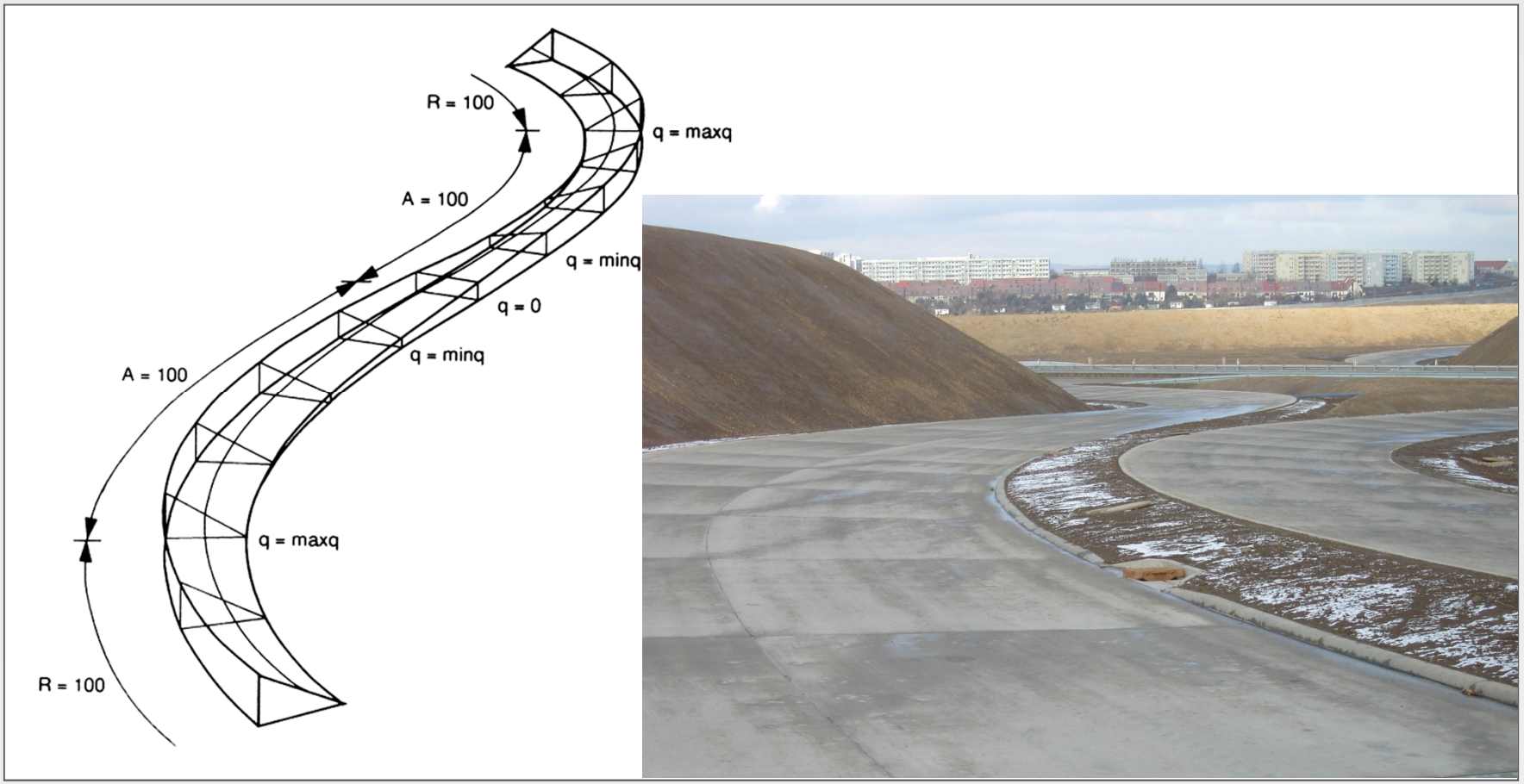
„Drainage of road surface on 6 or more lane motorways, measures against aquaplaning”

Rural Roads Design meeting nr 5.
on April 3th to 4th 2014 in Kopenhagen

Univ.-Prof. Dr.-Ing. Christian Lippold
Dipl.-Ing. Anne Vetters

Zones of low drainage



Measures on Critical Water Film Thickness

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- Special form of transition „rolling crown“
- Speed limit on wet road surface

Problem in our guidelines RAA

- The planing engineer has to select the measure.

