TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Bauingenieurwesen • Institut für Stadtbauwesen und Straßenbau • Professur für Straßenbau

THE GERMAN EMPIRICAL – MECHANISTIC DESIGN SYSTEM

PART I – M - E ASPHALT PAVEMENT DESIGN IN GERMANY

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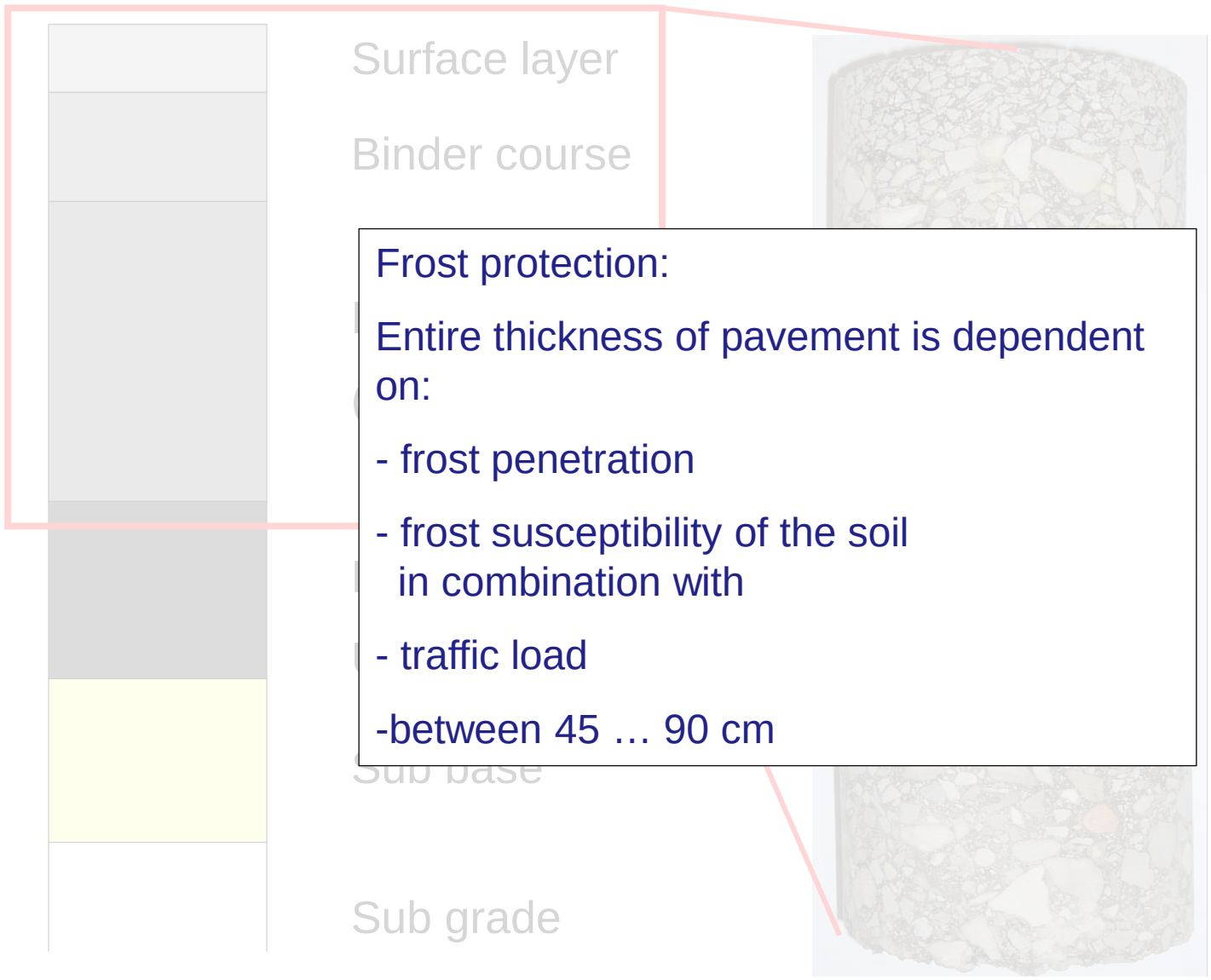
TU Dresden

NADim Seminar - Oslo 03.12.2015

Design Guides in Germany

Asphalt Pavements



Frost protection:

Entire thickness of pavement is dependent on:

- frost penetration

- frost susceptibility of the soil in combination with

- traffic load

-between 45 … 90 cm

RStO 12- Table I, Part I

LCC	100	32	10	3.2	1.8	1,0	0.3
10t EASLs - B [Mio]	>32	32-10	10 – 3,2	3,3 – 1.8	1.8 – 1,0	1,0 –0 .3	<0,3
	55 65 75 85	55 65 75 85	55 65 75 85	45 55 65 75	45 55 65 75	35 45 55 65	35 45 55 65
1 Asphalt FPL	34						14 (10)
	31[2] 41 51	25[3] 35 45 55	29[3] 39 49 59	- 33[2] 43 53	25[3] 35 45 55	17[2] 27 37 47	21 31 41 51
2.1 Asphalt CTB FPL	26			20			
	- - 34[2] 44	- 28[3] 38 48	- 30[2] 40 50	- 31[2] 41 51	25[3] 35 45 55	27[2] 37 47 57	21 31 41 51
2.2 Asphalt CTB FPL	28				14		14
	40[4] 20[4] 30 40	14[4] 24 34 44	18[4] 28 38 48	10[4] 20 30 40	14[4] 24 34 44	6[4] 16[4] 26 36	6[4] 16[4] 26 36
2.3. Asphalt CTB FPL	28				14		14
	5[4] 15[4] 25 35	9[4] 19[4] 29 39	13[4] 23 33 43	5[4] 15[4] 25 35	14[4] 24 34 44	6[4] 16[4] 26 36	6[4] 16[4] 26 36

