

THE GERMAN EMPIRICAL – MECHANISTIC DESIGN SYSTEM

PART II - DESIGN APPROACH FOR THIN SURFACED PAVEMENTS

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Two design processes for flexible pavements

- Empirical design chart – RStO
- M-E design procedure - RDO Asphalt

German Design Charts RStO 12

Bk 0.3 <
300,000 10-t-ESALs

(Dickeangaben in cm; ∇ E_{vz} -Mindestwerte in MPa)

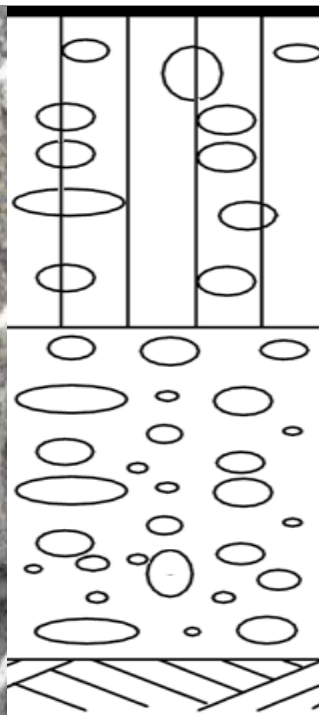
Zeile	Belastungsklasse	Bk100	Bk32	Bk10	Bk3,2	Bk1,8	Bk1,0	Bk0,3
	B [Mio.]	> 32	> 10 - 32	> 3,2 - 10	> 1,8 - 3,2	> 1,0 - 1,8	> 0,3 - 1,0	≤ 0,3
	Dicke des frostsich. Oberbaus ¹⁾	55 65 75 85	55 65 75 85	55 65 75 85	45 55 65 75	45 55 65 75	45 55 65 75	35 45 55 65

		Bk100	Bk32	Bk10	Bk3,2	Bk1,8	Bk1,0	Bk0,3
4	Asphalttragschicht und Kiestragschicht auf Frostschuttschicht							
	Asphaltdecke	12	12	12	10	4	4	4
	Asphalttragschicht	18	14	10	10	12	10	8
	Kiestragschicht $E_{vz} \geq 150(120)$	20	20	20	20	20	20	20
Frostschuttschicht	45	45	45	45	45	45	45	
	Dicke der Frostschuttschicht	- - 25 ¹⁾ 35	- - 29 ²⁾ 39	- - 33 ³⁾ 43	- - 25 ⁴⁾ 35	- - 29 ⁵⁾ 39	- 31 ⁶⁾ 41	1 - - 23 ⁷⁾ 33

		Bk100	Bk32	Bk10	Bk3,2	Bk1,8	Bk1,0	Bk0,3
5	Asphalttragschicht und Schotter- oder Kiestragschicht auf Schicht aus frostunempfindlichem Material							
	Asphaltdecke	12	12	12	10	4	4	4
	Asphalttragschicht	18	14	10	10	12	10	8
	Schotter- oder Kiestragschicht	30 ⁵⁾	30 ⁵⁾	30 ⁵⁾	30 ⁵⁾	30 ⁵⁾	30 ⁵⁾	25 ⁵⁾
Schicht aus frostunempfindlichem Material	45	45	45	45	45	45	45	
	Dicke der Schicht aus frostunempfindlichem Material	Ab 12 cm aus frostunempfindlichem Material, geringere Restdicke ist mit dem darüber liegenden Material auszugleichen						

Minimum thickness of the asphalt layers 10 cm also for LVR in Germany





Thin asphalt surface up to 4 cm

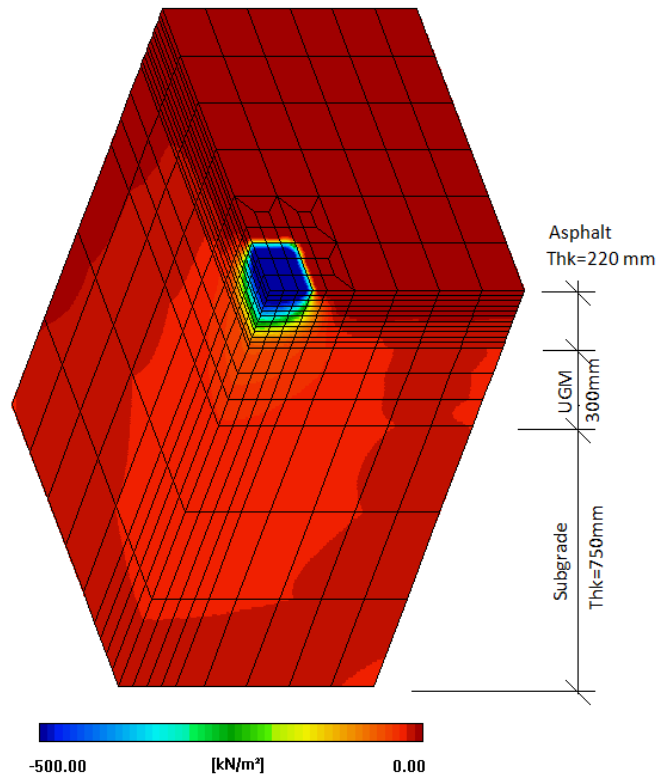
Base course
(High quality UGM)

Sub-base layer
(Frost protection)

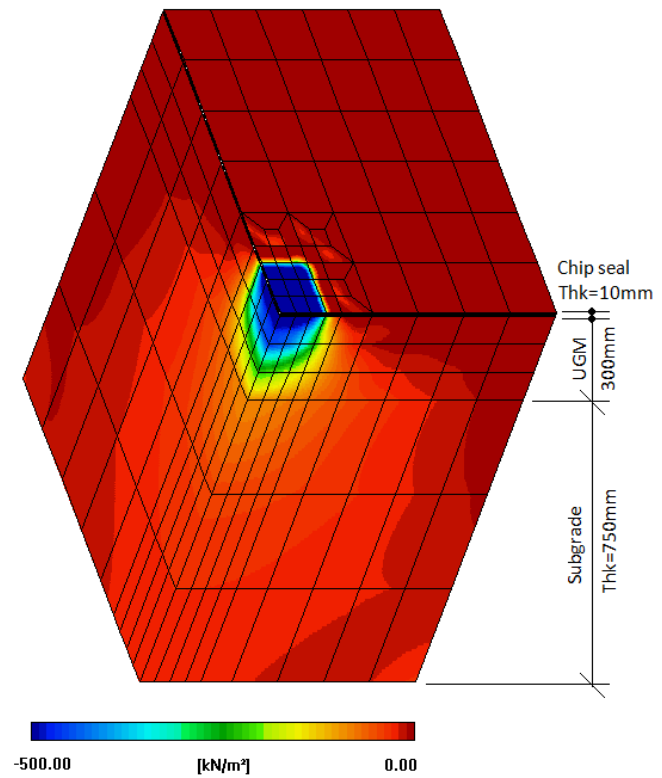
Subgrade

LVR < 100.000 10-t-standard axles

Pavement structure with thick asphalt layer (220mm)



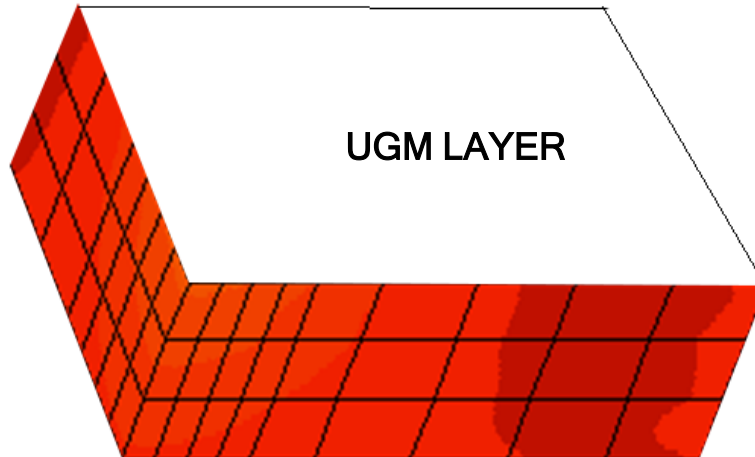
Pavement structure with thin asphalt layer (10mm)