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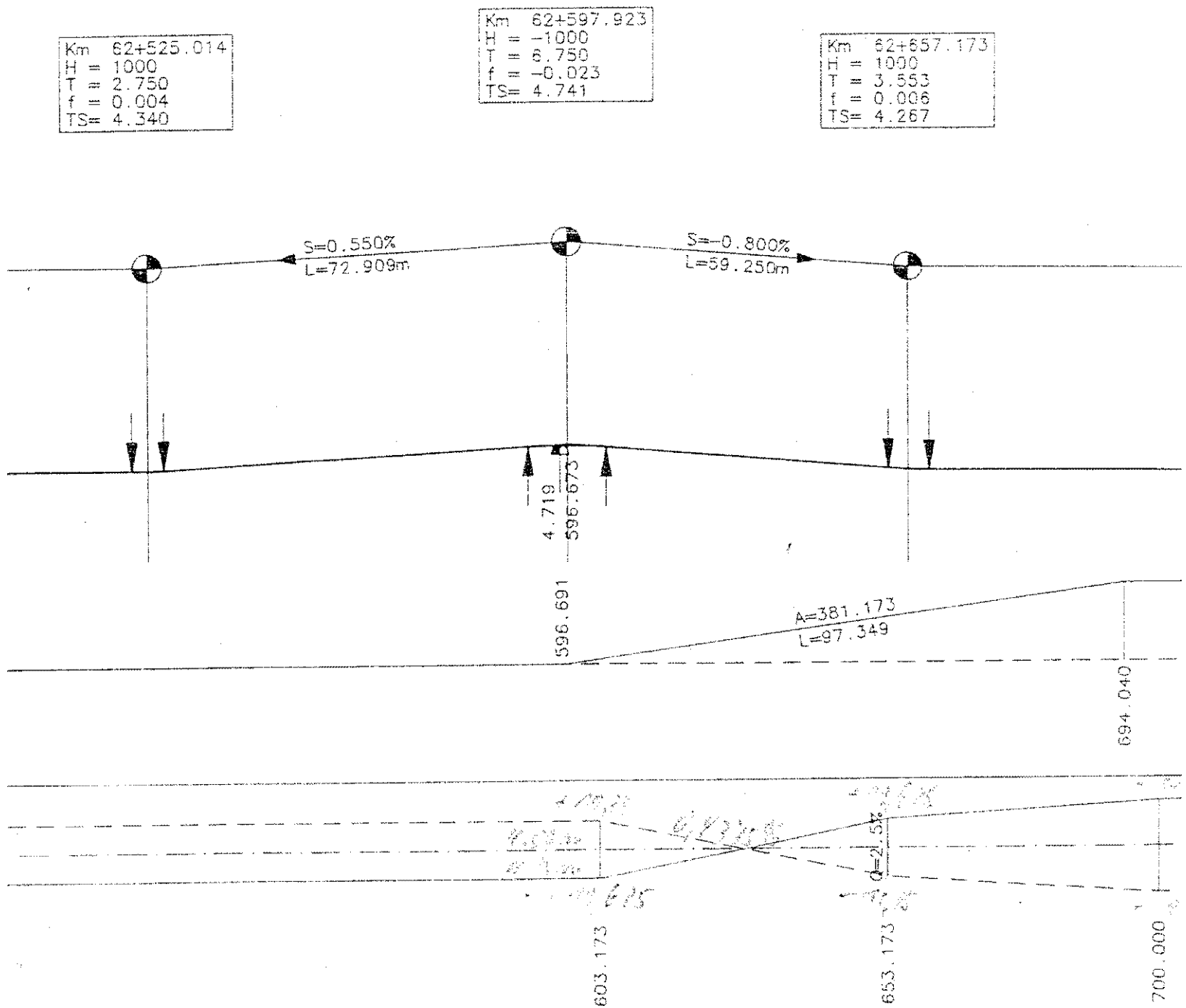
- There are no boundary conditions for selection.
- There is no information about effectiveness, sustainability and economic.
- There is no information to possible combinations of different measures.
- The different road authorities in Germany prefer different measures – there is no consistent opinion.