RStO Table I, Part II

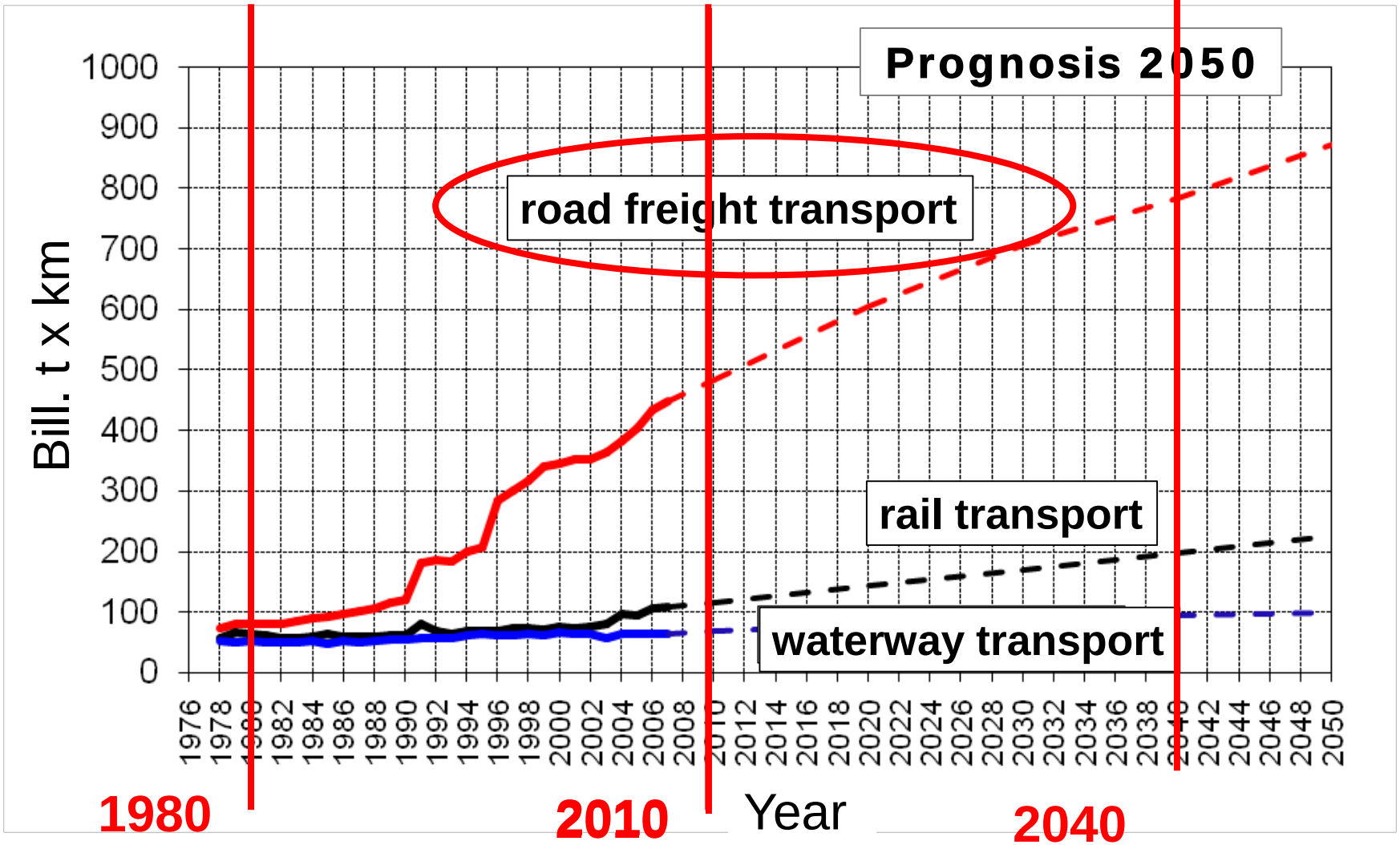
LCC	100	32	10	3.2	1.8	1.0	0.3
10t EASLs - B [Mio]	>32	32-10	10 – 3.2	3.2 – 1.8	1.8 – 1.0	1.0 –0 .3	<0,3
3 Asphalt CRB FPL	30	12 14 15 Σ41	12 10 15 Σ37	10 10 15 Σ35	4 12 15 Σ31	4 10 15 Σ29	14 (10)
	- - 30² 40	- - 34² 44	- 28³ 38 48	- - 30² 40	- 24³ 34 44	- 26³ 36 46	- 18³ 28 38
4 Asphalt GBC FPL	30	12 14 20 Σ46	12 10 20 Σ42	10 10 20 Σ40	4 12 20 Σ36	4 10 20 Σ34	14 (10)
	- - 25³ 35	- - 29³ 39	- 33² 43	- - 25³ 35	- - 29² 39	- - 31² 41	- - 23² 33
5 Asphalt CRB/GBC FPL	30	12 14 30⁵⁾ Σ56	12 10 30⁵⁾ Σ52	10 10 30⁵⁾ Σ50	12 30⁵⁾ Σ46	4 10 30⁵⁾ Σ44	14 (10)

Why

a new mechanistic approach for pavement design ?

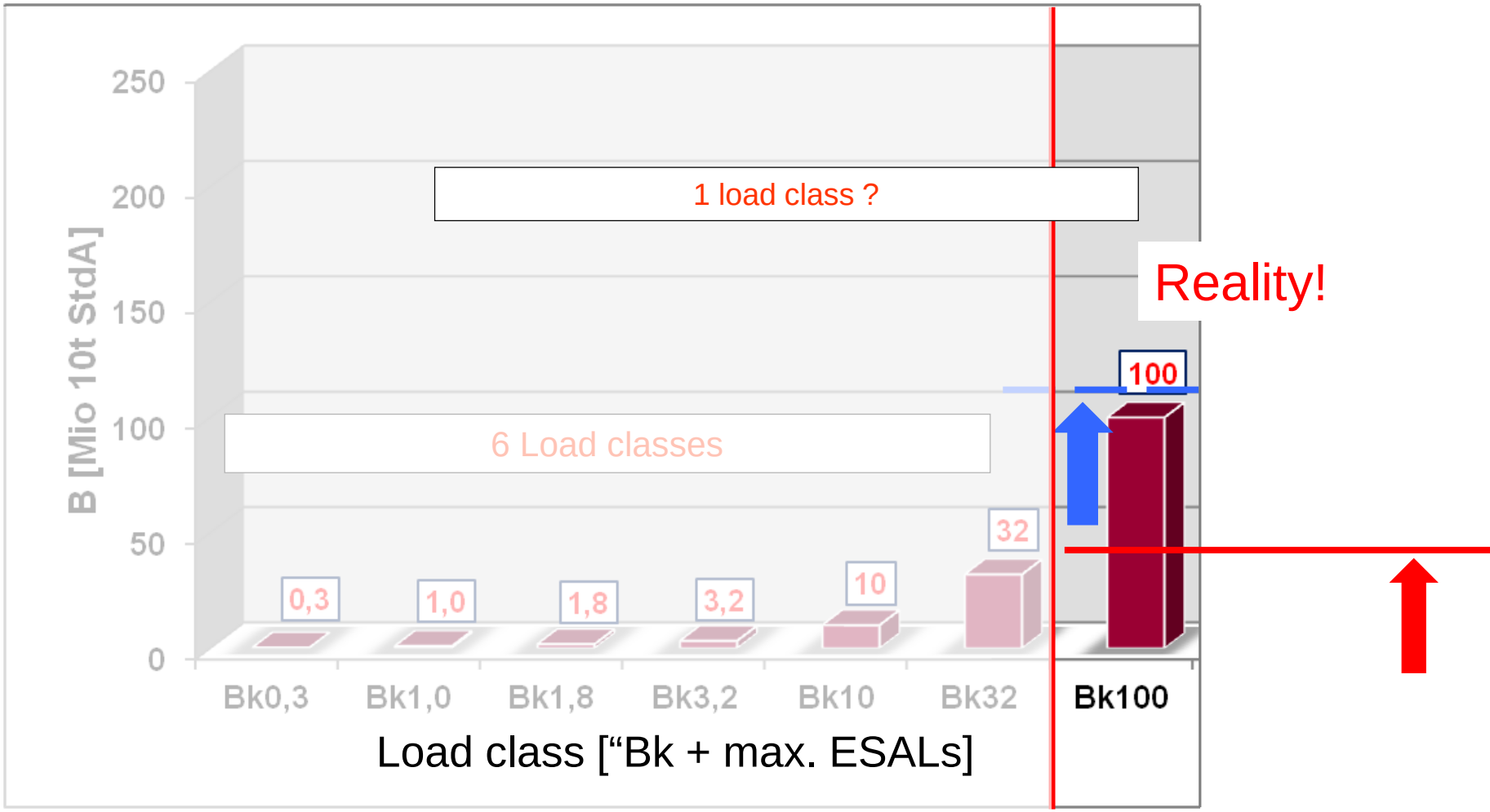
Development of traffic

Development of traffic



Source: Bast 2010

Standardised load classes ⇔ Reality



Why?