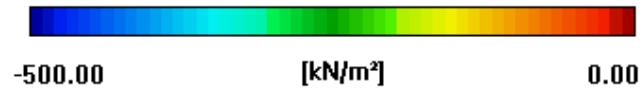
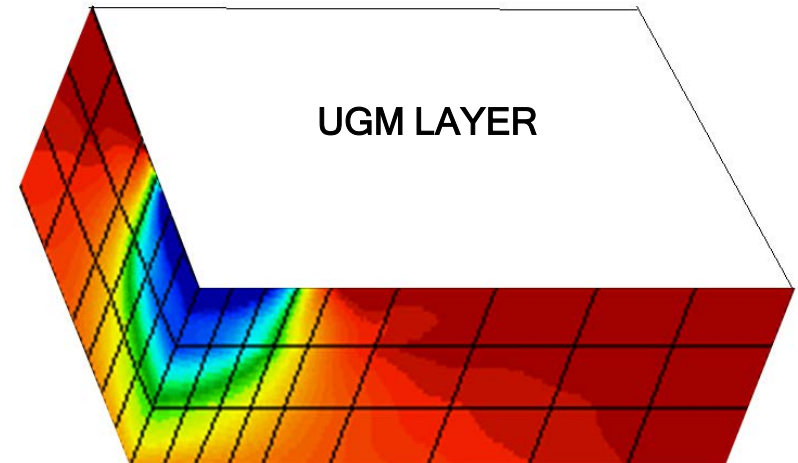
Vertical Stresses

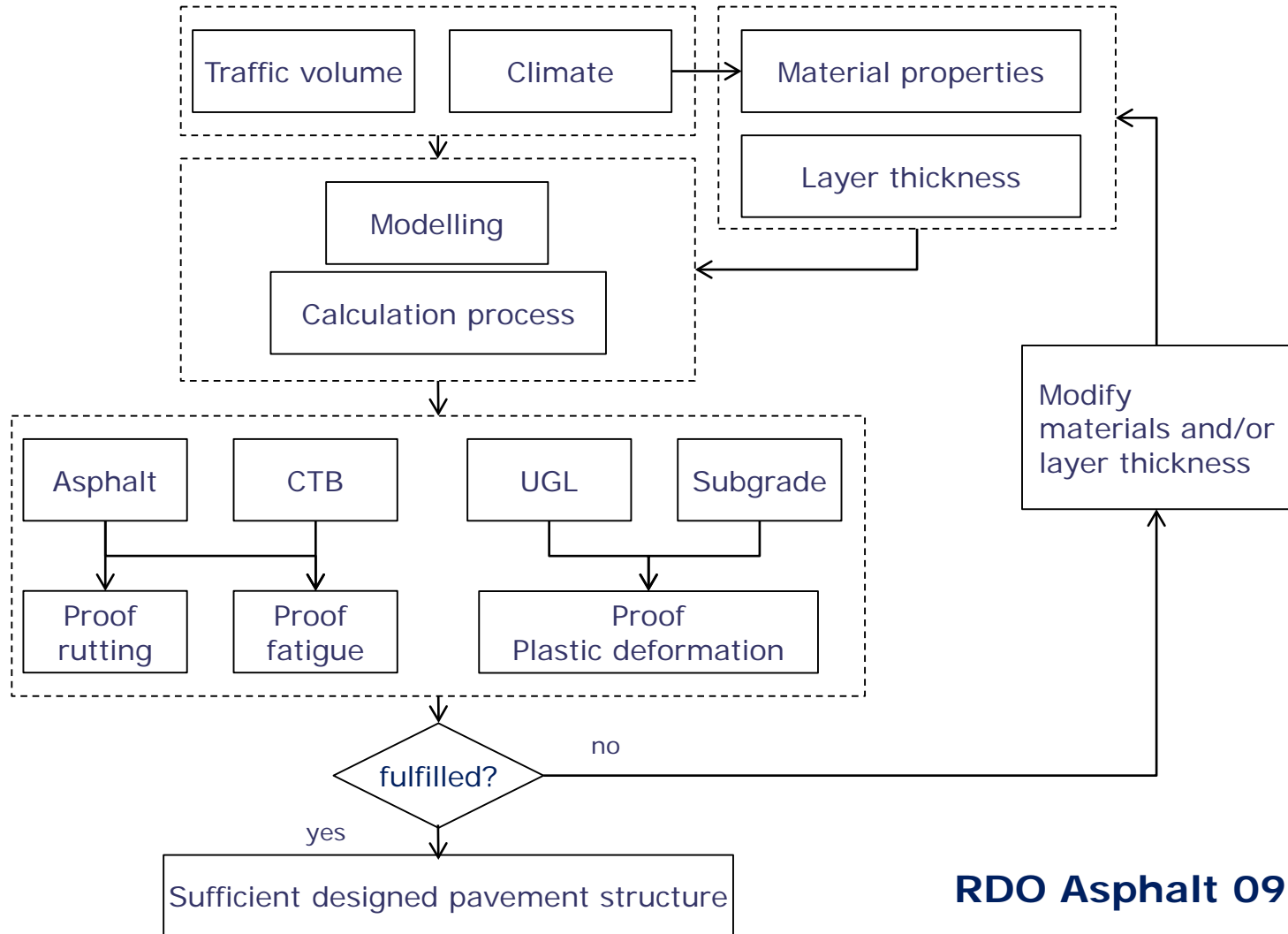
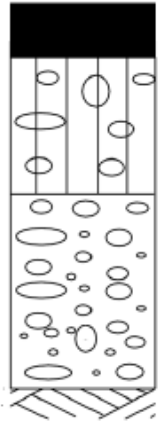
Vertical stresses within granular layer

Pavement structure with
thick asphalt layer (220mm)