Research goal / target

- Evaluation of different measures,
- Evaluation of effectiveness
- Evaluation of sustainability
- Evaluation of economic
- Recommendations for the choise of suitable measures or perhaps for combinations of measures which depend on different geometric conditions

Measures for Critical Water Film Thickness

- **Increase of longitudinal gradient**,
- Open-pored top layer (porous asphalt),
- Engineering drainage measures (rectangular gutter),
- Avoidance of superelevation transition by application of negative superelevation with very large radii,
- Special form of transition „rolling crown“
- Speed limit on wet road surface


Km 62+525.014
H = 1000
T = 2.750
f = 0.004
TS= 4.340
Km 62+597.923
H = 1000
T = 6.750
f = -0.023
TS= 4.741
Km 62+657.173
H = 1000
T = 3.553
f = 0.006
TS= 4.267
S=0.550%
L=72.909m
S=-0.800%
L=59.250m
4.719
596.673
596.691
A=381.173
L=97.349
694.040
603.173
653.173
700.000

Increase of longitudinal gradient

Advantage

- inexpensive

Disadvantage

- only on short length
- Only new construction, very difficult in reconstruction

Measures for Critical Water Film Thickness

- Increase of longitudinal gradient,
- **Open-pored top layer (porous asphalt)**,
- Constructional measures for drainage (rectangular gutter),
- Avoidance of superelevation transition by application of negative superelevation with very large radii,
- Special form of transition „Schrägverwindung“
- Speed limit on wet road surface

Open-pored top layer (pourus asphalt)

Open-pored top layer (pouros asphalt)

Advantage

- high effectiveness

Disadvantage

- very expensive
- high demands on the quality of construction
- low permanency / sustainability
- only for asphalt-construction, not for cement-concrete-construction

