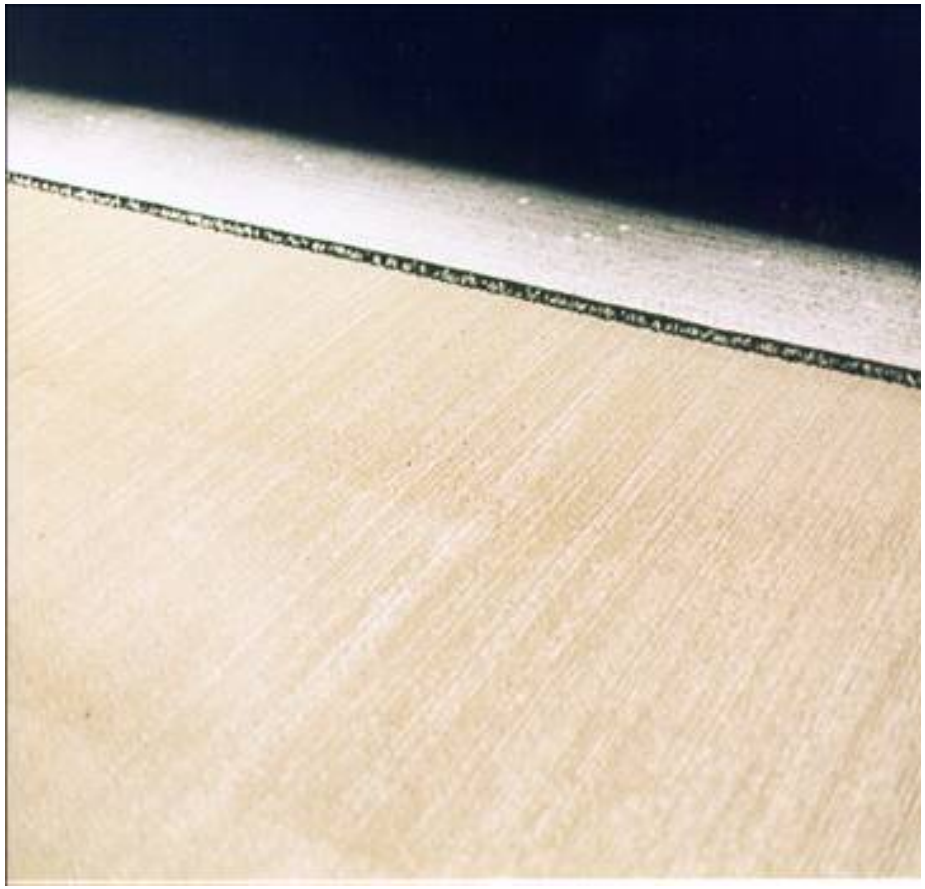
Surface Textures for (2000)

-Different Textures in Combinations,
-e.g.: Hard Plastic Brush + Tining - longitudinal -



Concrete Pavement

Surface Textures 2002
- Artificiale Turf -



Surface Textures
- Grip and Texture Measurement -

Skid Resistance Tester (SRT)