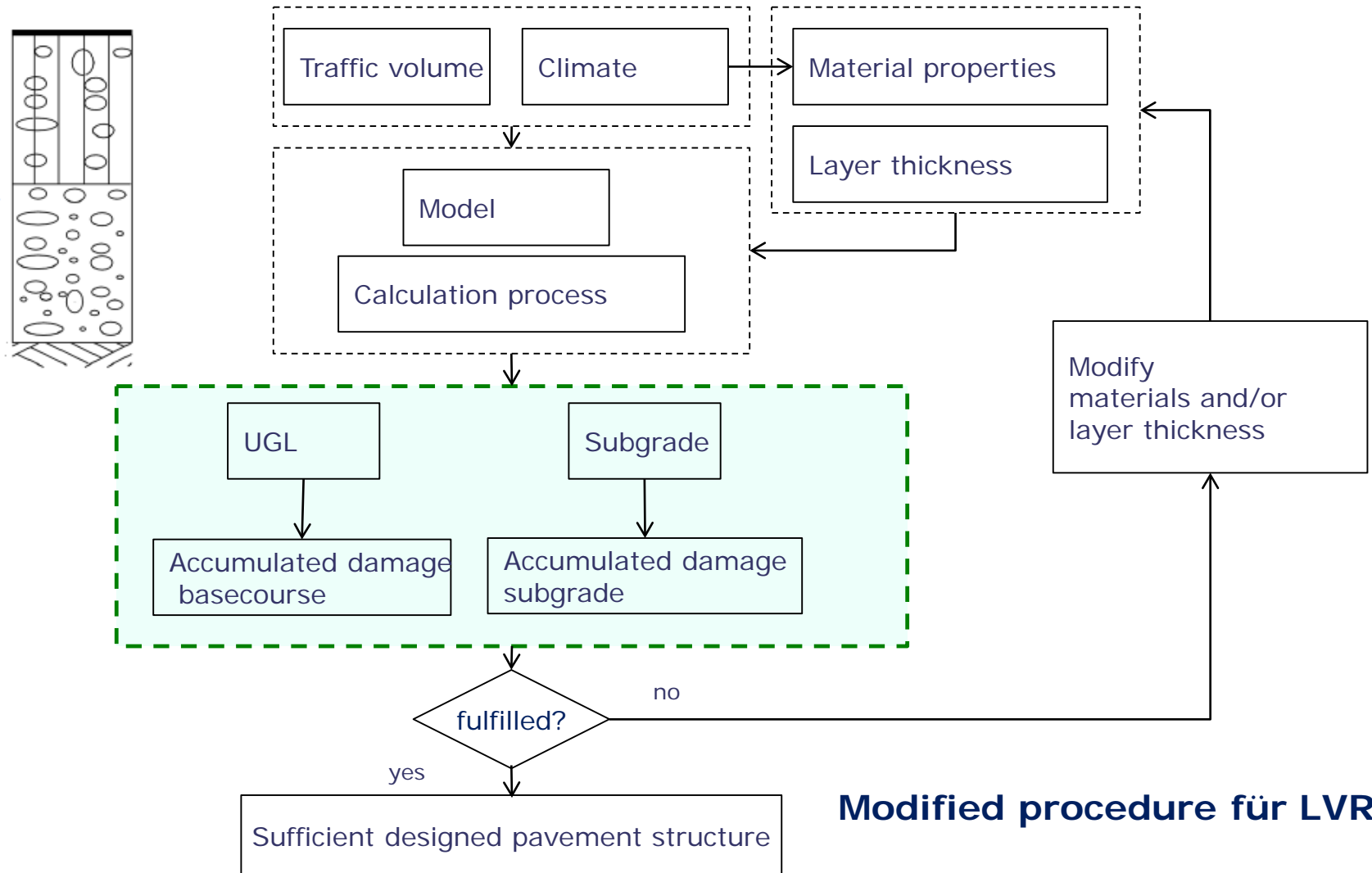


Pavement structure with
thin asphalt layer (10mm)





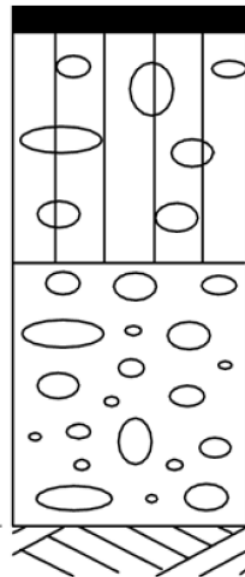
RDO Asphalt 09



Modified procedure für LVR

- The deformation performance of UGL is highly important for TSAP.
- The current aggregate mix/layer characteristics (DoC/grading lines, particle strengths) are insufficient for the evaluation of the deformation performance of UGM.
- Results of lab tests showed that UGM have different performance under cyclic loading even if they the have similar DoC, MC and grading lines.

Layer thickness: Frost protection



The minimum thickness for frost protection must be determined according to RStO

Min: 250mm
Max: 900mm

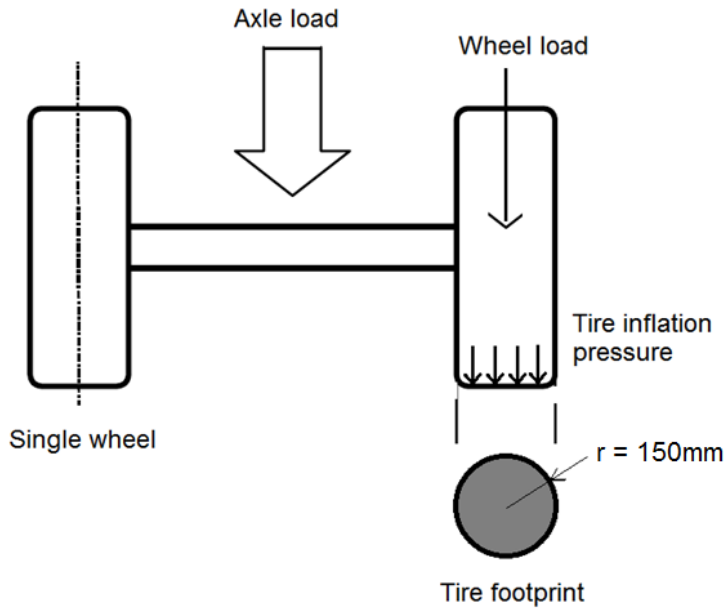
Tafel 1: Bauweisen mit Asphaltdecke für Fahrbahnen auf F2- und F3-Untergrund/Unterbau

(Dickenangaben in cm; ∇ E_{v2} -Mindestwerte in MPa)

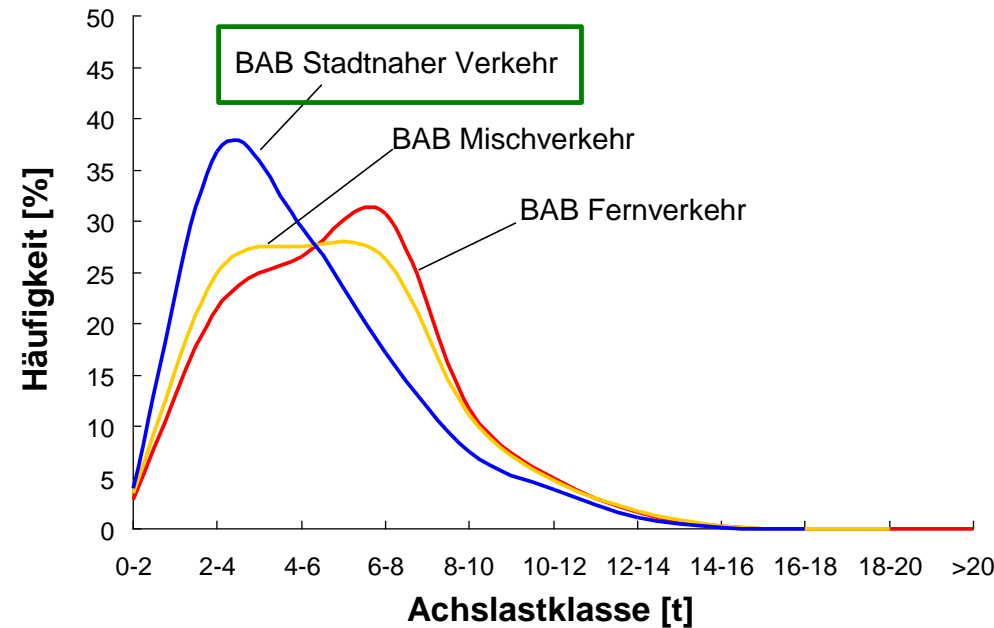
Zeile	Belastungsklasse	Bk100				Bk32				Bk10				Bk3,2				Bk1,8				Bk1,0				Bk0,3			
	B [Mio.]	> 32				> 10 - 32				> 3,2 - 10				> 1,8 - 3,2				> 1,0 - 1,8				> 0,3 - 1,0				≤ 0,3			
	Dicke des frostsich. Oberbaus ¹⁾	55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75	45	55	65	75	45	55	65	75	35	45	55	65