Measures for Critical Water Film Thickness

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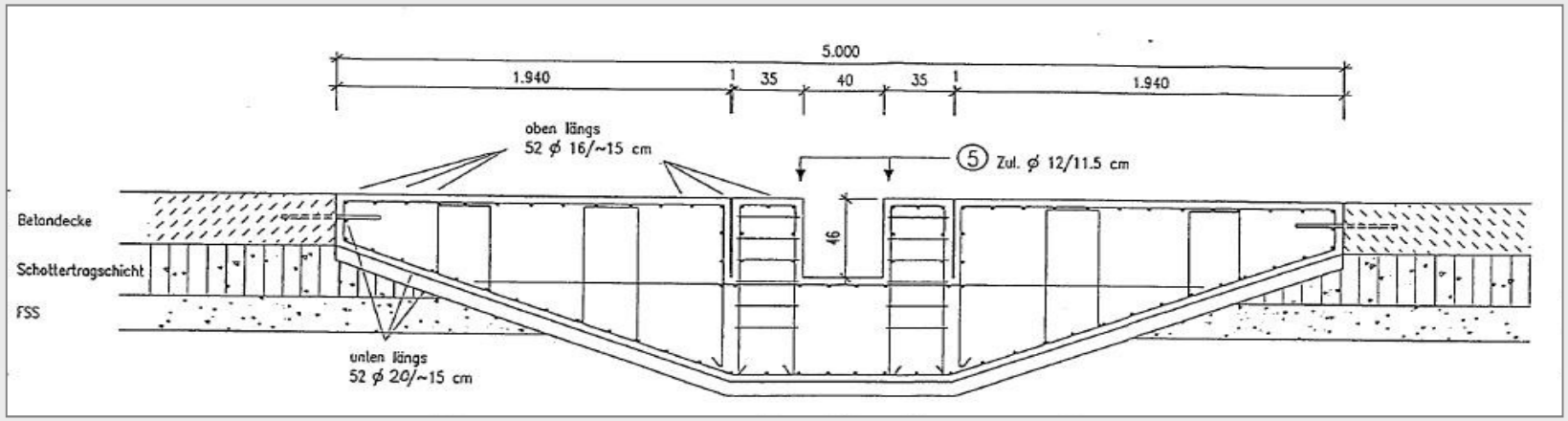
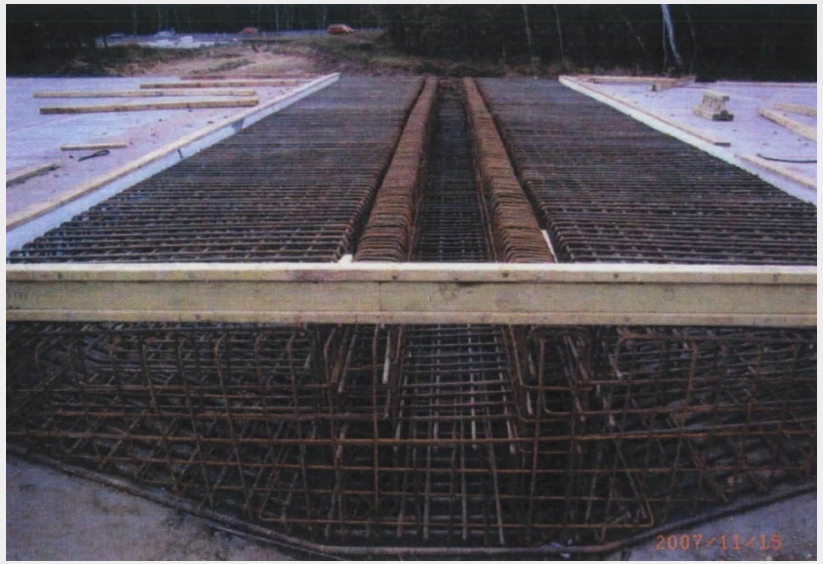
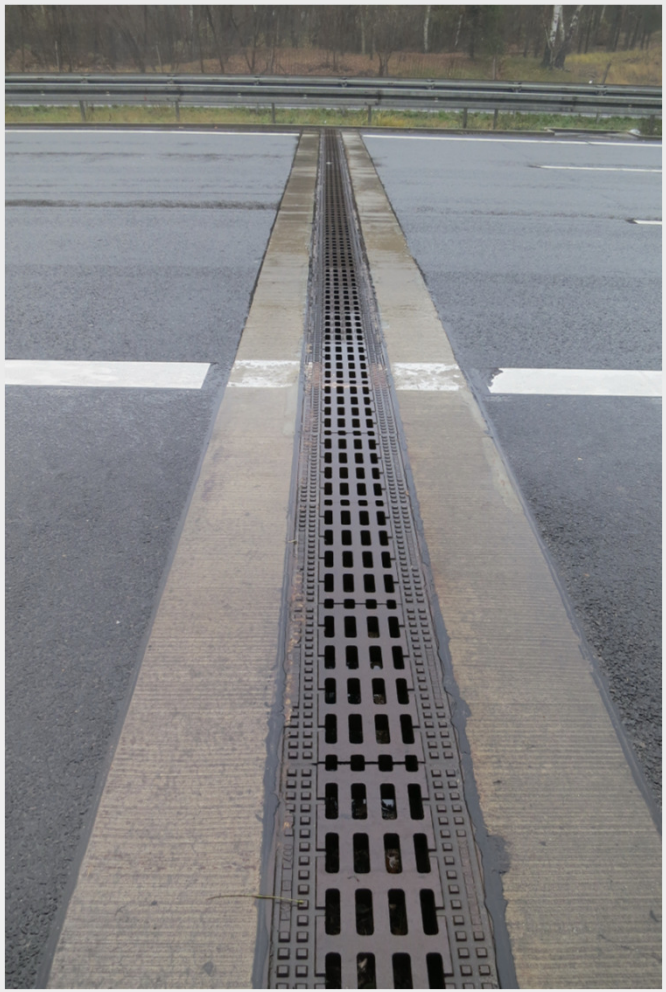
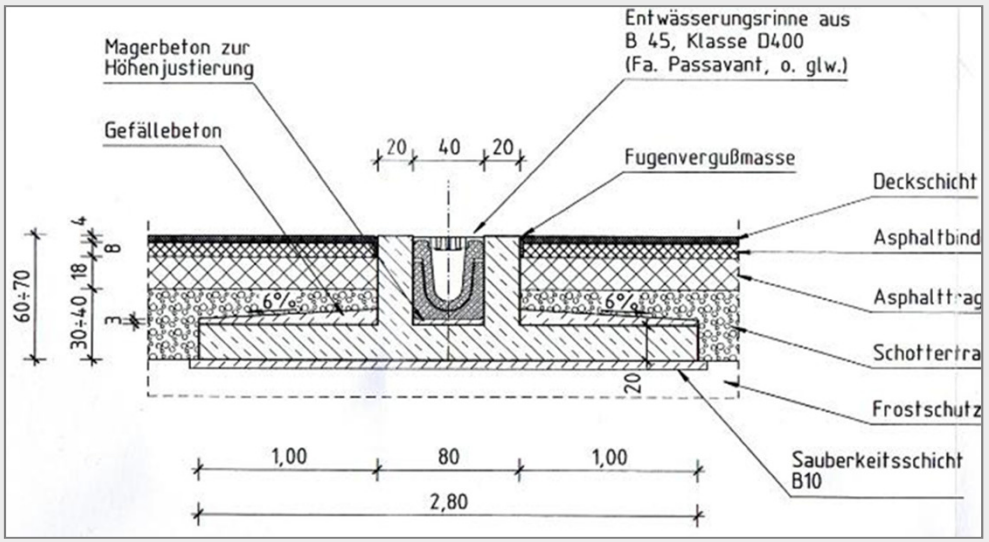
rectangular gutter (cement-concrete)