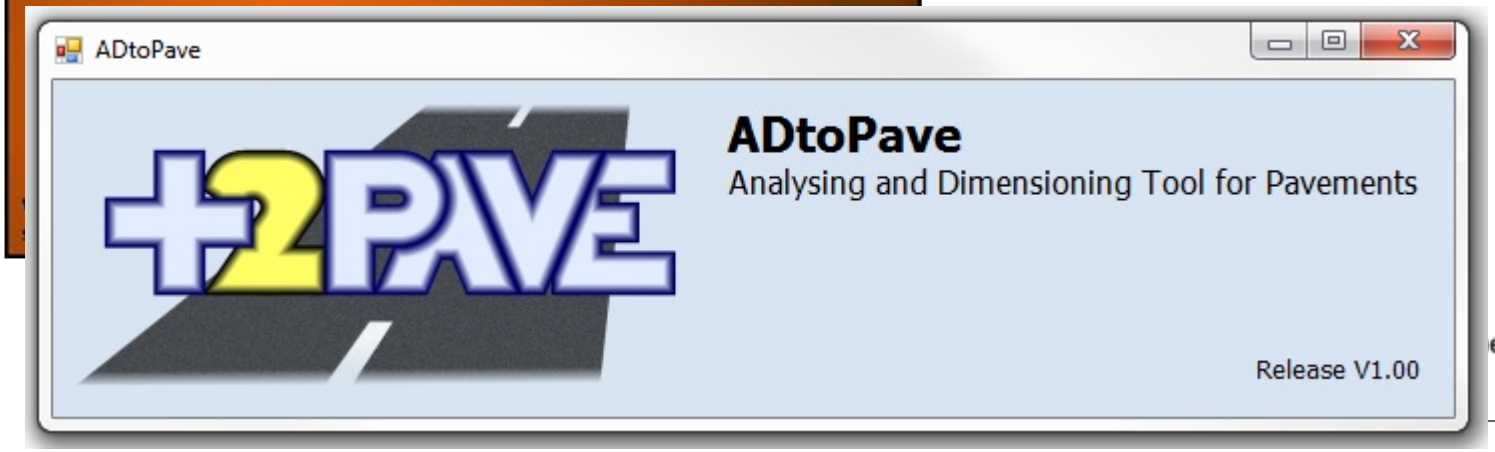
Technical background:

- permanent increasing traffic load
- climate change
- limited resources
- quality and costs of raw material

Background by contract:

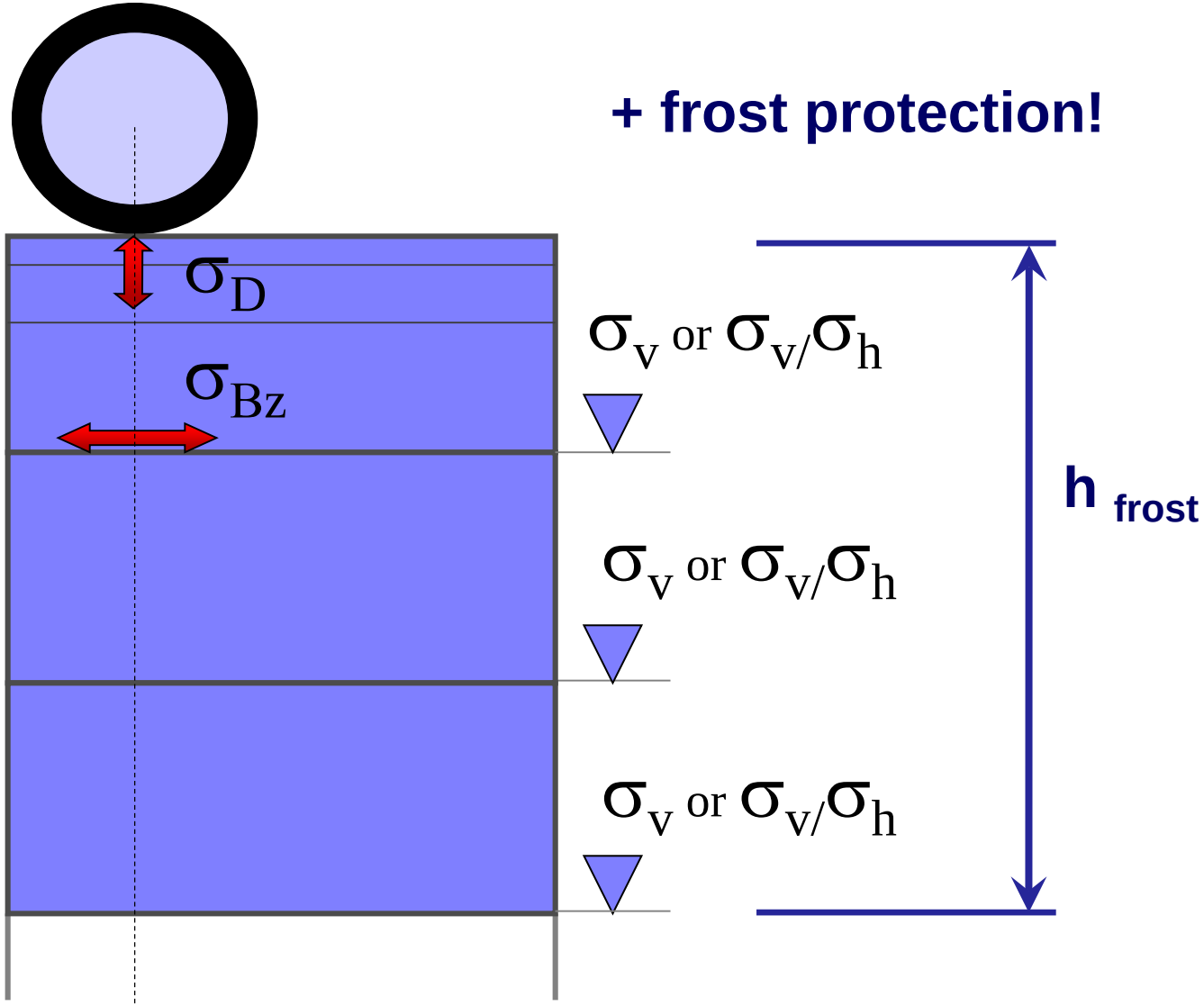
- change of empirical to fundamental requirements in Germany
- introduction of functional contracts

Analytical Pavement Design Guide + Software



Design criteria

+ frost protection!