Outflow Meter

Surface Textures
- Grip and Texture Measurement -

Measurement of Skid Resistance

Sideway Force Measurement

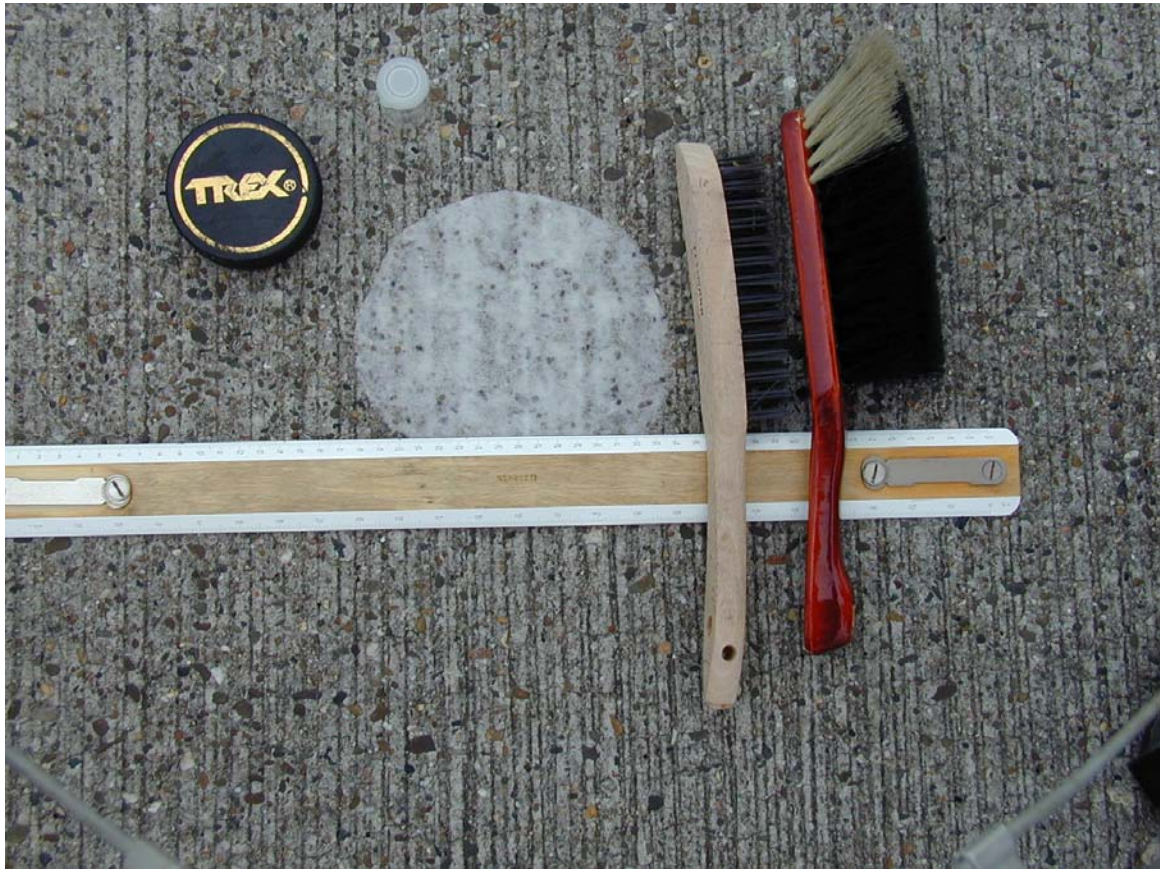
-high-speed measuring system

- skewed test wheel (20°) linear

-continuous data recording

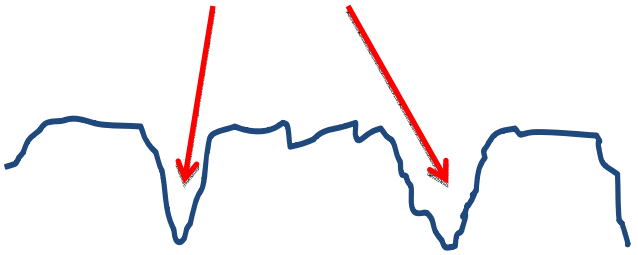
Typical measuring set-up

Surface Textures
- Grip and Texture Measurement -



Sand Patch Method

Volume of Gaps



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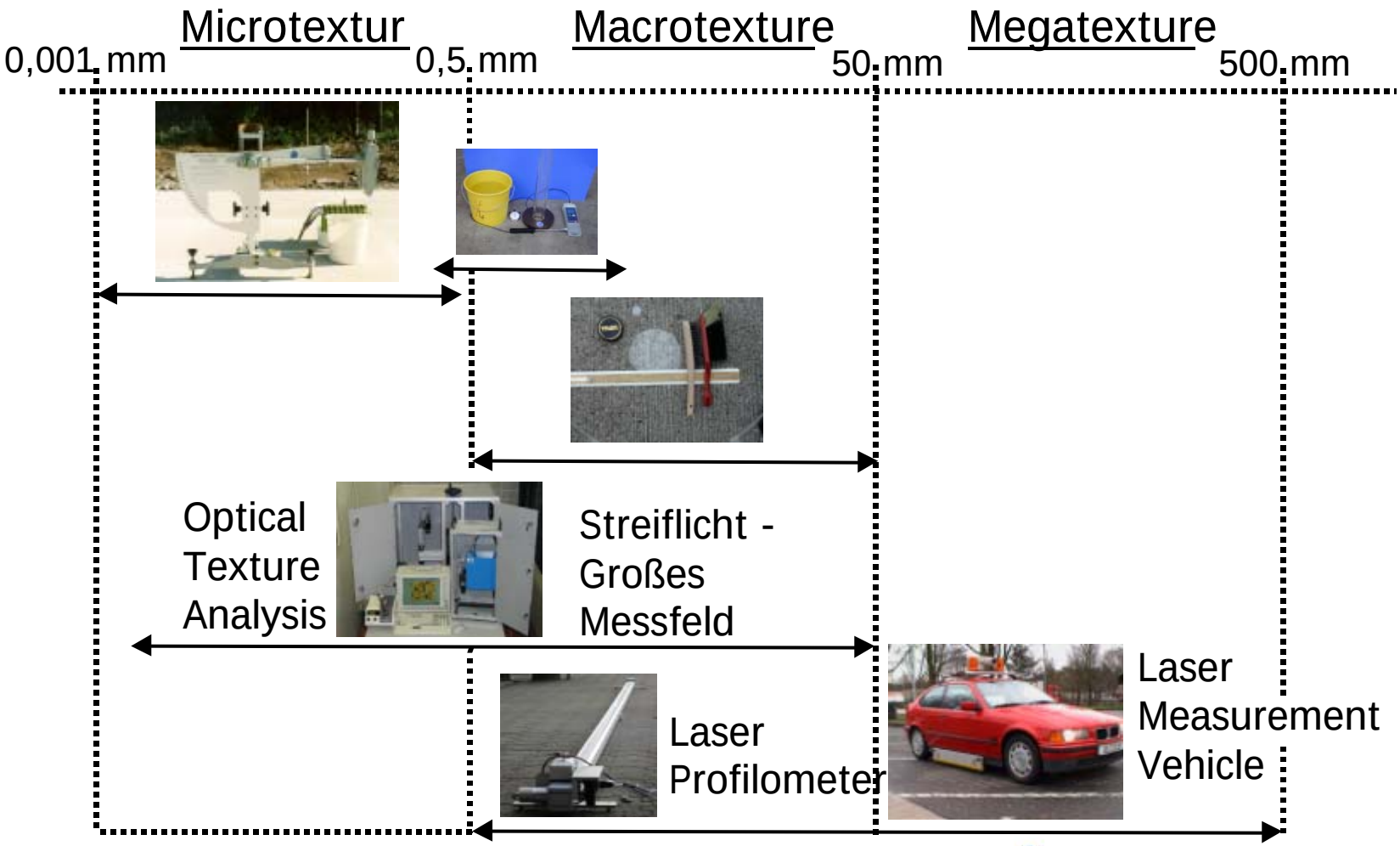
- Grip and Texture Measurement -

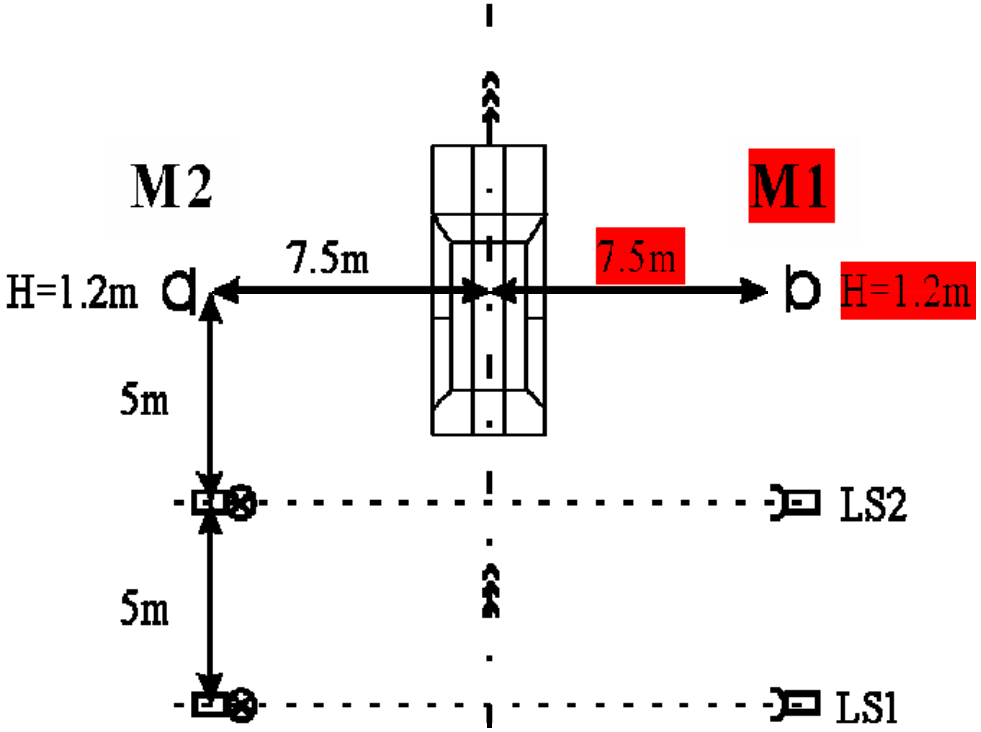


Surface Textures
- Grip Requirements -

Property	Requirement	
Grip	**SCRIM**	
(Construction Acceptance)	μ_{SRIM} (at 40 km/h)	0,56
	μ_{SRIM} (at 60 km/h)	0,51
	μ_{SRIM} at 80 km/h	0,46
	Alternative: SRT + Outflowmeter	
	SRT	60 [-]
	Outflowmeter	30 [s]
Grip	**SCRIM**	
(End of Warranty, 5 Years)	μ_{SRIM} (at 40 km/h)	0,49
	μ_{SRIM} (at 60 km/h)	0,45
	μ_{SRIM} at 80 km/h	0,40

Surface Textures
- Noise Measurement -

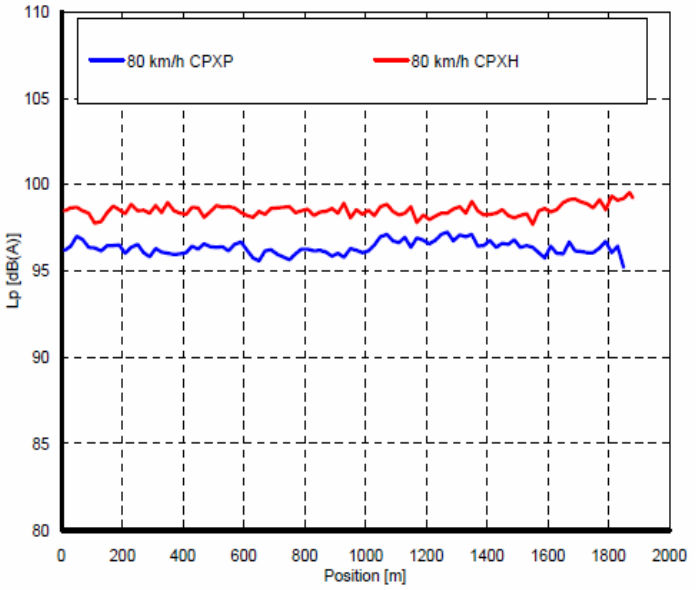
Statistical Pass By (SPB), Currently only Indiviual Cars no Trucks



Concrete Pavement

Surface Textures
- Noise Measurement -

CPX Trailer Measurement, Currently only for Research



Surface Textures
- Noise Requirements -

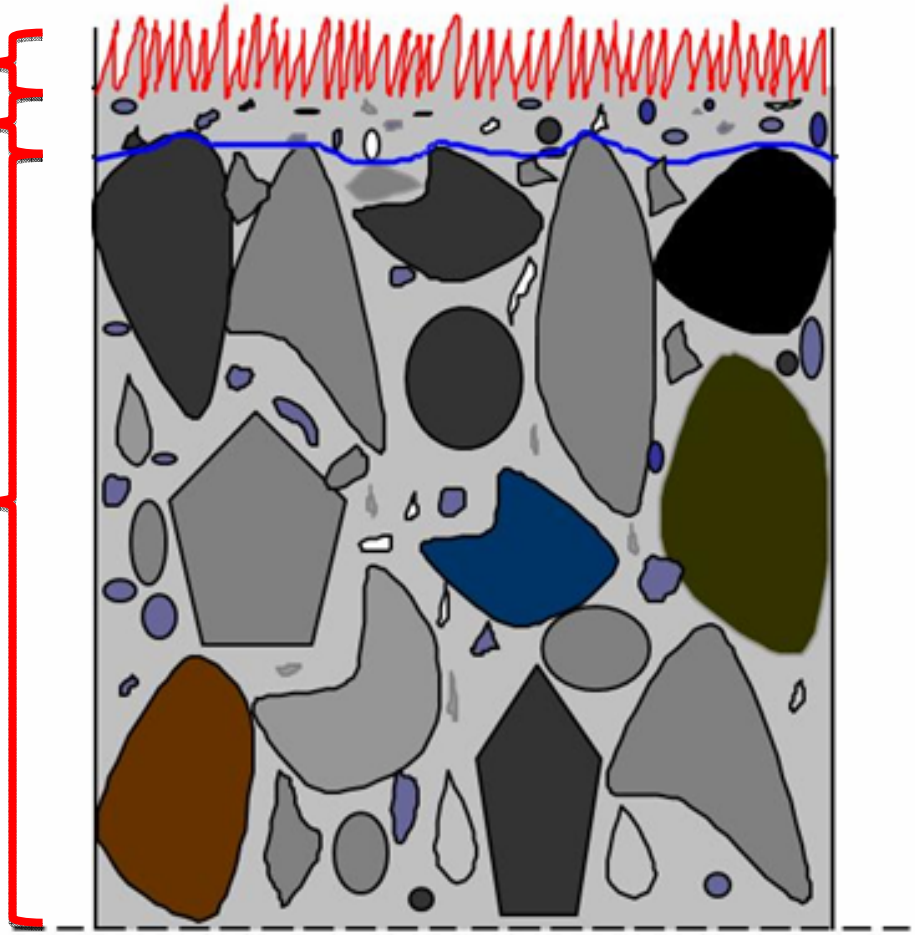
Property	Requirement
Noise	SPB
Reference Surface Texture:	
Ungrooved Mastic Asphalt	+/-0 dB (A)
Concrete Pavment	
Wire Brush - transversal	+ 1 dB (A)
Exposed Aggregate	- 2 dB (A)
Asphalt Pavement	
SMA	- 2 dB (A)