Traffic load

LVR
< 100,000 10-t-standard axles

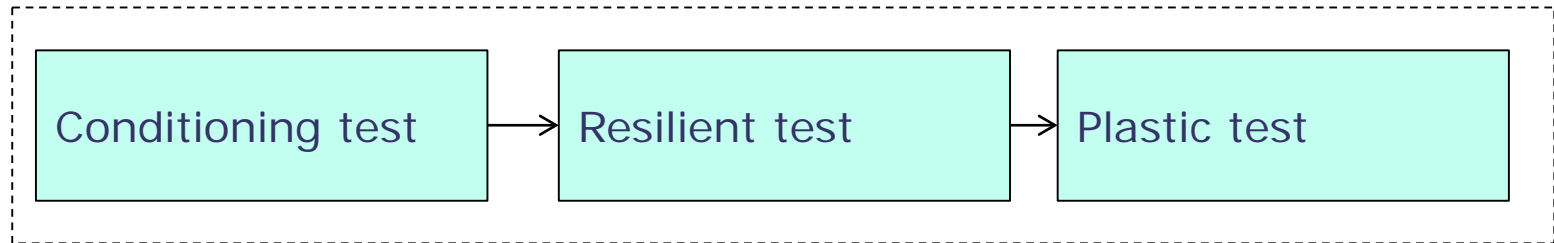


In future:
Consideration of the actual axle load distribution



[Data from UHLIG]

Test package



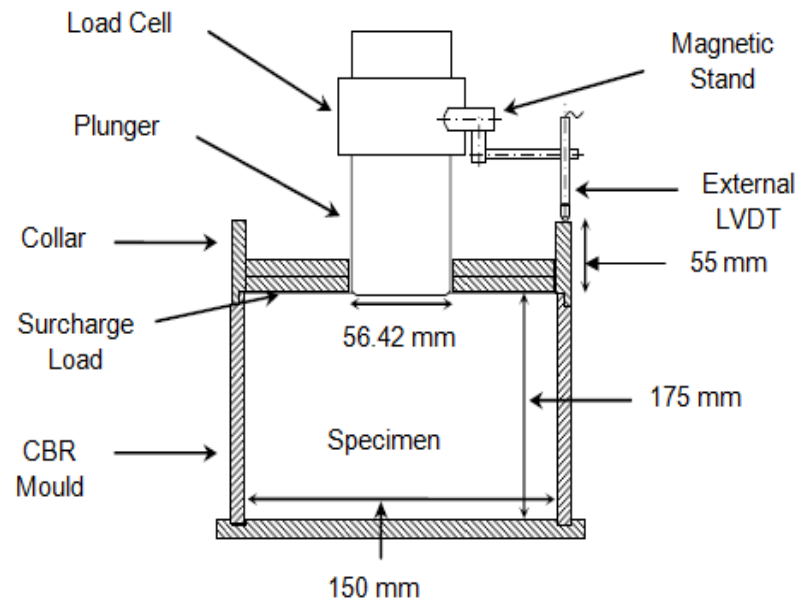
Sample preparation



Test set-up



**Test package
Approx 22h**



Property	Mixture A	Mixture B	Mixture C	Mixture D	Mixture E
Type	Natural sandy-gravel	Crushed rock Granodiorite	Crushed rock Andesite	Crushed rock FPM	Crushed rock Granite with quartz
Grain size	0/32	0/32	0/32	0/16	0/32
Maximum dry density [gr/cm ³]	2,200	2,170	2,010	2,198	2,000
OMC [m - %]	6,0	5,8	12,1	6,7	5,0
Fine Content	2,5	2,5	2,5	3,3	-



Ranking procedure for UGM

Conditioning Test:

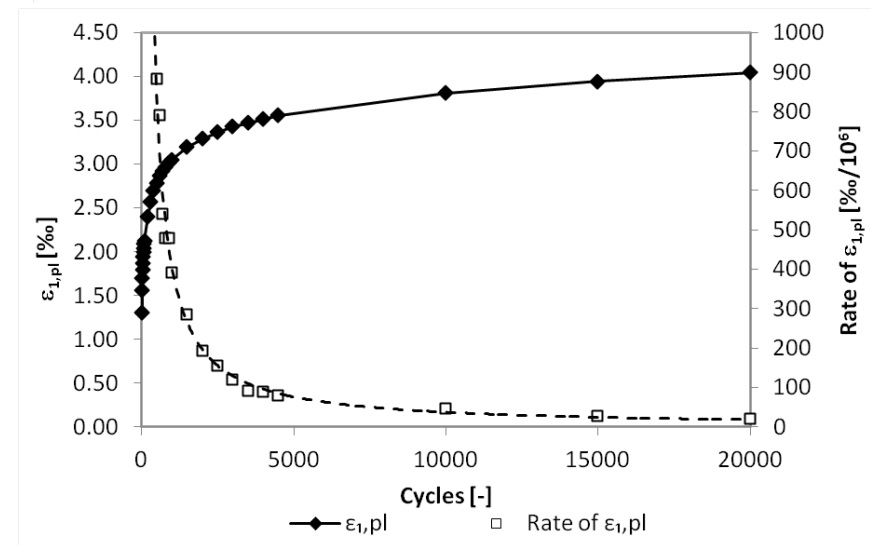
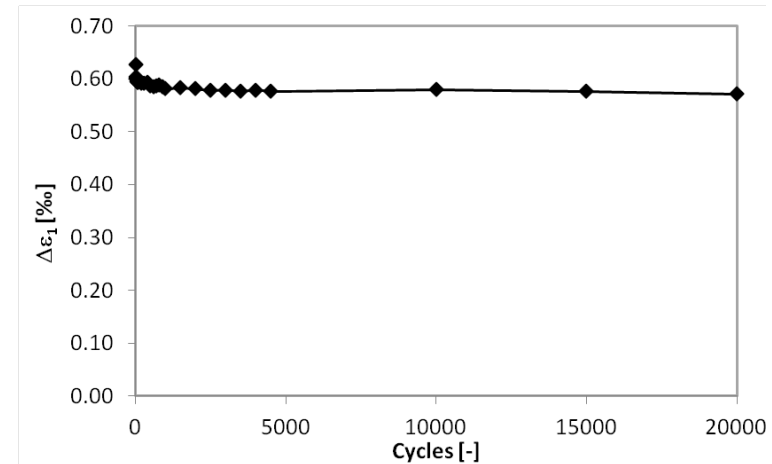
20.000 LC @

Cell pressure of 150kPa

Deviatoric stress of 300kPa

Tests at 70, 80 and 90% of OMC

- Characteristic stiffness
- Characteristic plastic strain rate



Ranking procedure for UGM

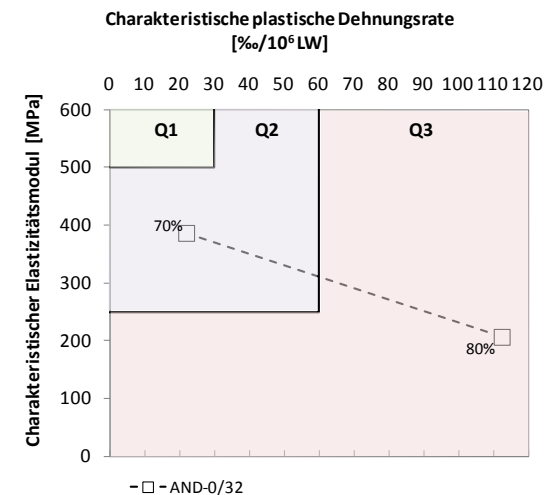
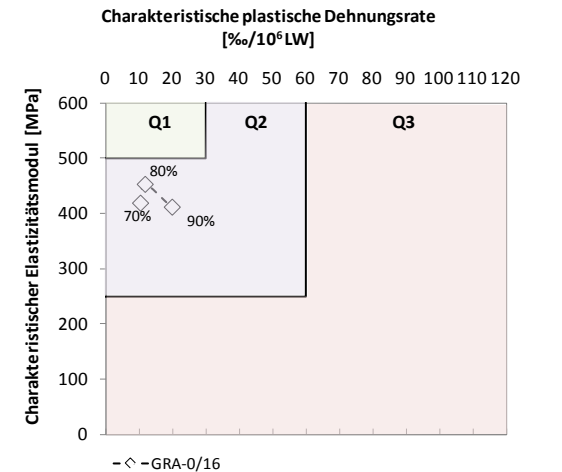
Conditioning Test:

20.000 LC @
 Cell pressure of 150kPa
 Deviatoric stress of 300kPa

Q₁ Material – excellent material
 Q₂ Material - good material
 Q₃ Material - bad material

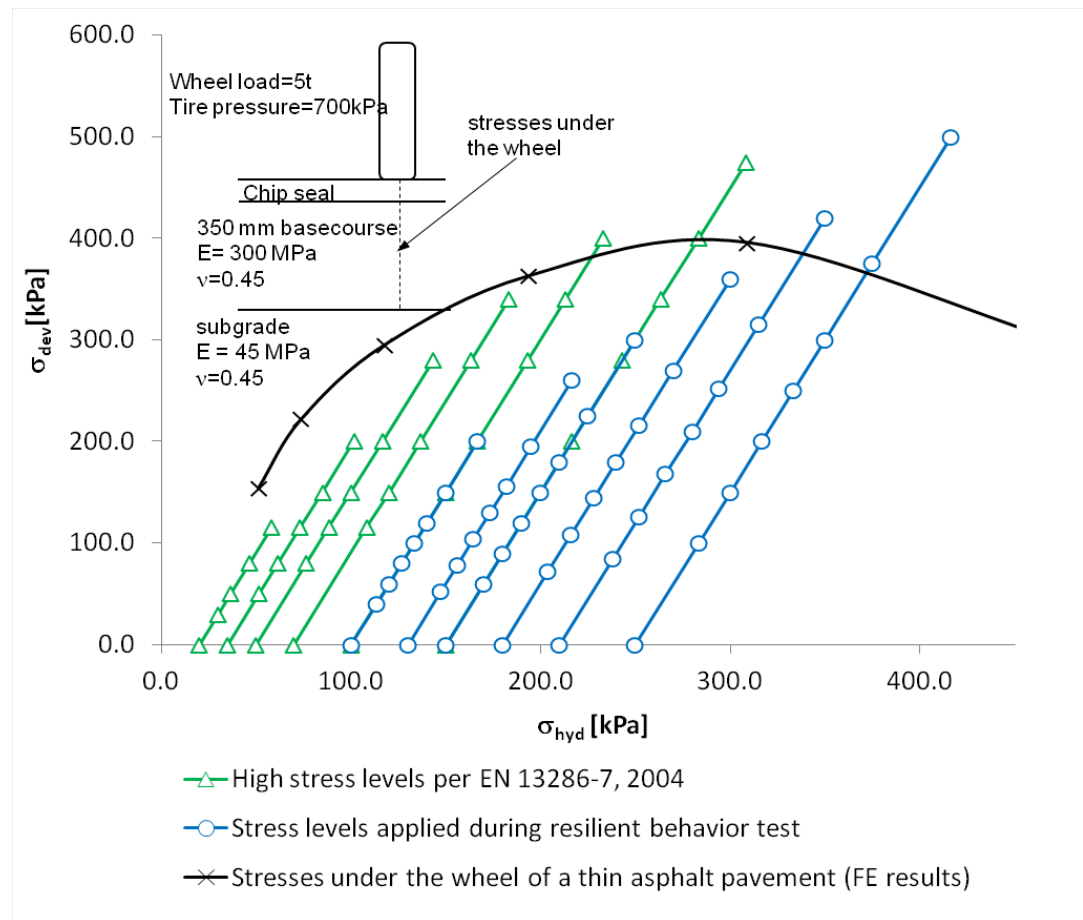
Q₂ Material
 Granit (FP Material)

Q₃ Material
 Andesit



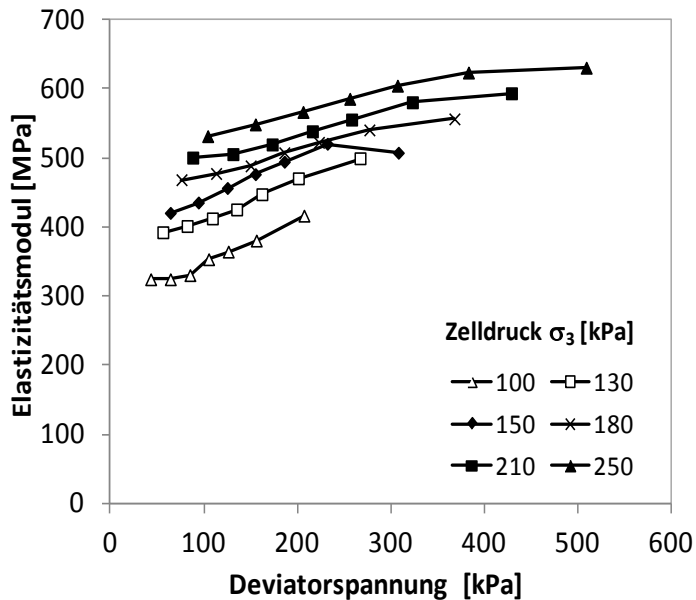
Characterization of elastic deformation behavior