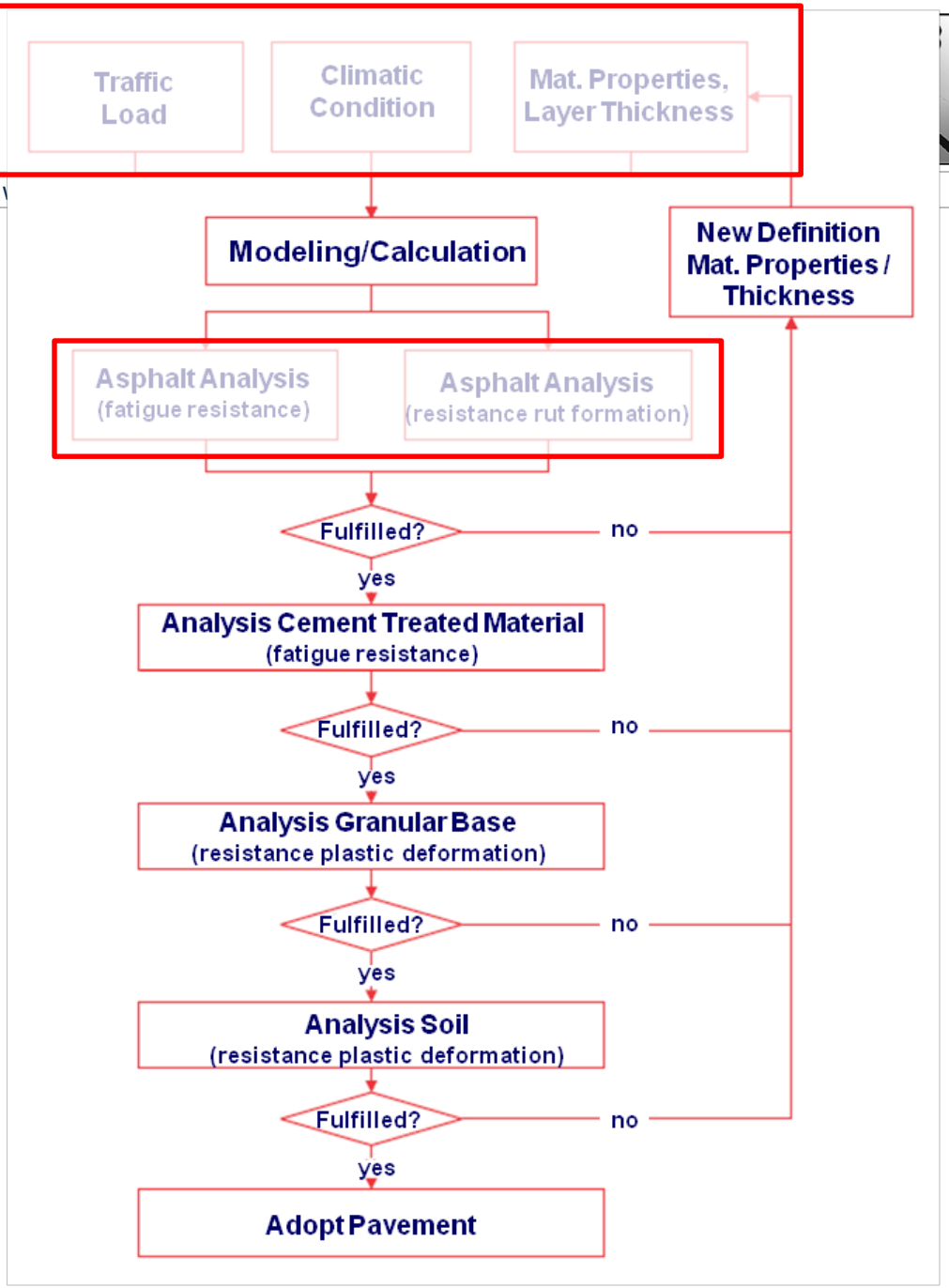


Pavement Design

Frost protection according to the RStO:

Entire thickness of pavement is depended on:

- frost penetration
- frost susceptibility of the soil in combination with
- traffic load



Input data

- **traffic load**
- climatic conditions
- stiffness
- fatigue resistance

Traffic loads in Germany

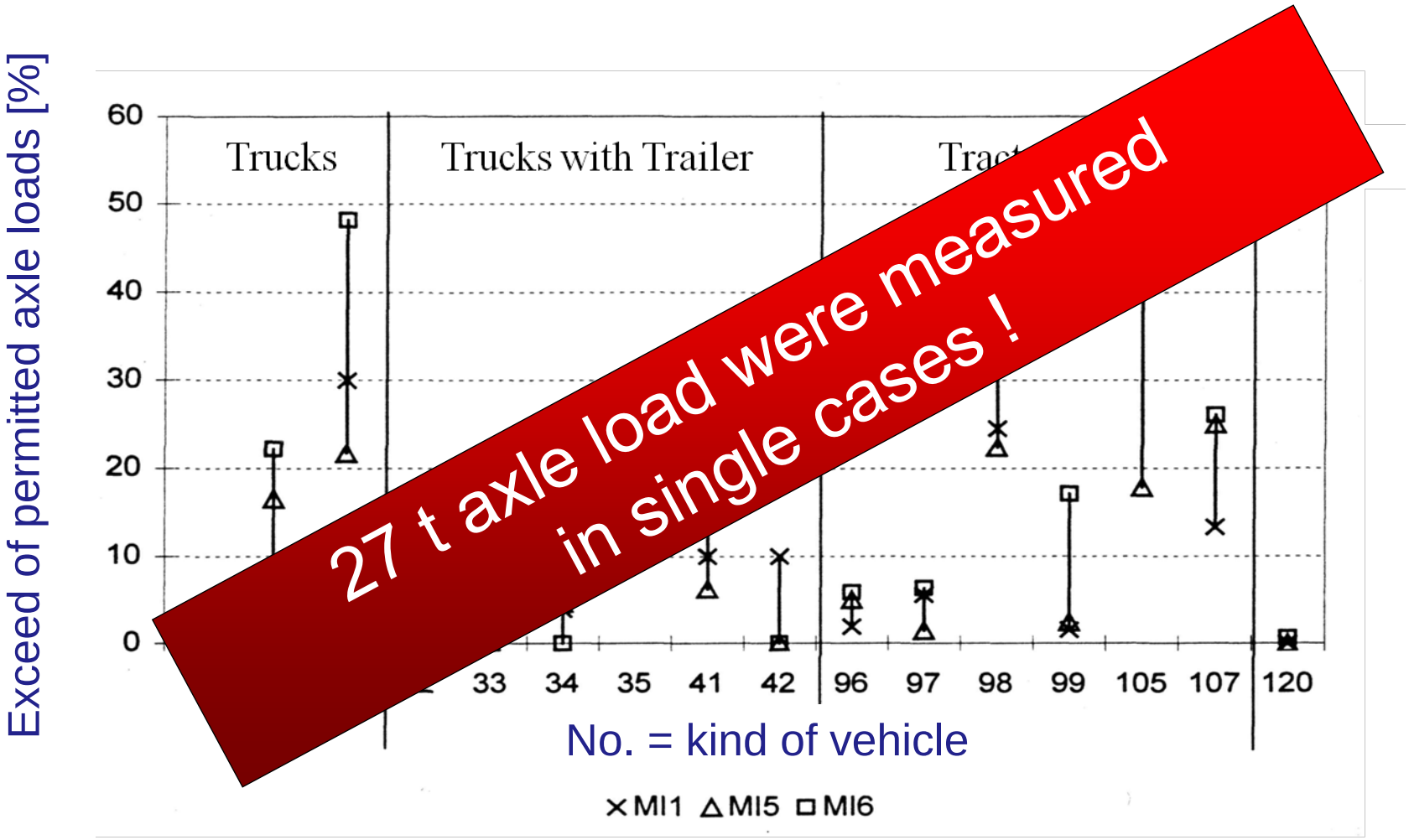
permitted traffic loads

heavy traffic:	3,5 t .. 44 t weight of the vehicle 11,5 t axle load = 5,75 t wheel load
average of wheel contact pressure:	0,6 ... 0,8 MPa

future:

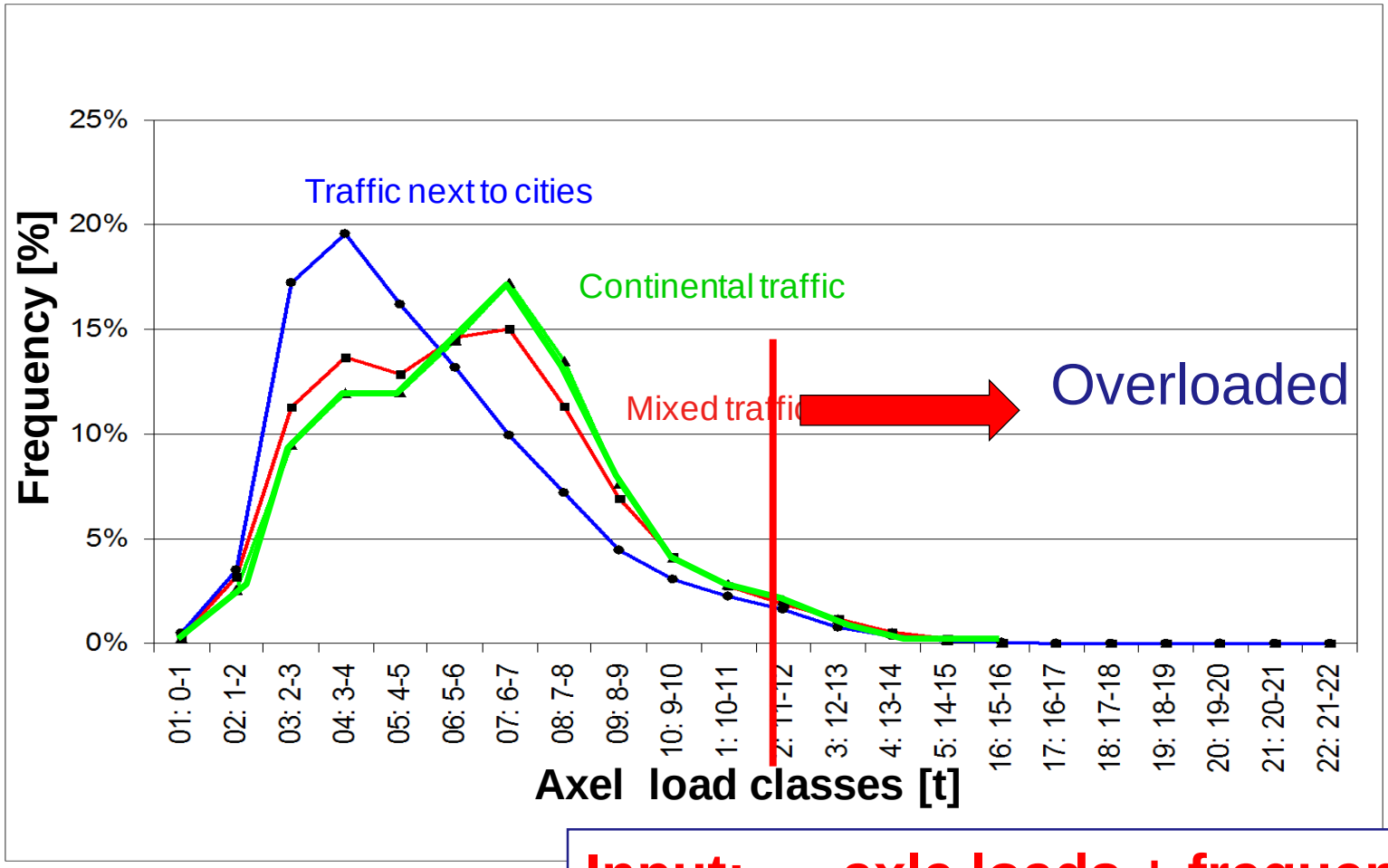
axle load	11,5 t ⇒ 13 t (???)
wheel contact pressure	0,8 MPa ⇒ 1,0 MPa (???)
number of car/trucks	increasing continuously