Surface Textures
- Three Stages -

Cement Paste

Cement Paste and Sand

Cement Paste, Sand and Aggregates



Surface Textures
- Exposed Aggregate -

Application of Retarder

Cover with Plastic Sheet

Concrete Pavement

Surface Textures
- Exposed Aggregate -

Application of Retarder and Curing Compound in Combination

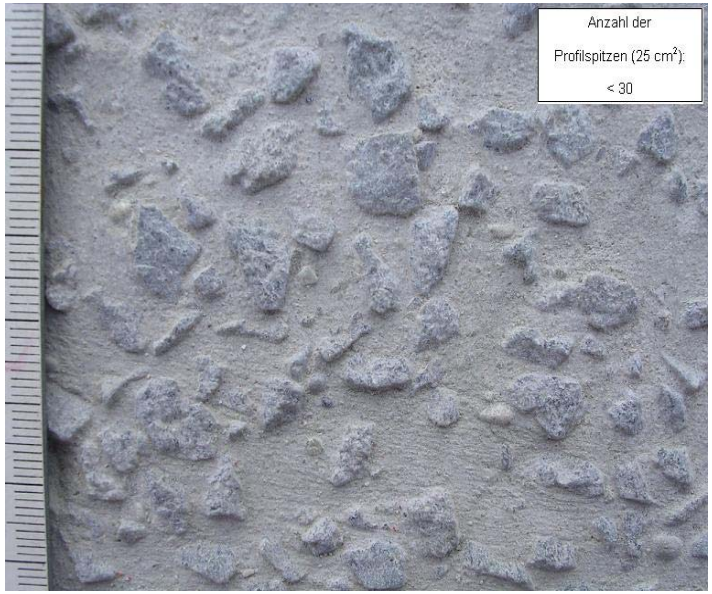
Surface Textures
- Exposed Aggregate -

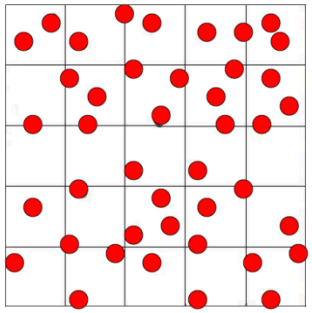
Brushing the Mortar with Water / without Water