rectangular gutter (asphalt-construction)





rectangular gutter

Advantage

- suitable for cement-concrete- and for asphalt-constructions
- high effectiveness
- 1 or 2 gutters are enough
- Durability: about 10 years

Disadvantage

- high demands on the construction
- regular maintenance

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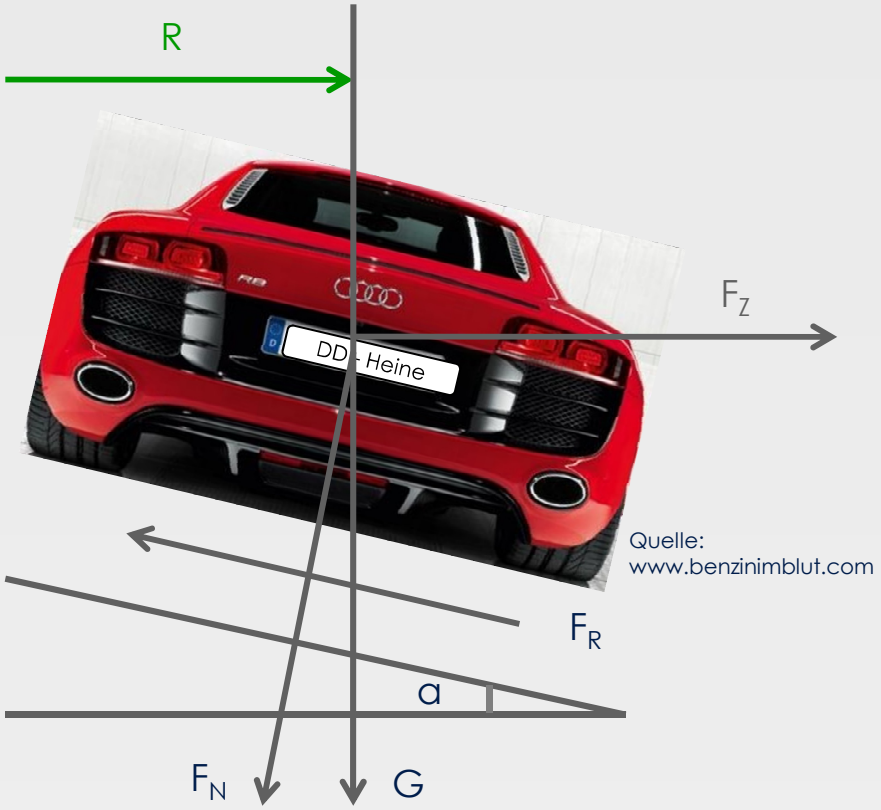
- Special form of transition „rolling crown“
- Speed limit on wet road surface

Negative superelevation



Quelle:
www.benzinimblut.com

$$\min R = \frac{V^2}{127\,(\max f_R \cdot n - q)}$$

$$\min R = 4.000\ \text{m} \quad (V = 130\ \text{km/h})$$

Negative superelevation

Advantage

- high effectiveness
- safe
- no additional costs

Disadvantage

- only for very large curve radii (R > 4.000 m)
- combination with speed limit on wet surface is useful