Traffic loads in Germany



WIM, Federal Road Research Laboratory

Traffic loads in Germany



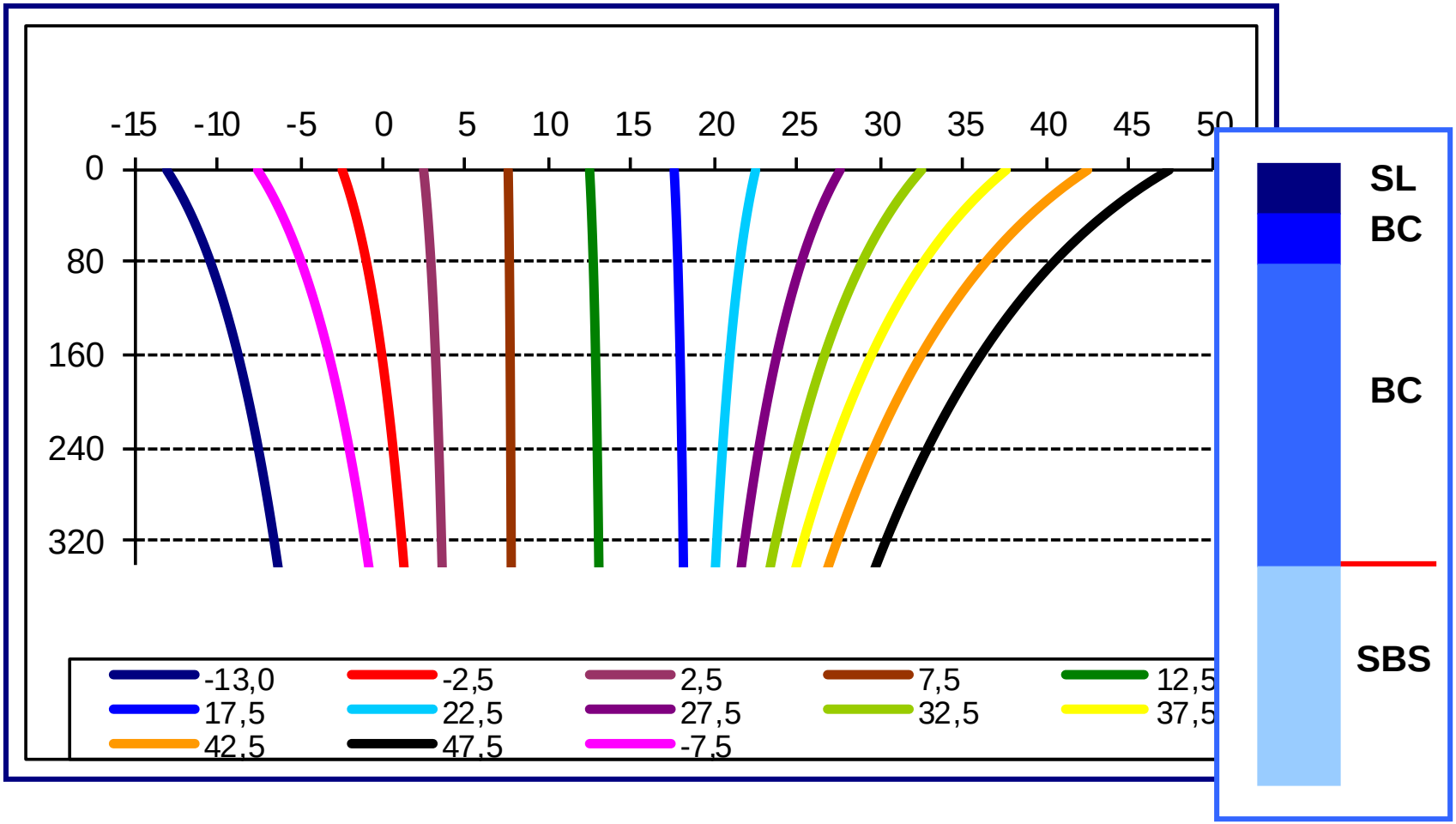
Input: axle loads + frequency of load classes

Input data

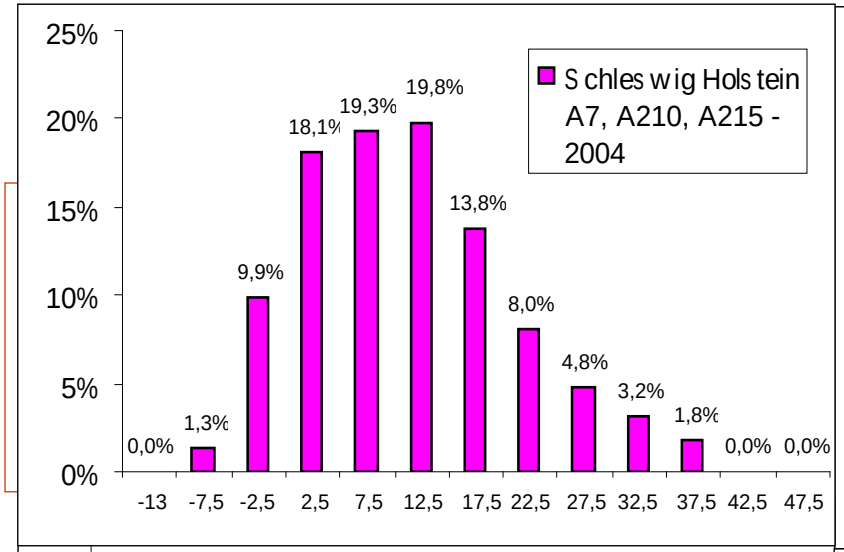
- traffic load
- climatic conditions
- stiffness
- fatigue resistance