Saw Cutting the Joints

Concrete Pavement

Surface Textures
- Exposed Aggregate -





22 Peaks (25 cm²)
Noise Level (SPB) 84,7 dB(A)
inhomogen, noisy

52 Peaks (25cm²)
Noise Level (SPB) 82,4 dB(A)
homogen, silent

Concrete Pavement

Surface Textures

„Manual

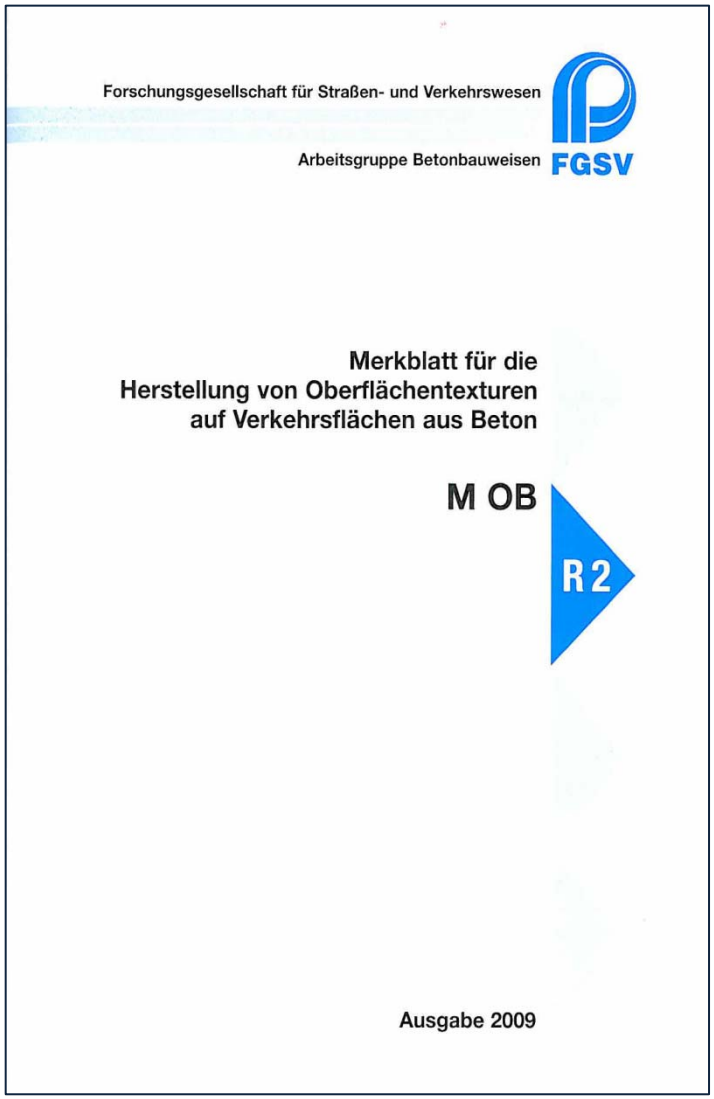
for

Concrete Pavement

Surfaces Textures“

Version 2009

by FGSV, Köln



Content

1.Introduction

2. Concrete Pavement Construction

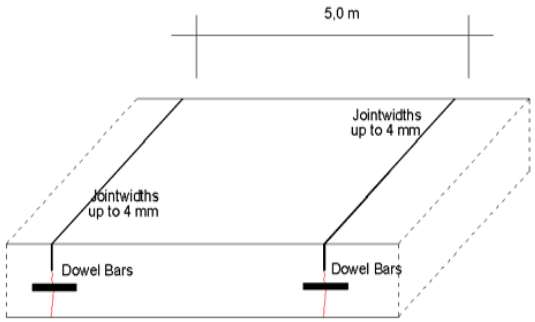
3. Concrete Pavement Surface Texture

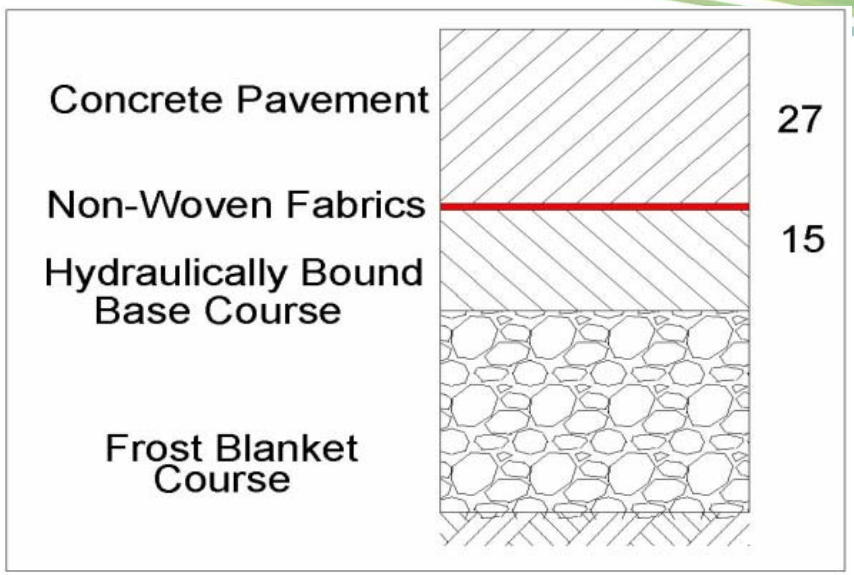
4.Interlayers, Base Course and Drainage

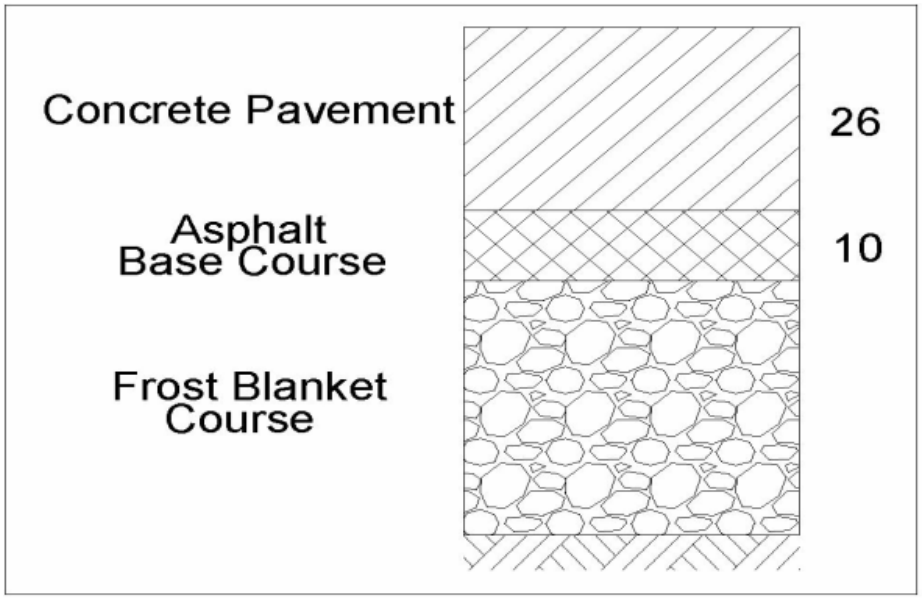
5.Outlook

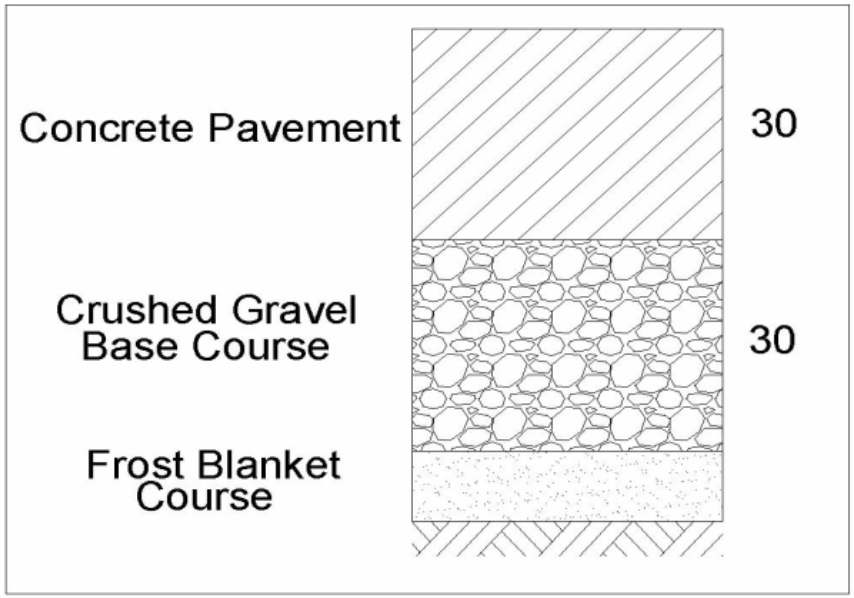
Concrete Pavement

Interlayer , Base Courses and Drainage







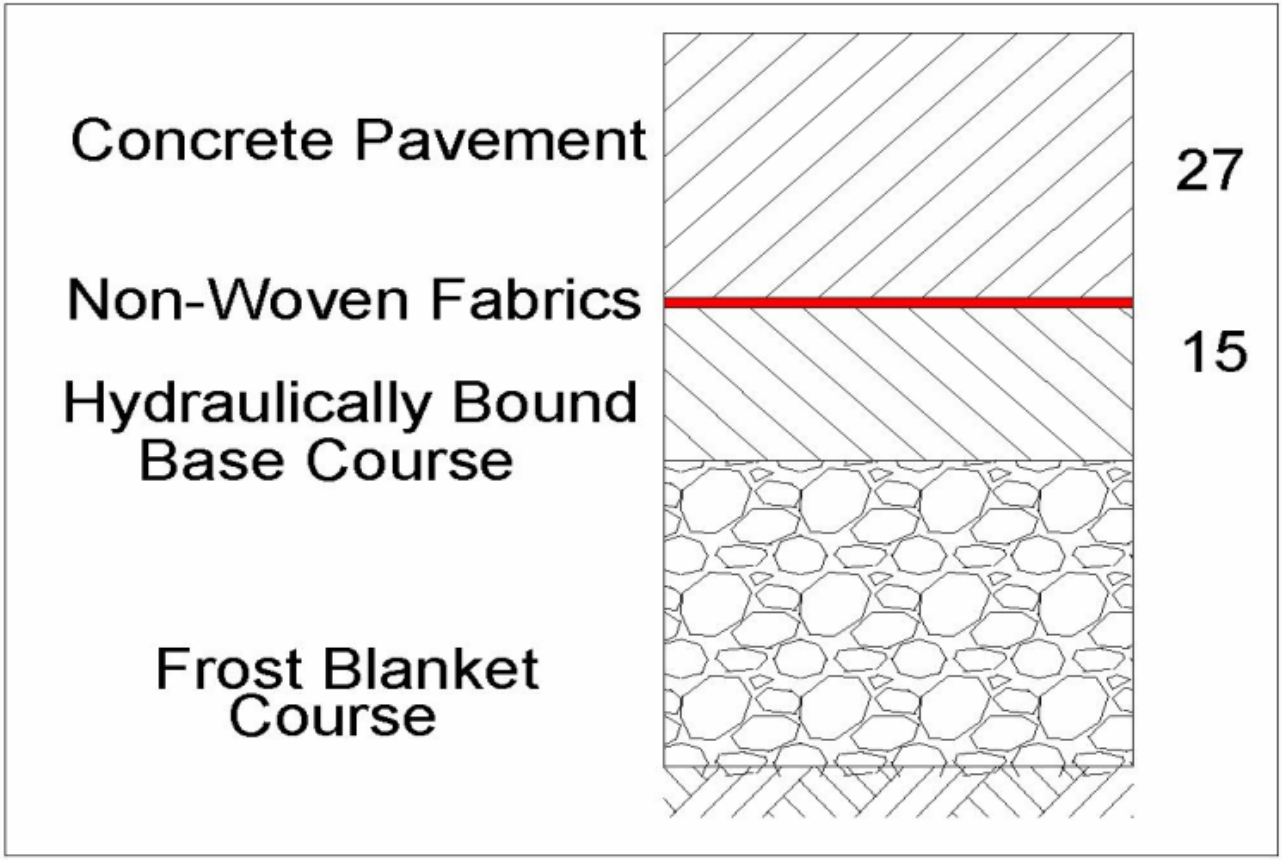


Concrete Pavement on

Hydraulically Bound Base Course / Cement Treated Base Course

With

An Interlayer of Non-Woven Geotextile



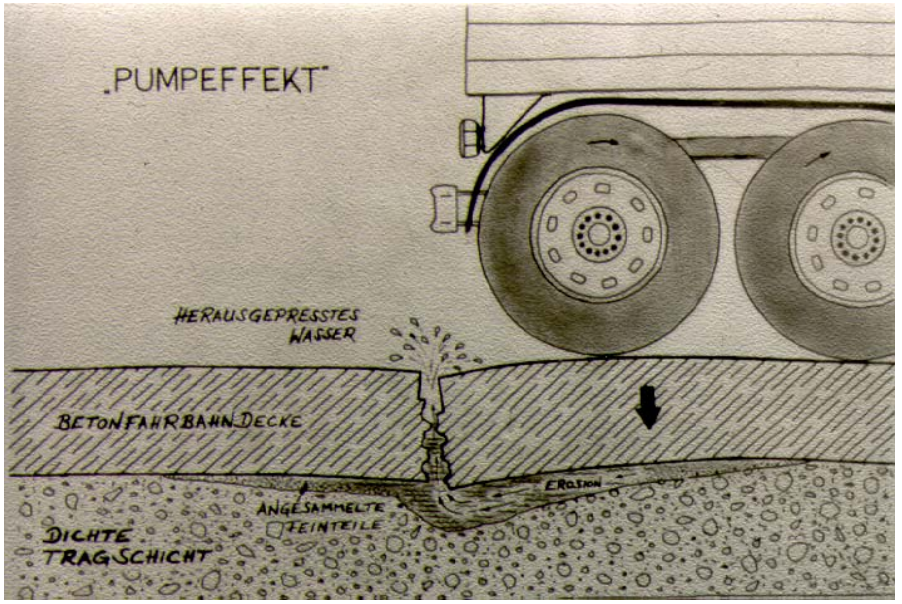
Concrete Pavement on

Hydraulically Bound Base Course / Cement Treated Base with an Interlayer of Non-Woven Geotextile