Measures for Critical Water Film Thickness

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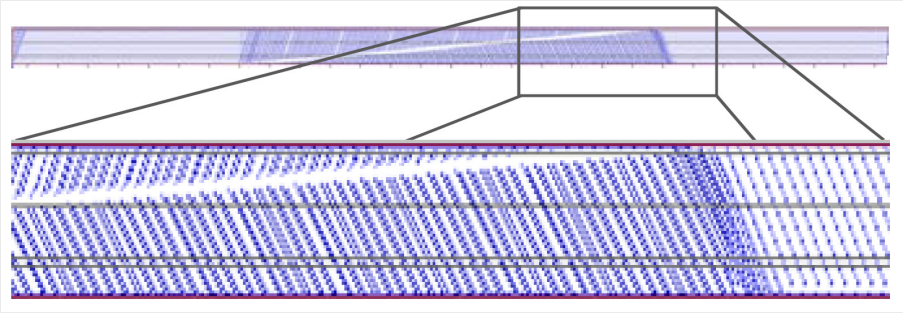
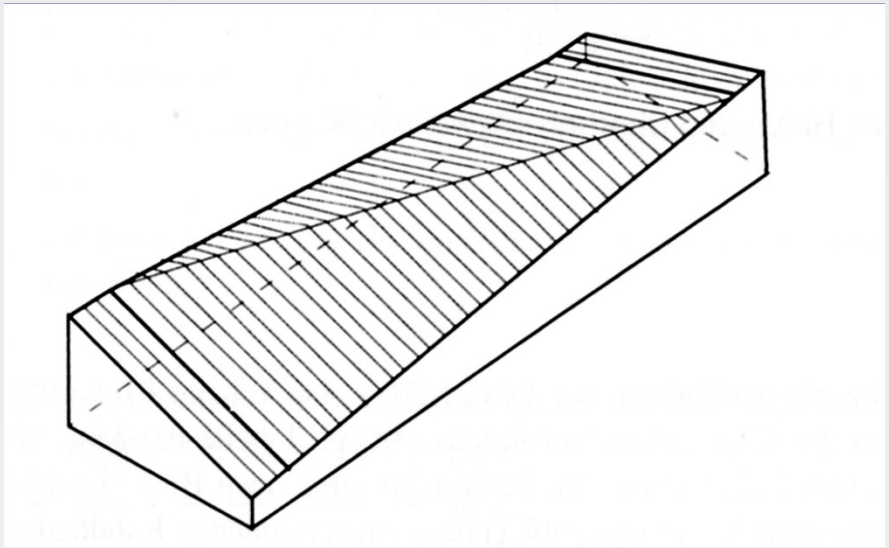
- Avoidance of superelevation transition by application of negative superelevation with very large radii,
- **Special form of transition „rolling crowns (crowns that run diagonally)”** (Diagonal torsion)
- Speed limit on wet road surface

„Rolling crown“





„Rolling crown“

Advantage

- high effectiveness (q ≥ 2,5 %)
- safe
- no problems with the driveability
- very good for low longiditunal gradients (s < 1,0 %)

Disadvantage

- difficult to construct
- not for cement-concrete pavement

Measures for Critical Water Film Thickness

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- Special form of transition „rolling crown“
- **Speed limit on wet road surface**

Speed limit on wet surface

Speed limit on wet surface

Advantage

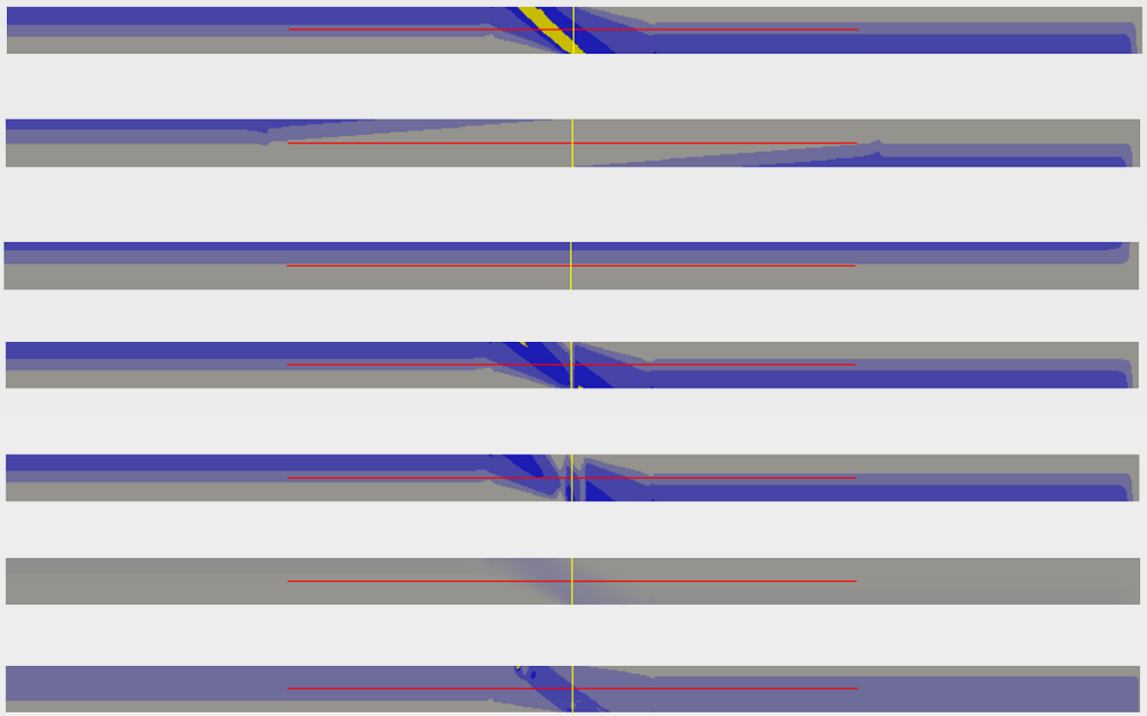
- No costs
- Realisable afterwards
- (limited) effects
- Legally certain / safe