Multistage repeated load triaxial test at CCP

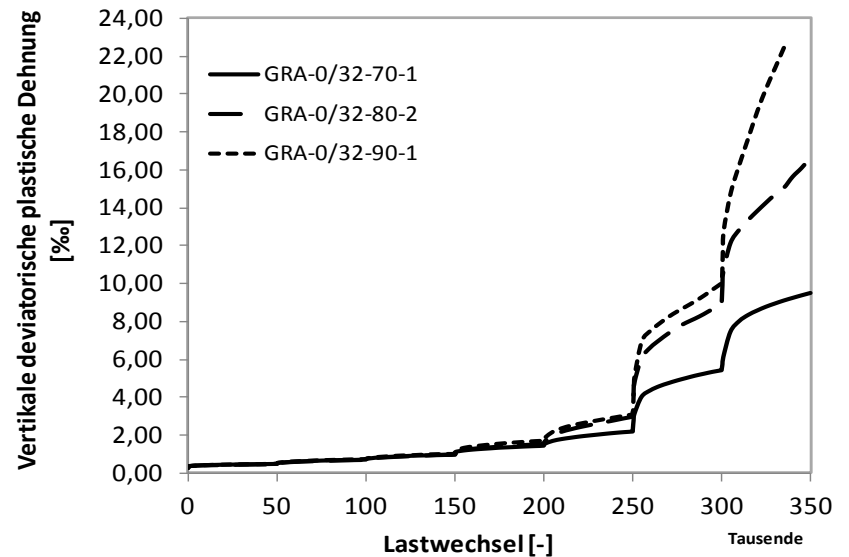


Results of the RLT tests

Elastic deformation performance

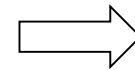
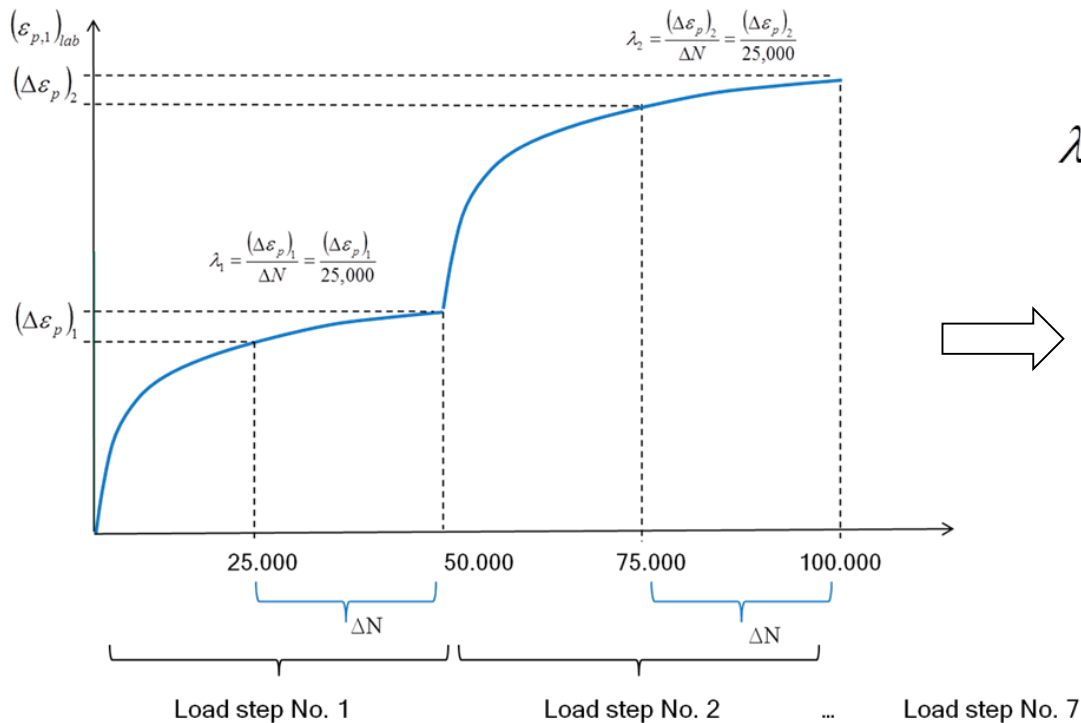


Plastic deformation performance

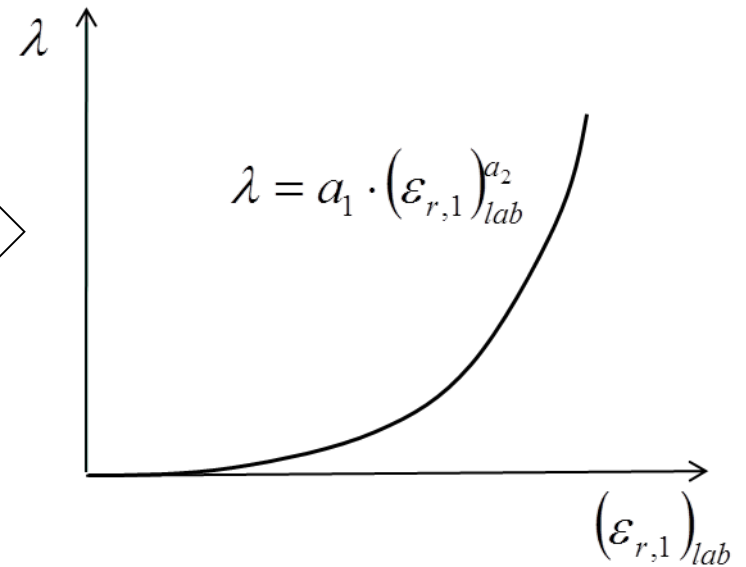


-> Determination of the model parameters

Modeling of permanent deformation response

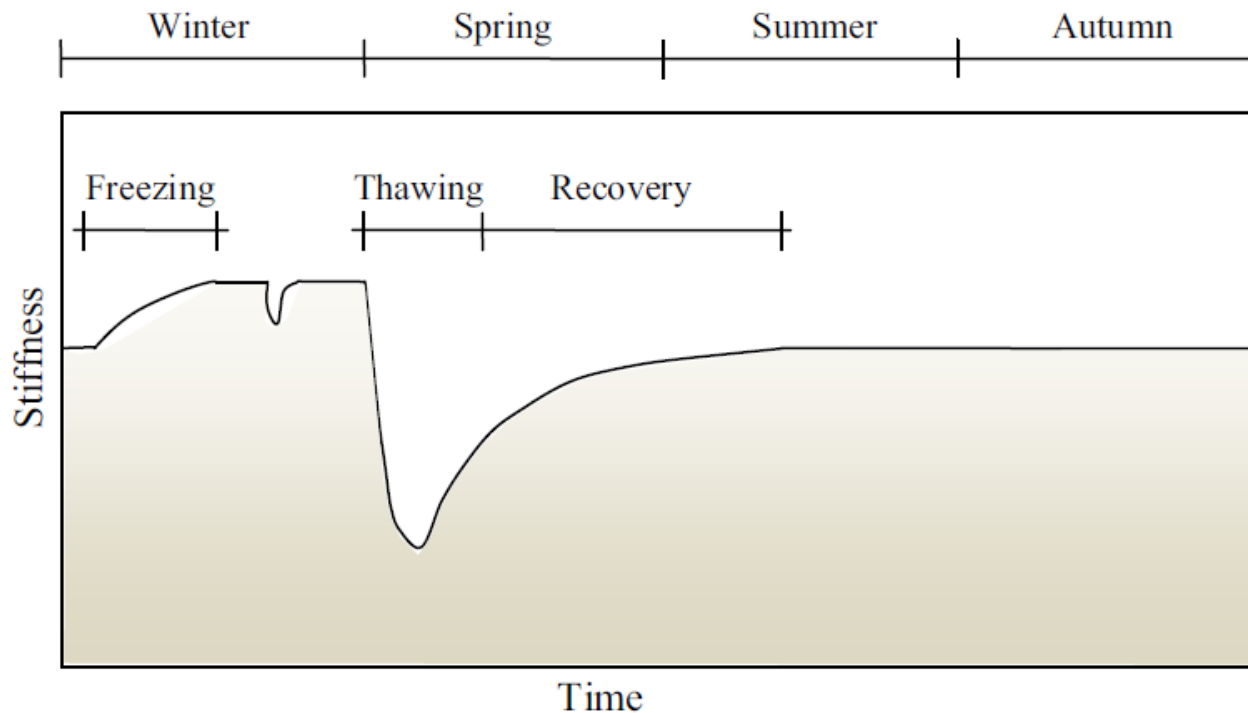


$$(\varepsilon_{p,1})_{lab} = (\varepsilon_{p,1})_{N_0} + (N - N_0) \cdot \lambda$$