<u>Before</u>: Concrete Pavement directly on on hydraulically bond base course / cement treated base, <u>Problems at the interface:</u>:

<u>In the Beginning:</u>
Separation and Waterpumping

<u>Finally</u>: Erosion and Loss of Structural surpport



Concrete Pavement on

Hydraulically Bound Base Course / Cement Treated Base Course

With

An Interlayer of Non-Woven Geotextile

- History -

Concrete Pavement on

Hydraulically Bound Base Course / Cement Treated Base with an Interlayer of Non-Woven Geotextile - 3 Functions of the Nonwoven Geotextile Interlayer -

1. Separation
2. Elastic Bedding
3. Drainage

Concrete Pavement on

Hydraulically Bound Base Course / Cement Treated Base with an Interlayer of Non-Woven Geotextile

Cement Treated Base Course, mixed in place

Hydraulically Bound Base Course, mixed in plant

Concrete Pavement on

Hydraulically Bound Base Course / Cement Treated Base Course

- Requirements -

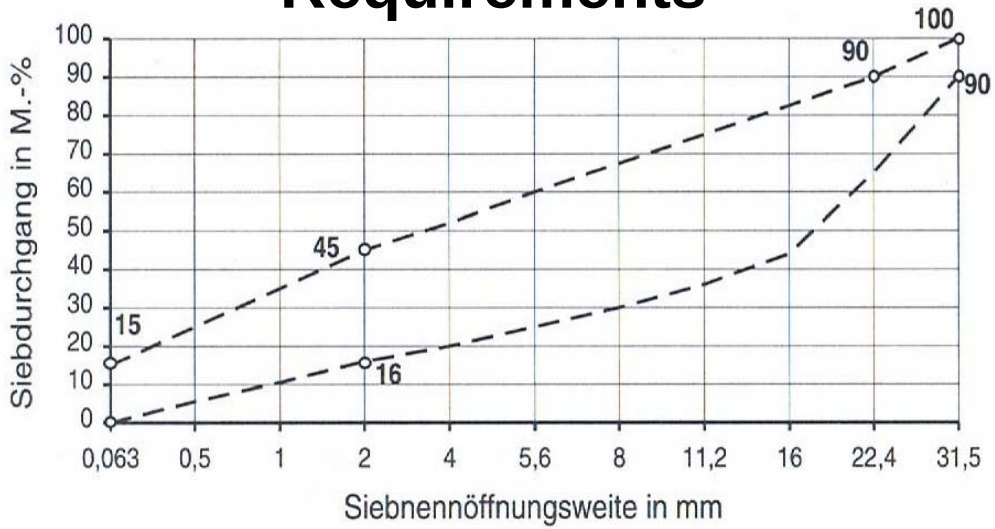


Bild 1: Sieblinienbereich der Baustoffgemische für hydraulisch gebundene Tragschichten 0/32

Grading Curve:
only Hydraulically Bound Base Course

Property	Requirement
Grain Size	0-32 mm, 0-45 mm
	(only Hydraulically Bound Base Course)
Fines	max. 5 % by m.
(< 0,063 mm)	max. 15 % by m.
	=>Frost test required
Cement Content	min. 3,0 % by m.
Compressive Strength	15 N/mm² (28 Days)

Property	Requirement
Layer Thickness	15 cm, 20 cm, 25 cm +/- 3,0 cm
Compaction Degree	≥ 100 %
Eveness	< 1,5 cm /4 m
Defined Surface	max. + 0,5 cm
	min. - 1,5 cm

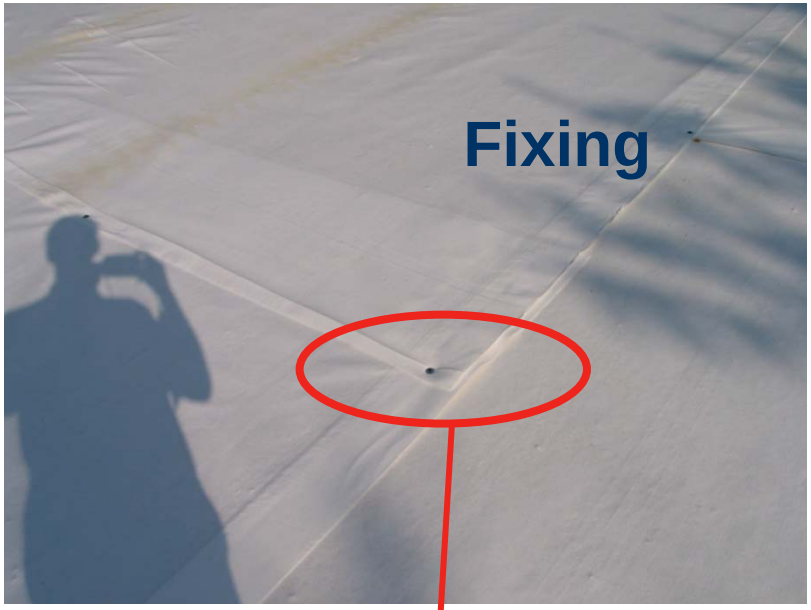
Installation of Non-Woven Geotextile

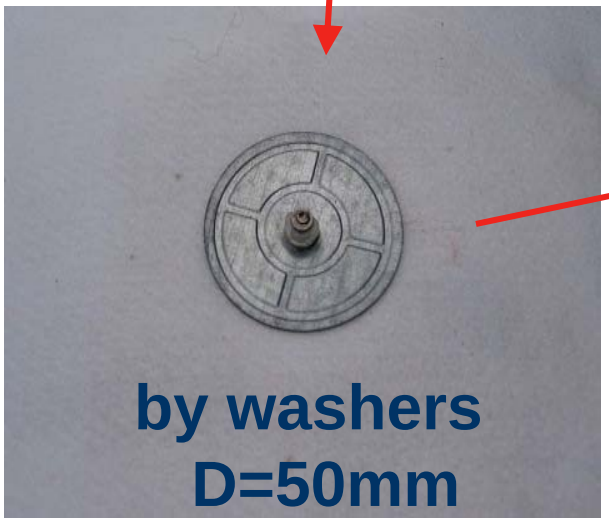
Concrete Pavement Surface on Non-woven Geotextile Interlayer

Semi-mechanical Installation of Non-woven Geotextile

Turning Points Outside the installed Non-woven Geotextile

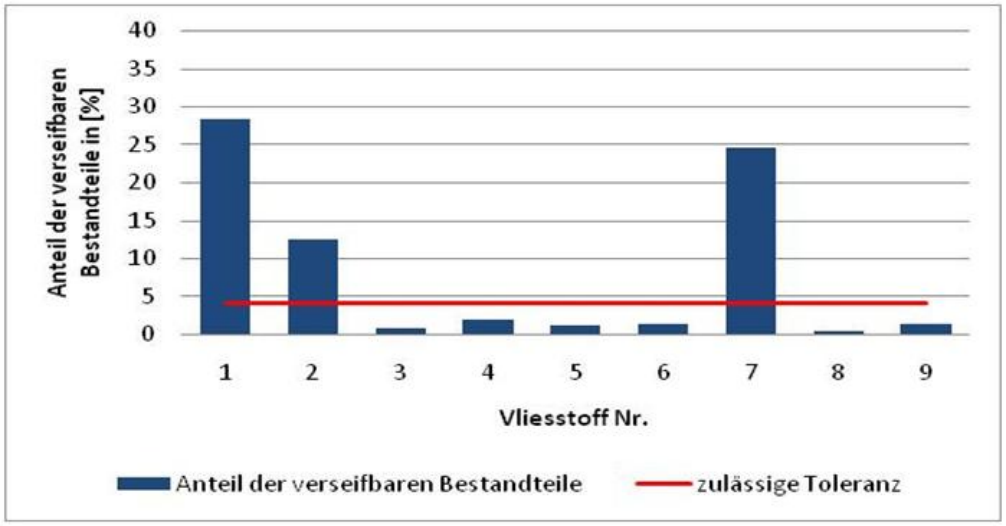
Fixing of Non-Woven Geotextile





- Production of Non-Woven Geotextile -

Non-Woven Geotextile manufactured with multicolor fibers: Completely Alkali Resistant?

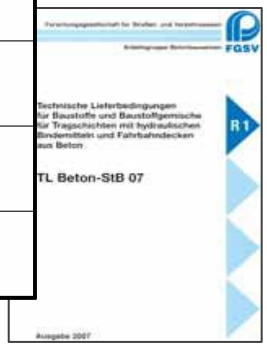


Additives During manufacturing: 100% Polyolefine?