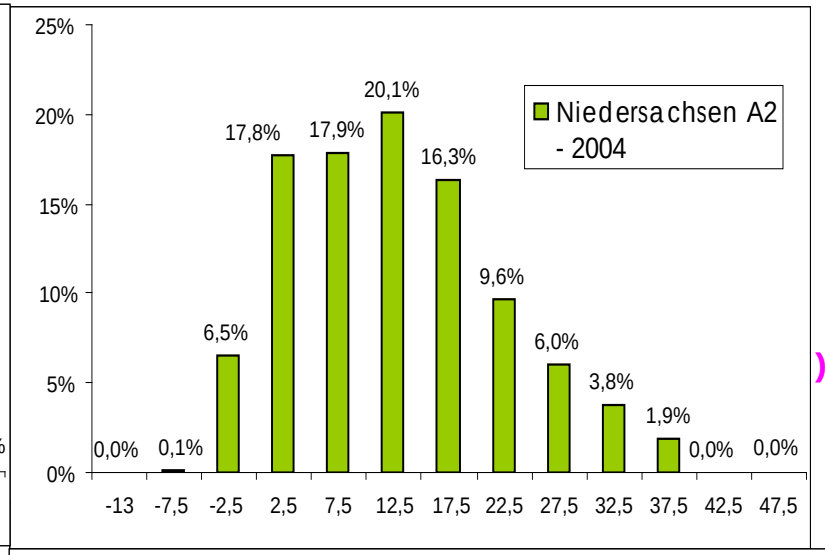
Surface temperatures

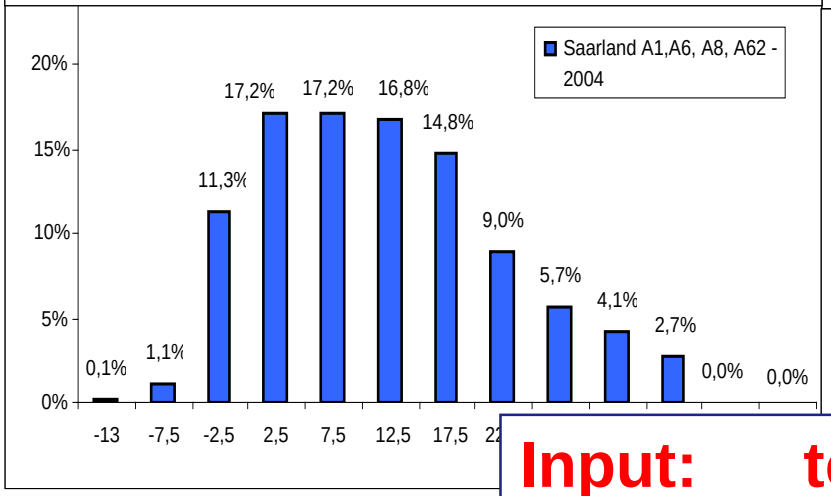
Temperature functions

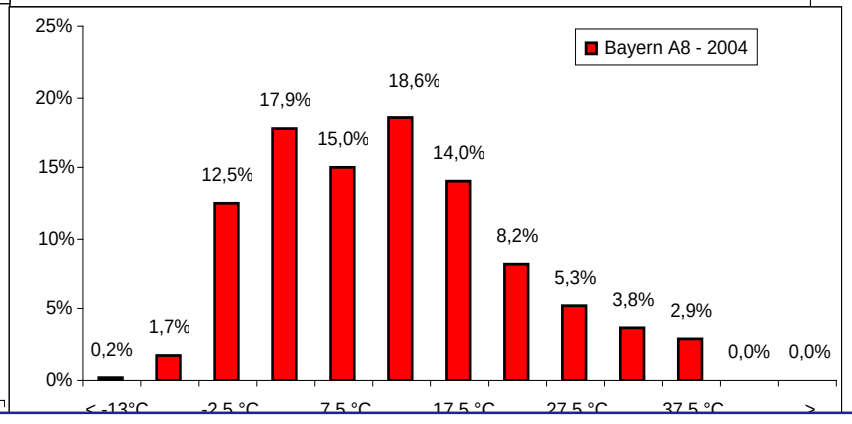


Frequency of appearance of temperature functions