Climate

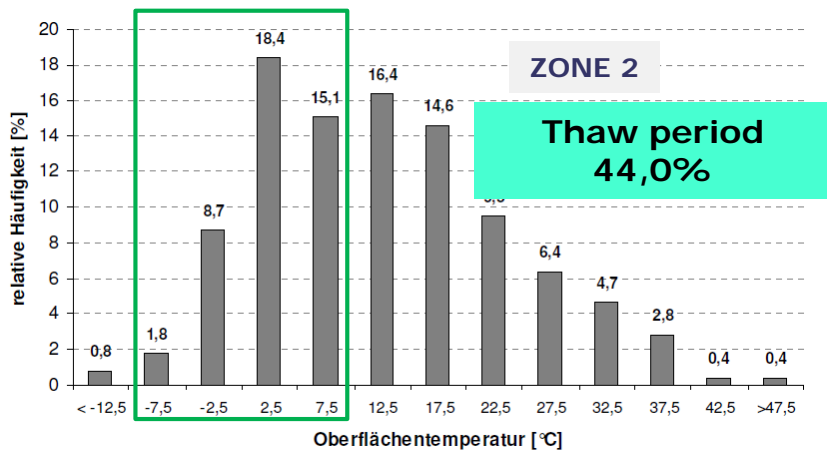
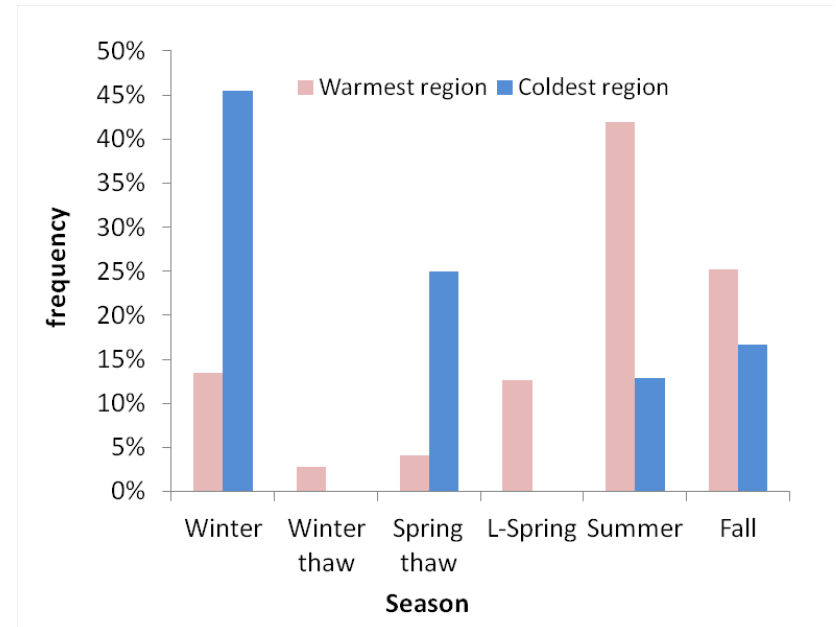
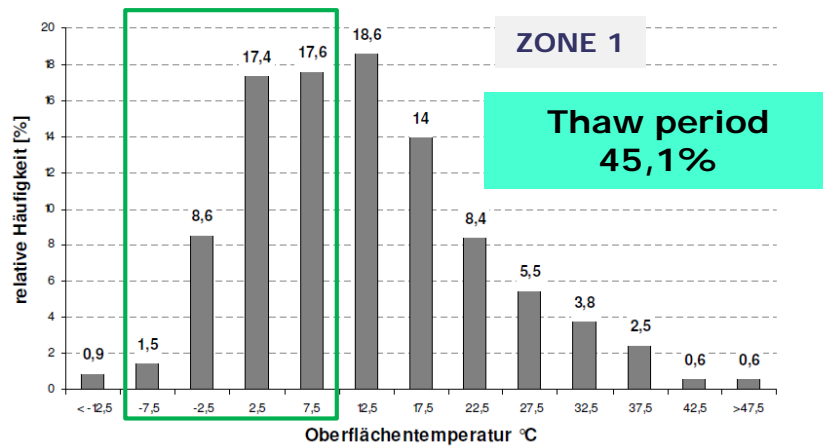
Stiffness changes of the BC/subgrade due to changing moisture content during the year

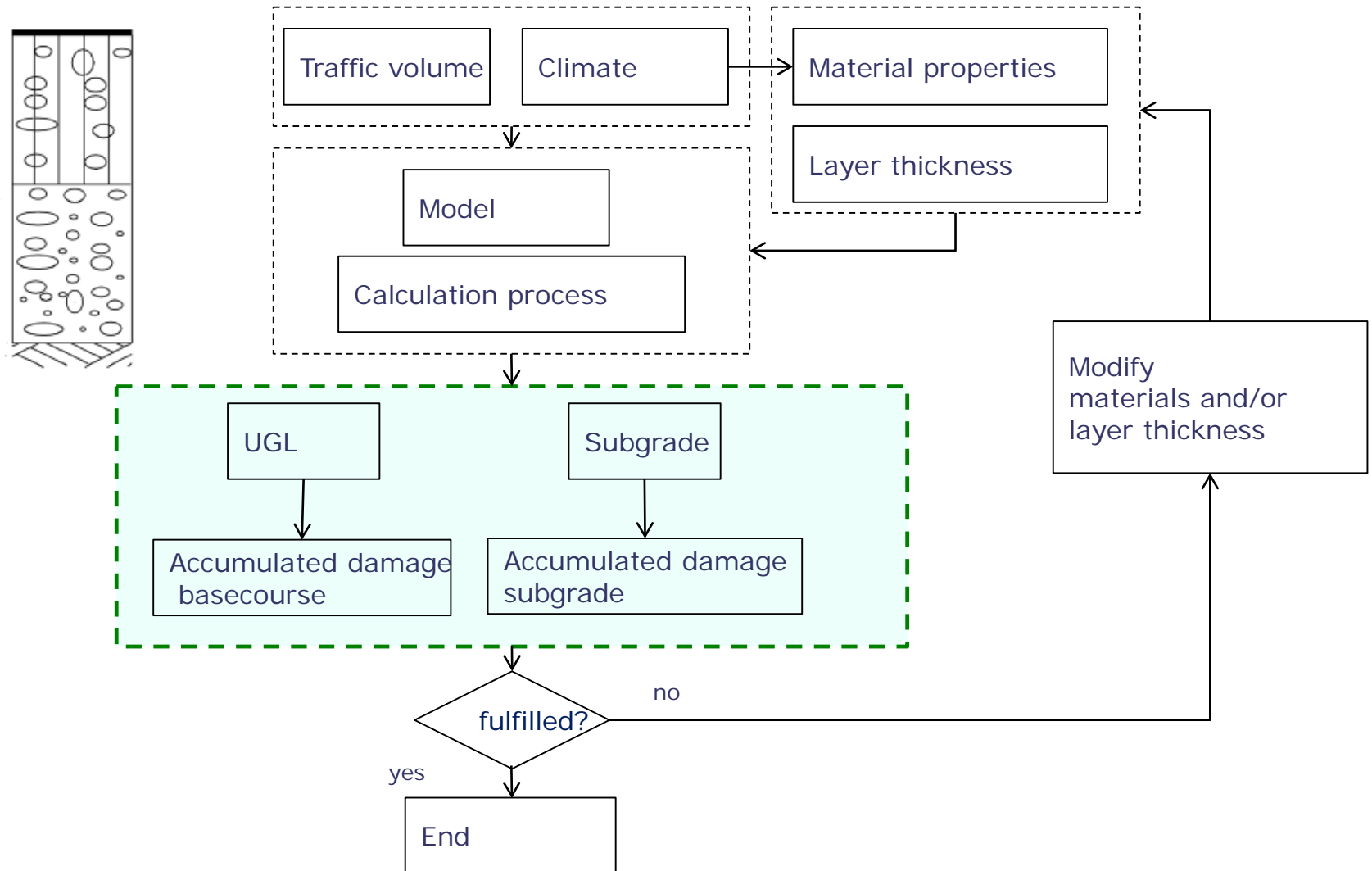


[ERLINSON 09]