- Requirements for Non-Woven Geotextile -

for the Non-Woven Geotextile Product

Property	Requirement
Mas per Unit Area	450 g/m² ≤ $m_{A,5\%}$ ≤ 550 g/ m²
Thickness for Load of 2 / 20 / 200 kN/m²	$d_{2,5\%}$ ≥ 3 mm
	$d_{20,5\%}$ ≥ 2,5 mm
	$d_{200,5\%}$ ≥ 1 mm
Maximum Tensile Strength	$F_{z,5\%}$ ≥ 10 kN/m
Maximum Elongation	$\varepsilon_{z,k,5\%}$ ≤ 130 %
Water Permeability normal to the Plane at a Load of 20 kN/m²	$k_{V,20,\ 5\%}$ ≥ 1 * 10 -4 m/s
Drainage Capacity at a Plane at a Load of 20 / 200 kN/m²	$k_{H,20,\ 5\%}$ ≥ 5 * 10 -4 m/s; $k_{H,200,\ 5\%}$ ≥ 2 * 10 -4 m/s
Weather resistance	Residual Strength ≥ 60%
Alakali Resistance	min. 96 % PP / PE
typ of Non woven Geotextile	no Multi Color Products



for the Installation of the Interlayer

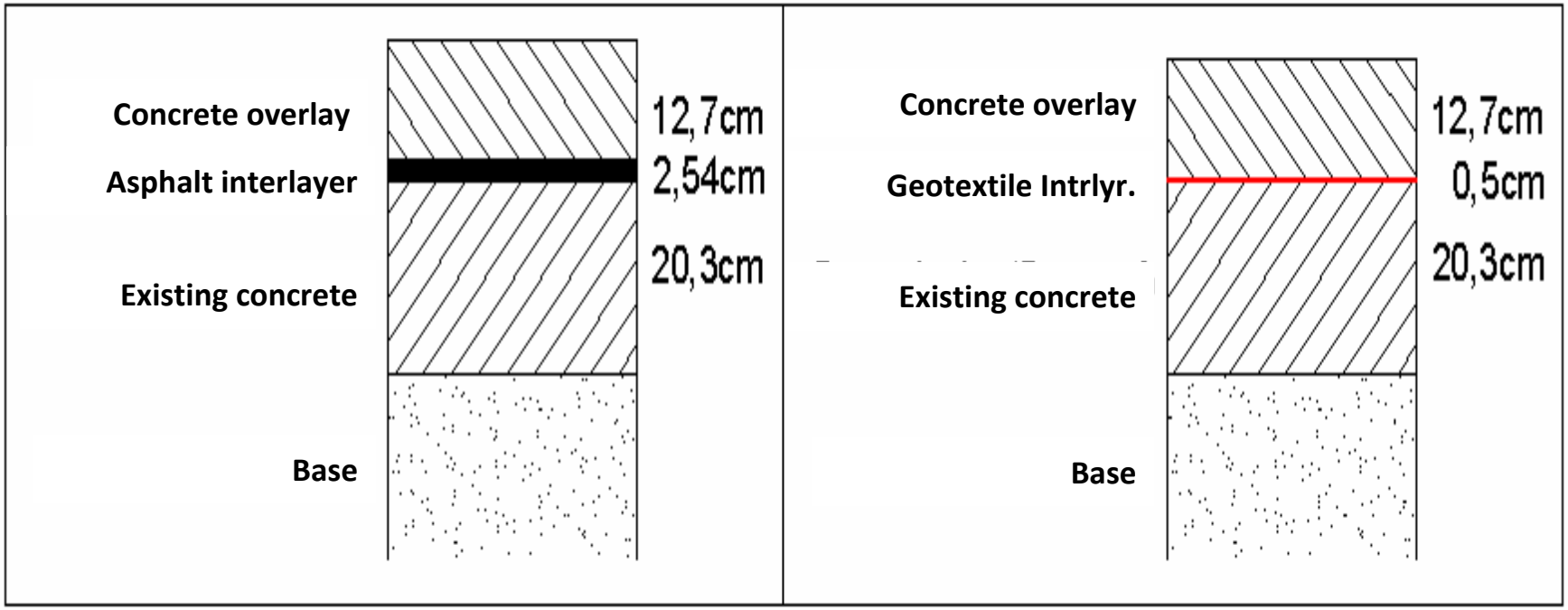
Property	Requirement
placement	tight without creasing
fixing	with nails and washers
overhang sideways	10cm +/-5cm
Overlapp	20cm+/5cm
Quadruple overlaps	not Permissible

Trial applications in the USA

Test Section 1: Route D in Kansas City, Missouri (2008)
-Overlay technique –

(Overlay of a damaged concrete pavement with a concrete overlay)

Before: Asphalt interlayer **Now: Geotextile interlayer**

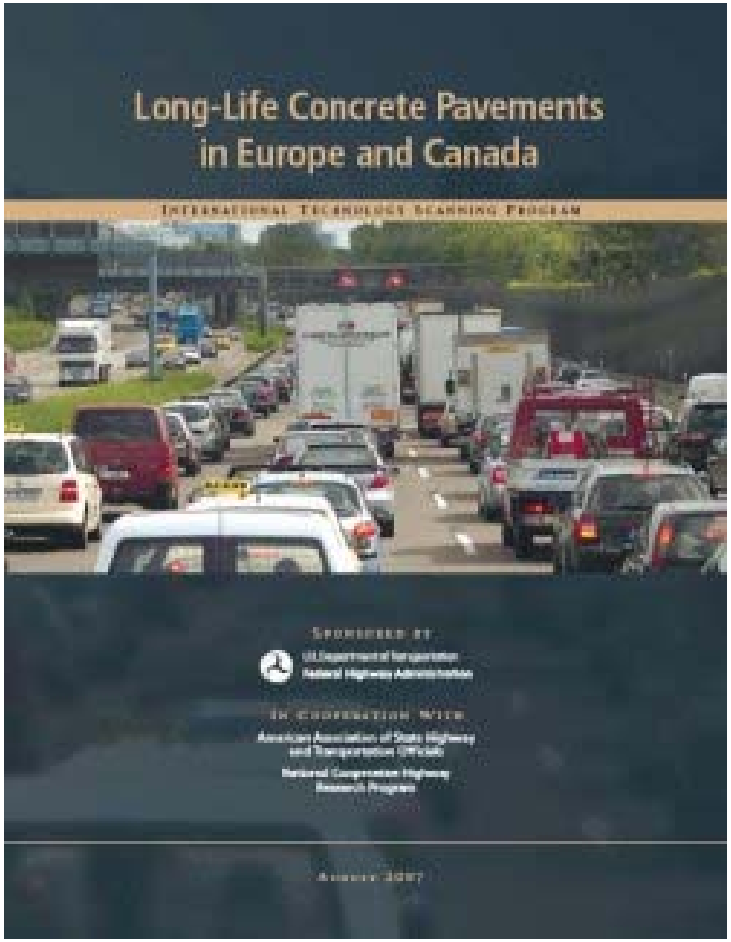


Trial applications in the USA

Test section 2: Interstate 40 in Warner, Oklahoma (2008)

-New construction (on cement-treated base) –

Concrete placement



Concrete Pavement

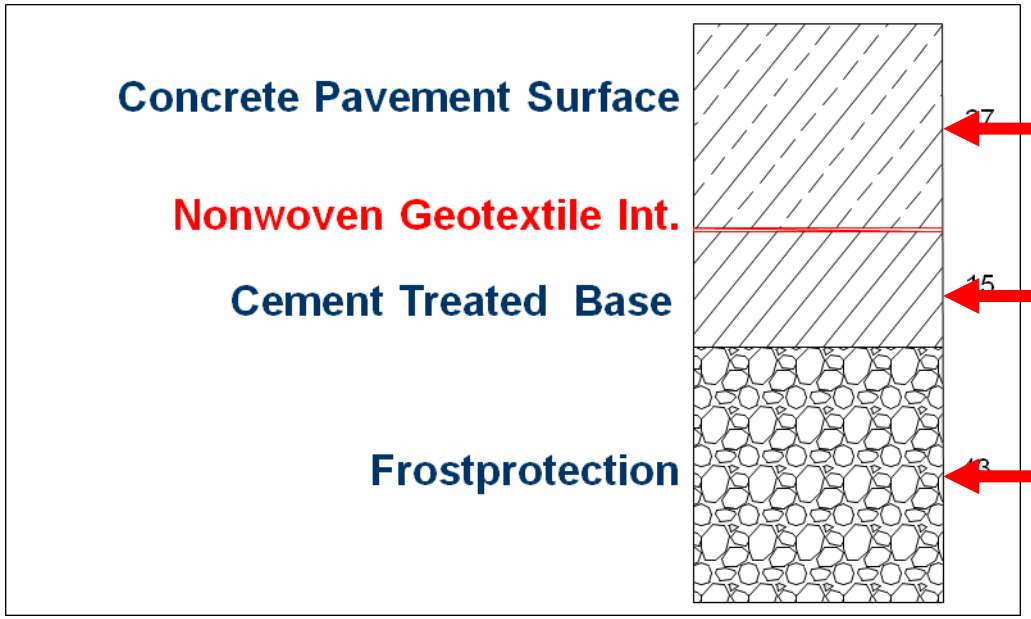
on hydraulically bond base course / cement treated base