Disadvantage

- Acceptance of traffic authorities is neccessary
- Control is useful

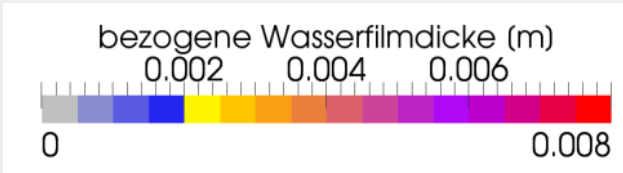
PSRM – Simulation of water film thickness

3 lanes (B = 14,50 m), s = 1, 0 %



- Standard torsion
- Diagonal torsion
- Negative superelev.
- 1 regtangular gutter
- 2 regtangular gutters
- PA drainage max
- PA drainage min

Universität Stuttgart



Distribution profile depth of tyre for pass. veh.

Quantil	Profile depth
5%	3,0 mm
10%	3,5 mm
15%	4,0 mm
20%	4,0 mm
50%	5,4 mm

Cross section	roughness	s [%]	WFT > 2mm	measure	WFT > 3mm	measure
RQ 31	fine	0	1,72	OPA, 2 gutter, rolling crown	0	-
		1	1,19	OPA, 1 gutter, rolling crown	0	-
		4	0,23	-	0,02	-
	rough	0	> 3,98	OPA, 3 gutter, rolling crown	1,19	OPA, gutter, rolling crown
		1	3,98	OPA, 3 gutter, rolling crown	0	-
		4	1,98	OPA, 2 gutter, rolling crown	0,08	-
RQ 36	fine	0	1,93	OPA, 2 gutter, rolling crown	0	-
		1	1,65	OPA, 1 gutter, rolling crown	0	
		4	0,22	-	0,08	
	rough	0	4,63	OPA, 5 gutter, rolling crown	1,45	OPA, gutter, rolling crown
		1	3,0	OPA, 3 gutter, rolling crown	0,75	OPA, gutter, rolling crown
		4	≥ 3,0	OPA, 3 gutter, rolling crown	0,02	

Example for a selection scheme (WFT = 2mm)

cross section	roughness	s [%]	measure
RQ 36	fine	0	OPA, 2 gutter, rolling crown
		1	OPA, 1 gutter, rolling crown
		1 < s ≤ 4	???
		≥ 4,0 %	no measure
	rough	0,0 %	OPA, gutter, rolling crown
		≥ 1,0 %	OPA, 3 gutter, rolling crown

Example for a selection scheme (WFT = 3mm)

cross section	roughness	s [%]	measure
RQ 36	fine	-	no measure
	rough	0,0 %	OPA, gutter, rolling crown
		1,0 %	OPA, gutter, rolling crown
		$1 < s \leq 4$	???
		≥ 4,0%	no measure

Questions

- minimum profile of tyres?
- water film thickness?
- physical models to estimate the water film thickness and perhaps a necessary speed limit?
- additional measures in zones of poor / low drainage?
- measures depend on the number of lanes or the width of the cross section?
- speed limit during raining on a wet road surface?
- accidents in such zones of low drainage?

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