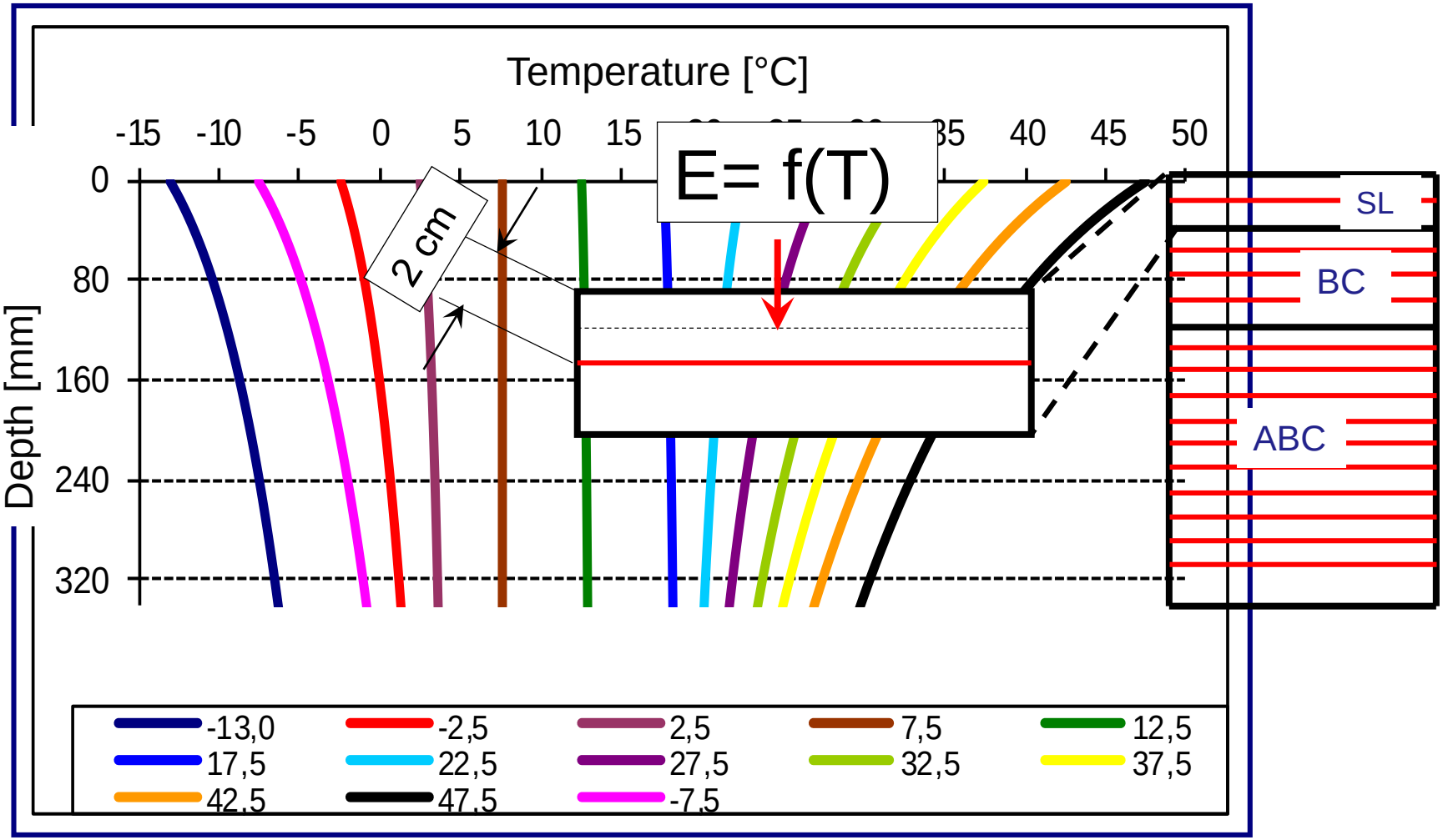




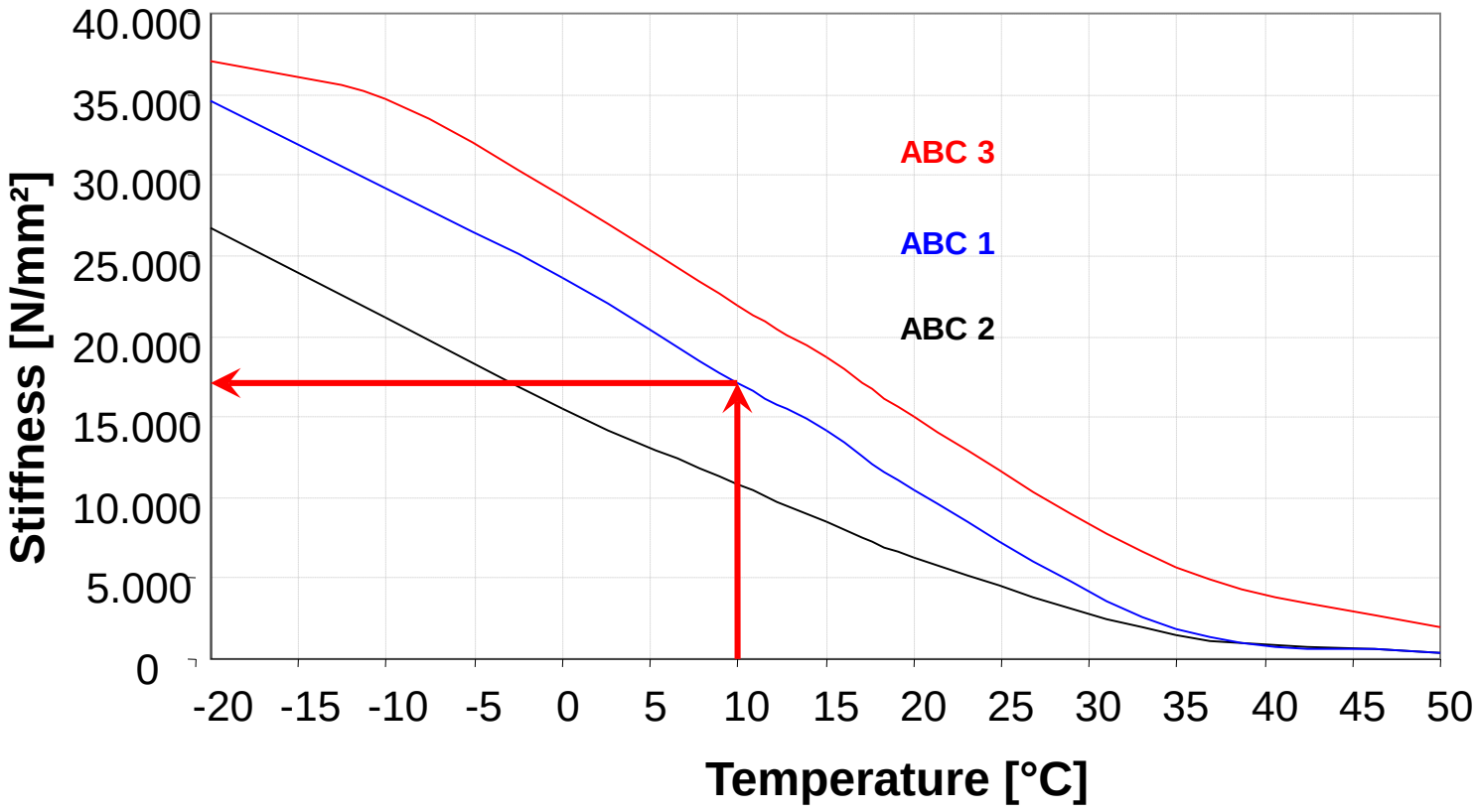


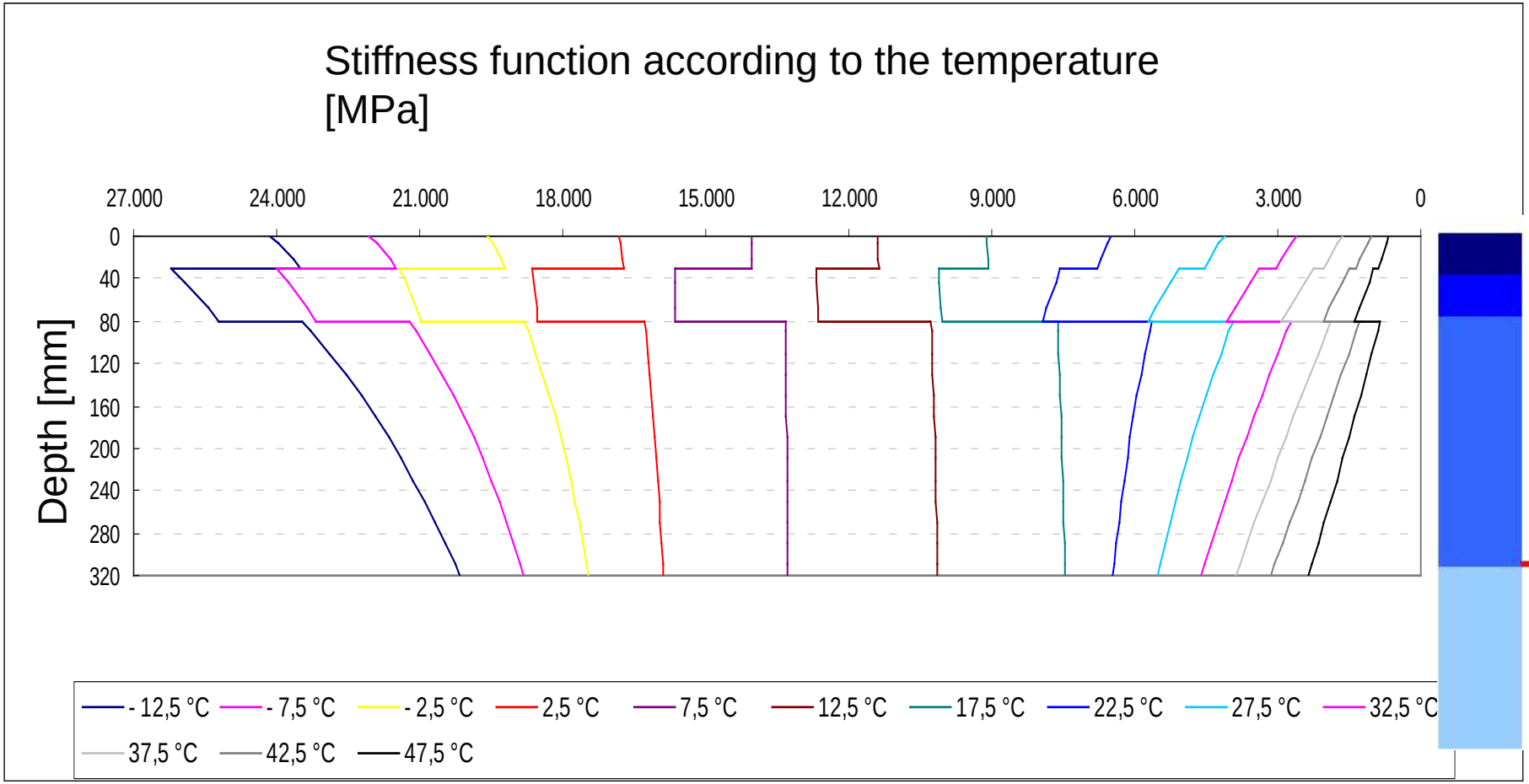
Input: temperature functions + frequency of appearance

Temperature functions (examples) in the asphalt layers [MPa]