with

an interlayer of Non-Woven Geotextile

- Recycling -

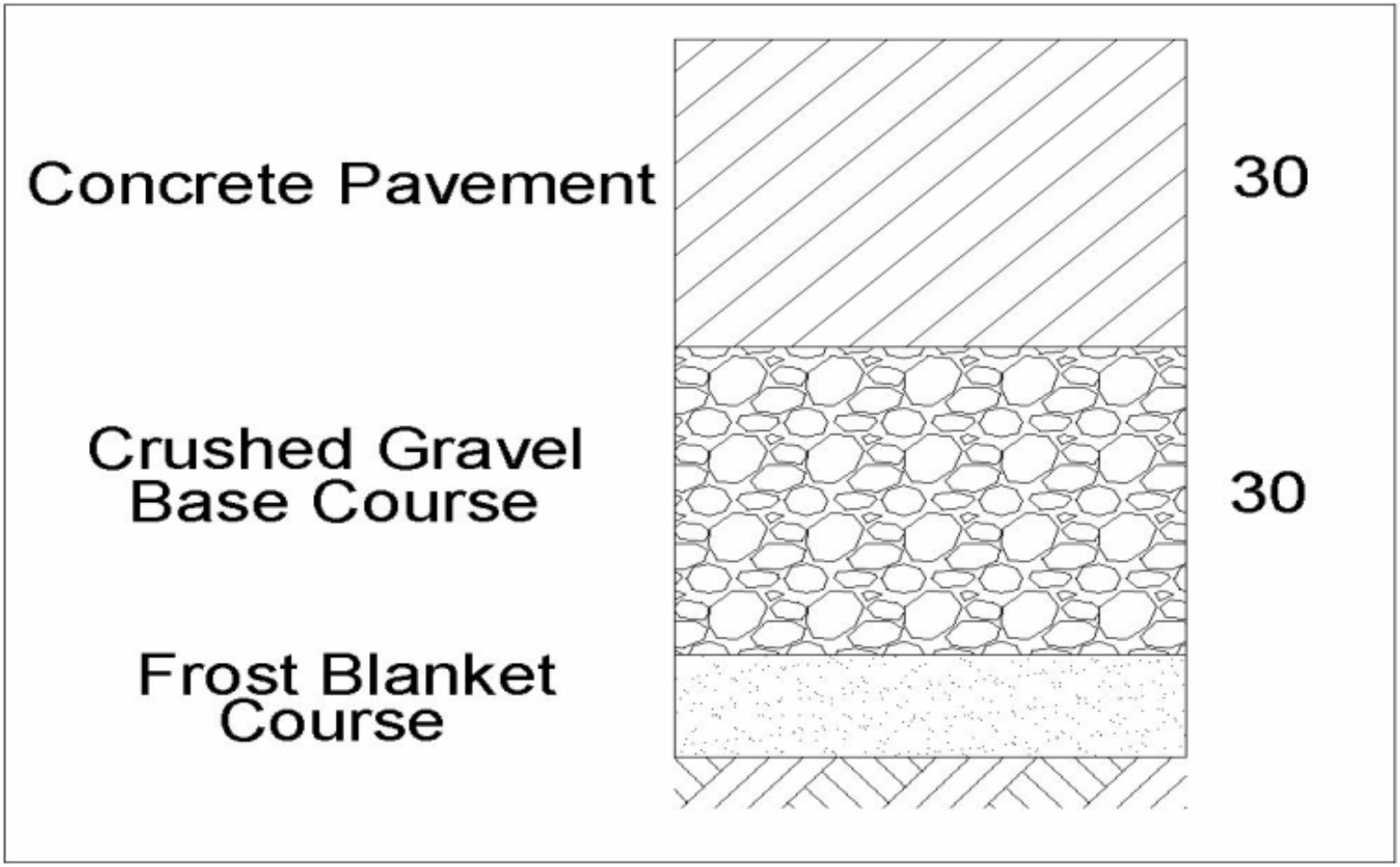
Possibilities of using RC-Aggregates



Adhesion to the Concrete Pavement and the Base Course

Concrete Pavement with

Crushed Gravel Base Course



Concrete Pavement on

Crushed Gravel Base Course
- Research on the drainage behavior -

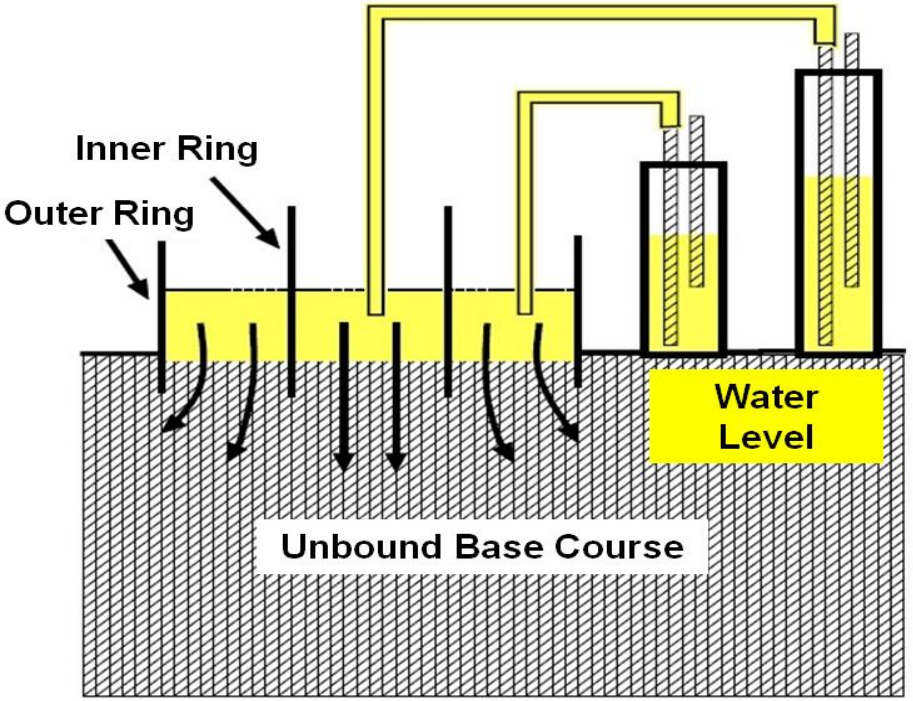
the idea

the reality

Concrete Pavement on

Crushed Gravel Base Course
- Research on the Drainage Behaviour -

„Double-Ring“ Infiltration



Concrete Pavement on

Crushed Gravel Base Course

- Requirements -

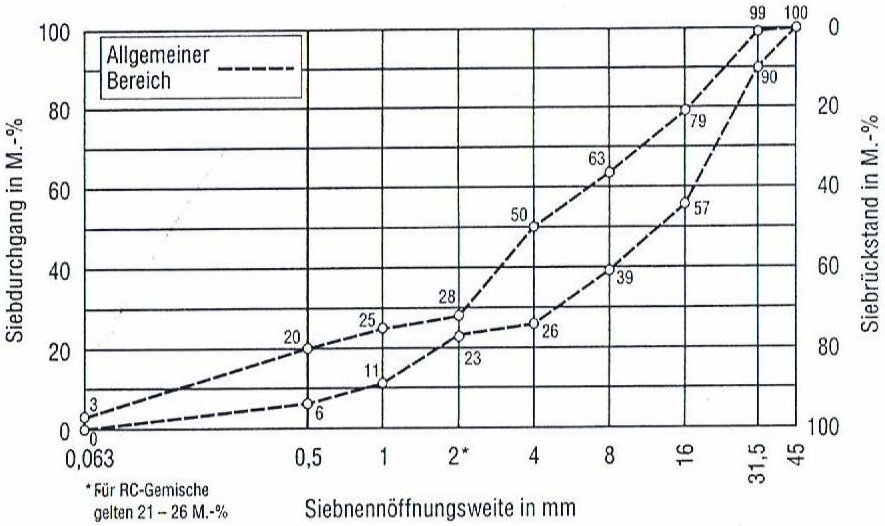


Bild C.2: Baustoffgemisch 0/32 für Schottertragschichten unter Betondecken

Property	Requirement
Grain Size	0-32 mm, 0-45 mm, 0-56 mm
Fines (< 0,063 mm)	max. 5 % by m.
CBR-Value	≥ 80 %