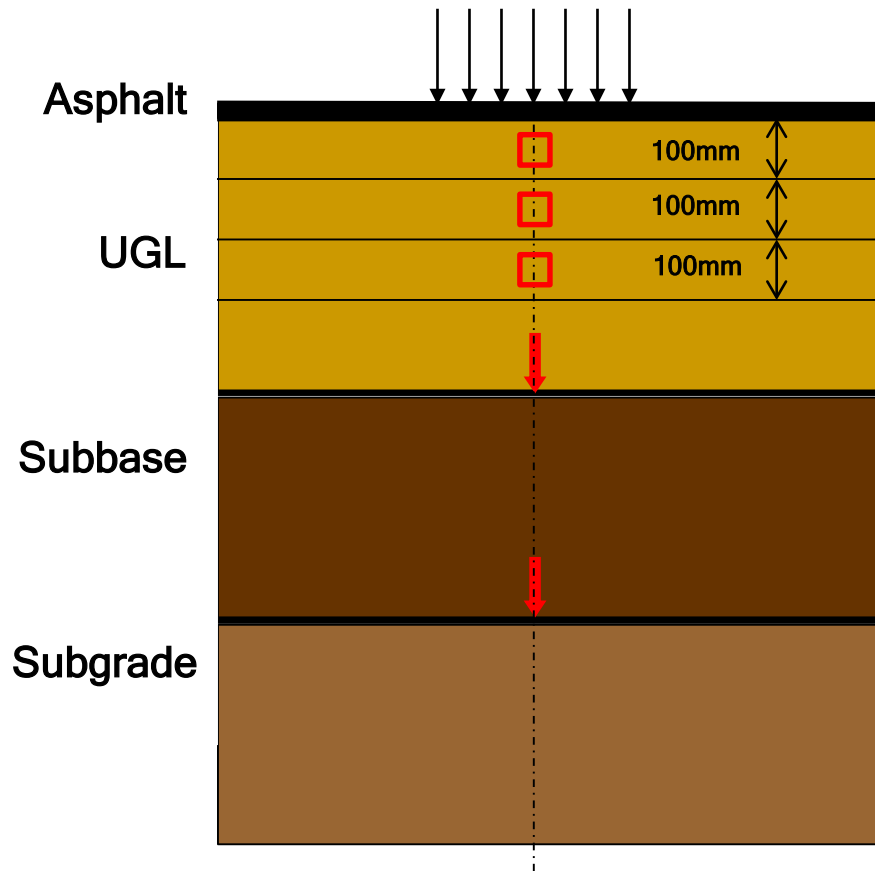
Climatic condition Germany

Sweden





Design process



1. Calculation of plastic deformation of the UGL
Representative elastic strains in the UGM at three sublayers of a thickness of 100mm

2. Vertical compressive strain/stress at top subbase

3. Vertical compressive strain/stress at top subgrade

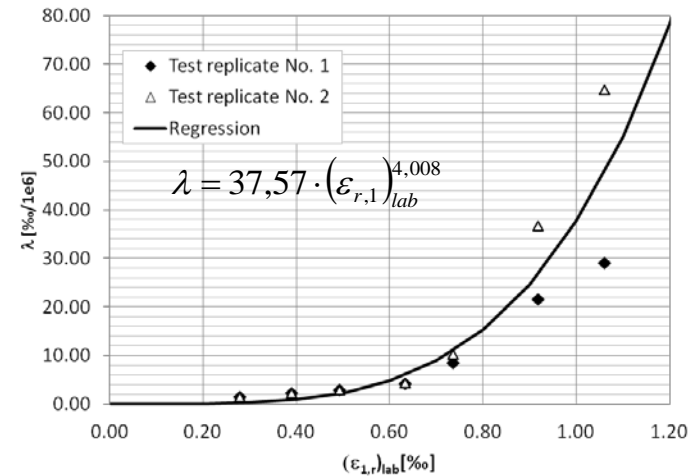
Plastic deformation UGL

Elastic strains

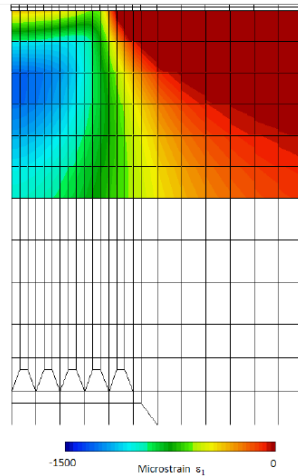
$$Mr = k_1 \left(\frac{P}{P_a} \right)^{k_2} \left(\frac{\tau_{oct}}{P_a} + 1 \right)^{k_3}$$

Basecourse Material	Target W.C. [% of OWC]	k_1 [MPa]	k_2 [-]	k_3 [-]
GRA	70	358.3	0.5923	-0.1946

Plastic strains



Elastic strain distribution



Performance Criteria Subgrade/FPL: plastic deformation

Austrroads (Australia)

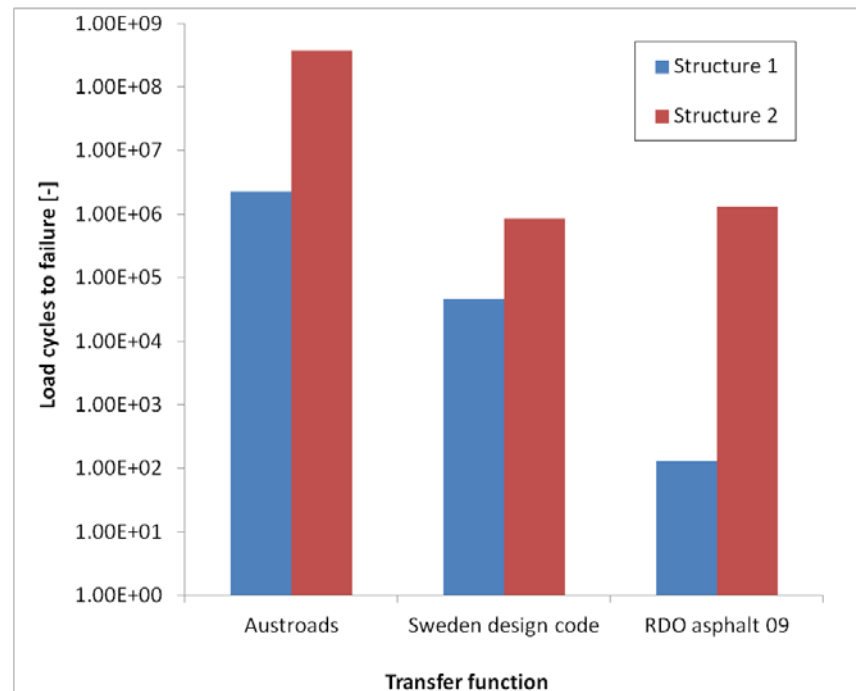
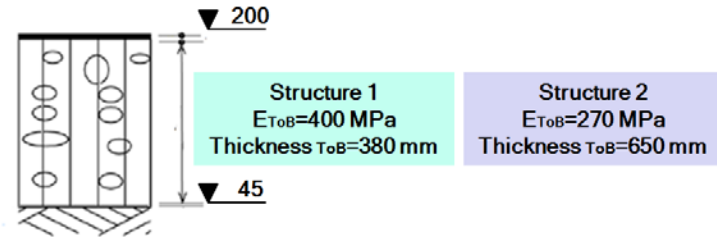
$$N = \left(\frac{9300}{\mu \varepsilon_{v,SG}} \right)^7$$

Sweden design code

$$N = \frac{8,06 \cdot 10^{-8}}{\left(\varepsilon_{v,SG} \right)^4}$$

German ME design code

$$N = 10^{0,7 \left(\frac{0,00875 E_{v2}}{2,5 \cdot \sigma_{z,SG}} \right)}$$



Based on Strain

Based on Stress

Material parameter: Asphalt – no structural layer

Layer	Layer modulus (E-Modulus)	Poisson's ratio	Material behavior
Asphalt t < 20mm	E = (5.000 MPa) (Membrane behaviour)	$\mu = 0,35$	Linear elastic
Asphalt t > 20mm	E = 5.000 MPa Standard condition E = 10.000 MPa Thaw period	$\mu = 0,35$	Linear elastic

Tabelle A 6.3: Zuordnung Steifigkeitsmodul – Temperatur für den Kalibrierasphalt der Deckschicht [Kiehne 2007]

Temperatur [°C]	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50
Steifigkeitsmodul [MPa]	26.319	24.664	22.196	19.172	16.255	13.443	10.729	8.111	5.581	3.425	2.119	1.332	850	550	360

Thaw period

- Using the results of RLTT on UGM the basis for the ME design of TSAP was established
- It is possible to have pavement structures with asphalt layers of less than 40mm thickness for low trafficked pavements in Germany
- Only high quality UGMs that have high stiffness and low susceptibility to plastic deformation even at high moisture contents should be used in TSAP.

This presentation is based on parts of the research project carried out at the request of the Federal Ministry of Transport, Building and Urban Development, represented by the Federal Highway Research Institute under research project No. 09.0175/2011/ERB.