Property	Requirement
Layer Thickness	30 cm, 20 cm, 25 cm +/- 3,0 cm
Compaction Degree	≥ 103 %
Deformation Modulus	E_{V2} = 180 N/mm²
Eveness	2,0 cm / 4 m
Defined Surface	max. +/- 2,0 cm

Concrete Pavement on

Crushed Gravel Base Course
- Construction Site -

Grader

Finisher

Concrete Pavement on

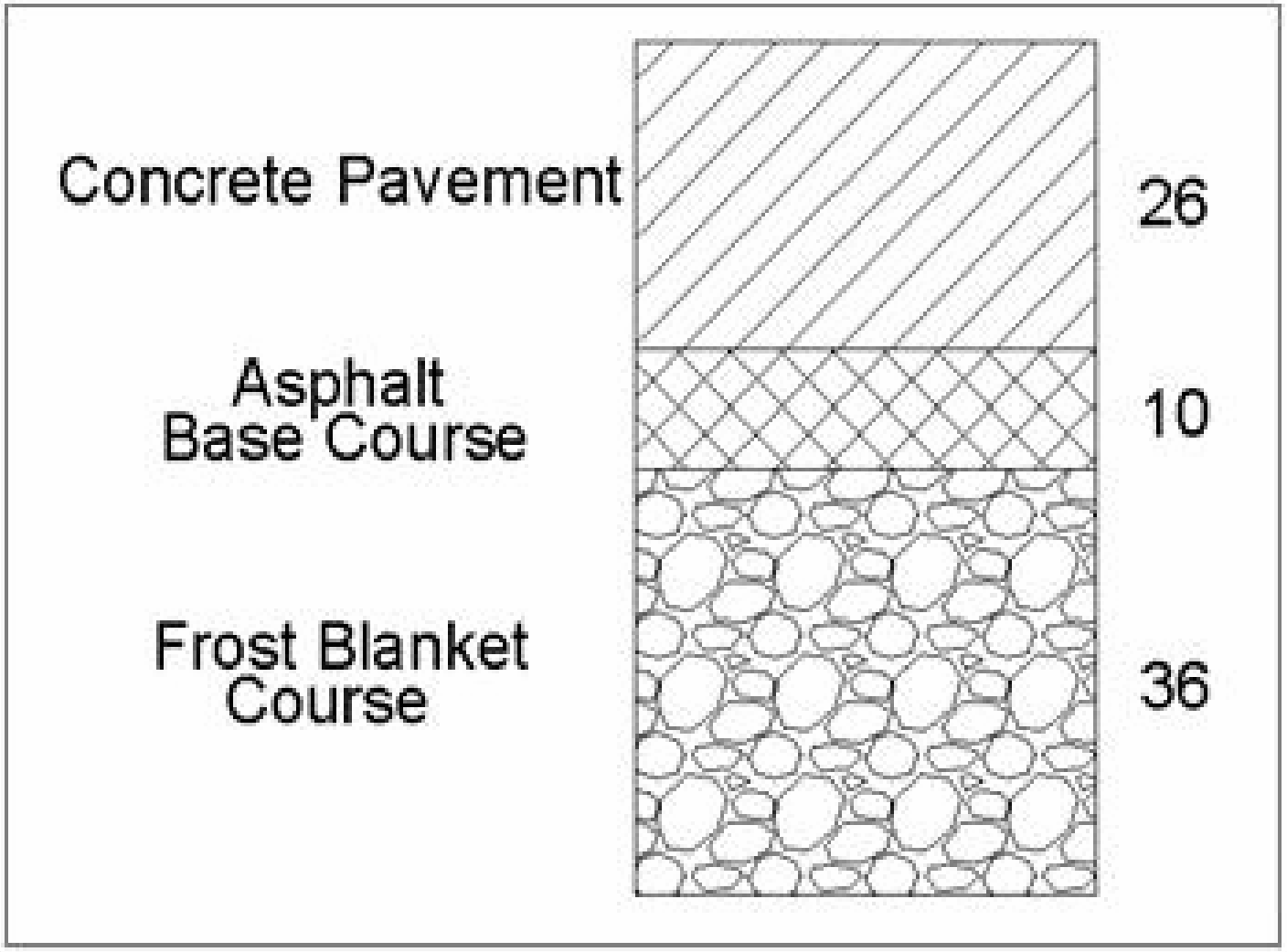
Crushed Gravel Base Course
- Traffic on Construction Site -

Concrete Pavement on

Crushed Gravel Base Course
- Recycling -

Concrete Pavement on

Asphalt Base Course



Concrete Pavement on

Asphalt Base Course
-Construction Site –

Finisher

Roller Compaction

Concrete Pavement on

Asphalt Base Course
-Requirements –

Property	Requirement
Bitumen	30/45; 50/70; 70/100
Grain Size	0-16 mm, 0-22 mm, 0-32 mm
Fines	max. 10 % by m.
Binder Content	min. 3,8 % by m.
Void Content	min. 4 % by v.
	max. 10 % by v.

Property	Requirement
Layer thickness	10cm +/- 2,5cm
compaction degree	≥ 97 %
Eveness	max. 10 mm
Defined surface	max. + 0,5 cm
	min. - 1,5 cm

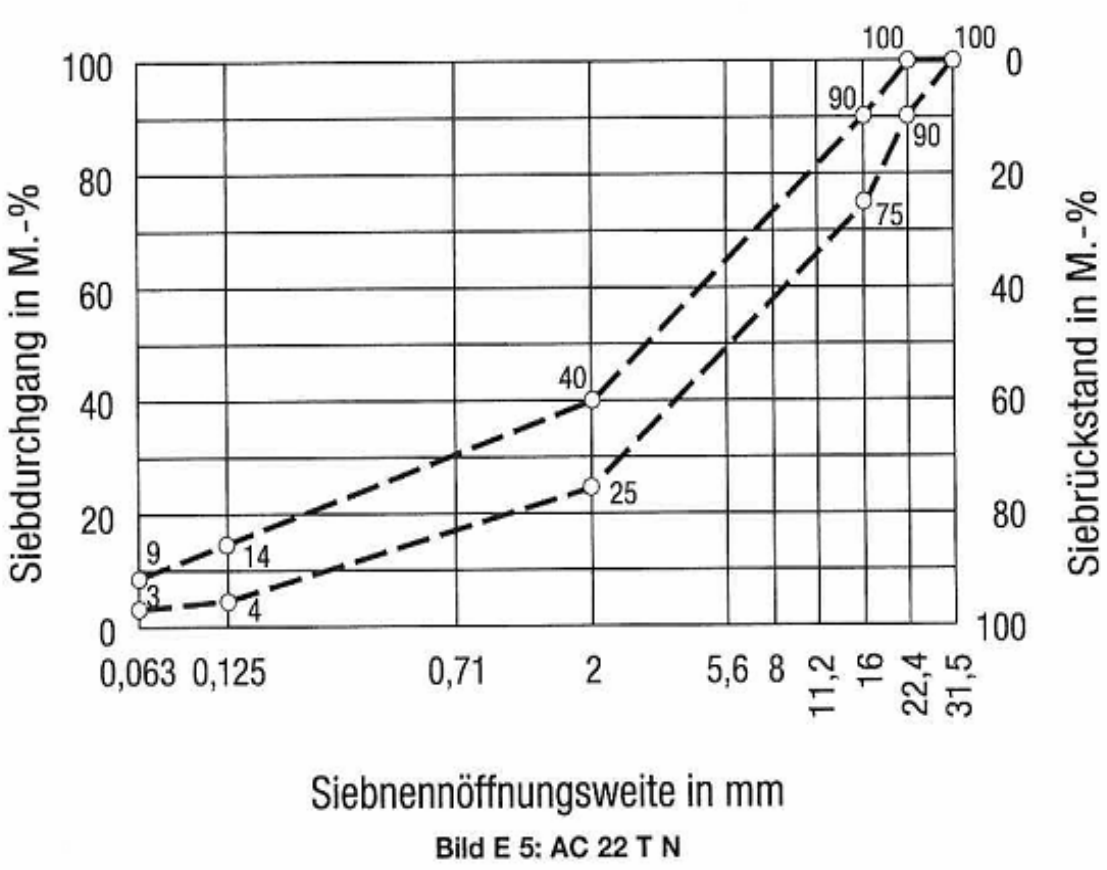


Bild E 5: AC 22 T N

Content

1.Introduction

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Concrete Pavement Innovations

-Poures Concrete –

Modified Asphalt Paver

Air Void Content 23 % b. vol.

Concrete Pavement Innovations

-Diamond Grinding –

Concrete Pavement Innovations

- Epoxy Coating with Chrome-Ore Slag –

Thank You for Your Kind Attention!

Questions?

hoellers@bast.de