Stiffness function



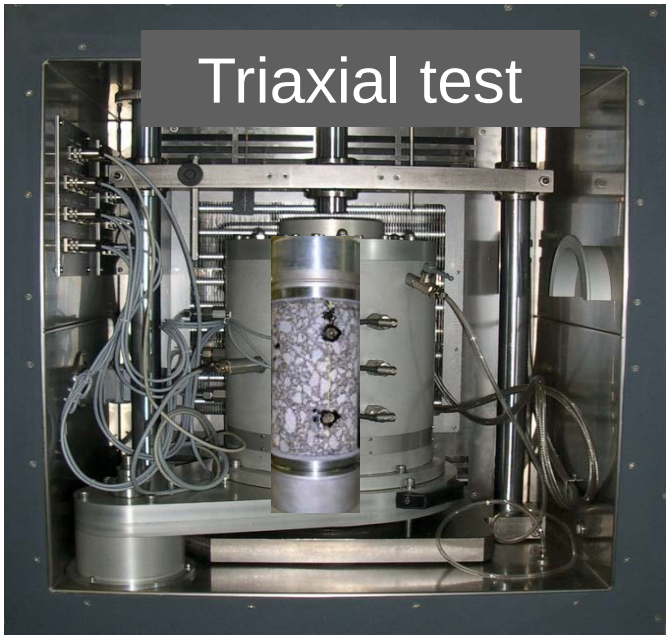


Based on this => calculation of stresses/strains

Input data

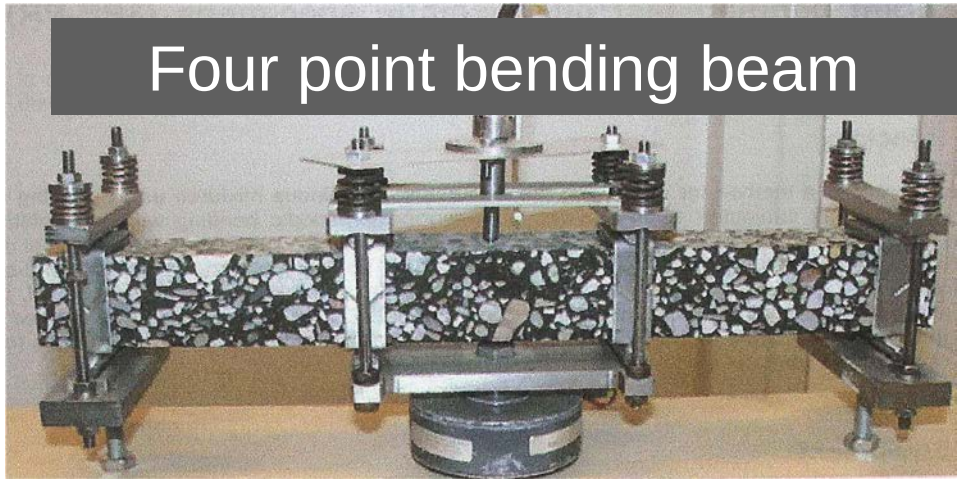
- traffic load
- climatic conditions
- stiffness
- fatigue resistance

Which test?


Triaxial test


Direct tension test
?


Indirect tension test

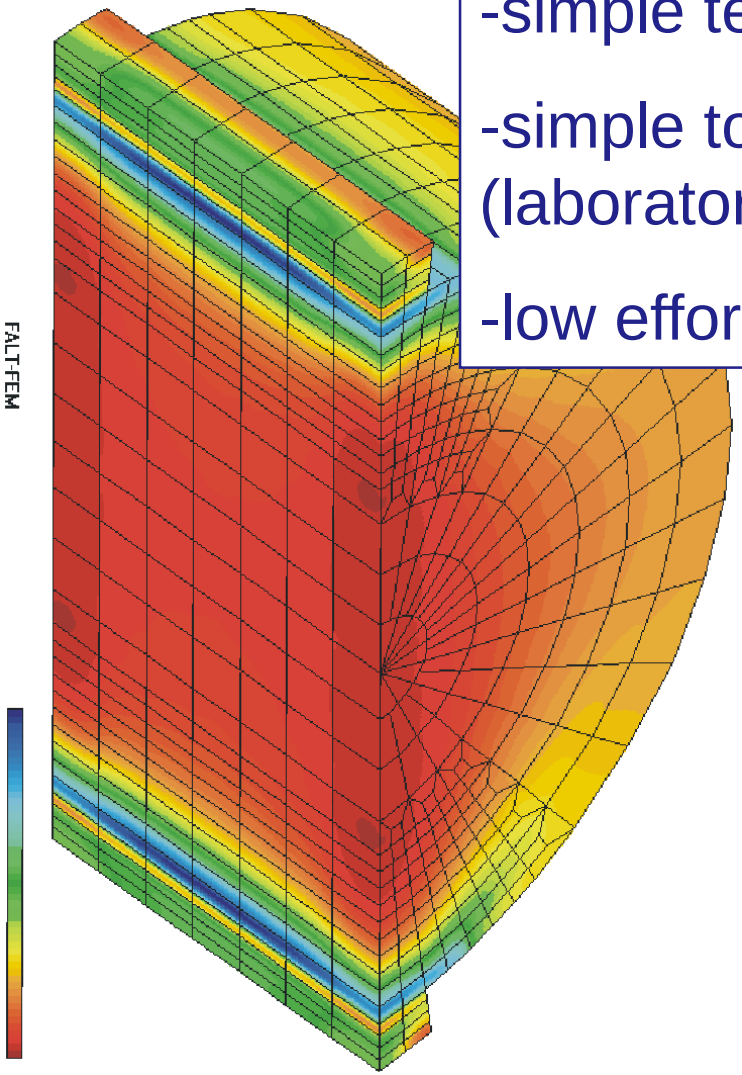

Four point bending beam

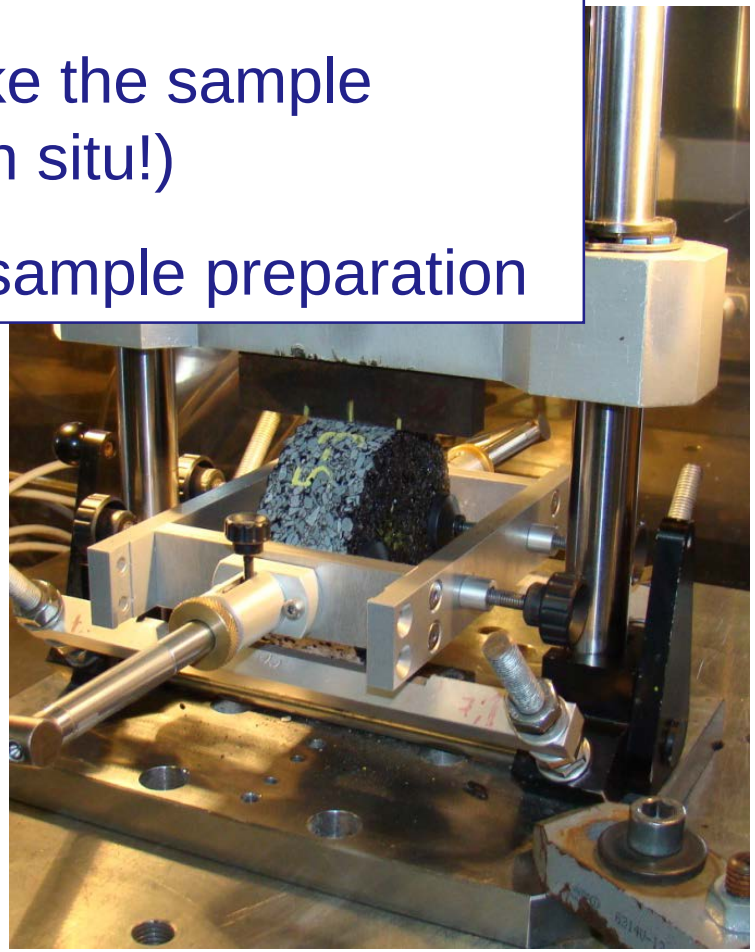
Indirect tension tests

-simple test

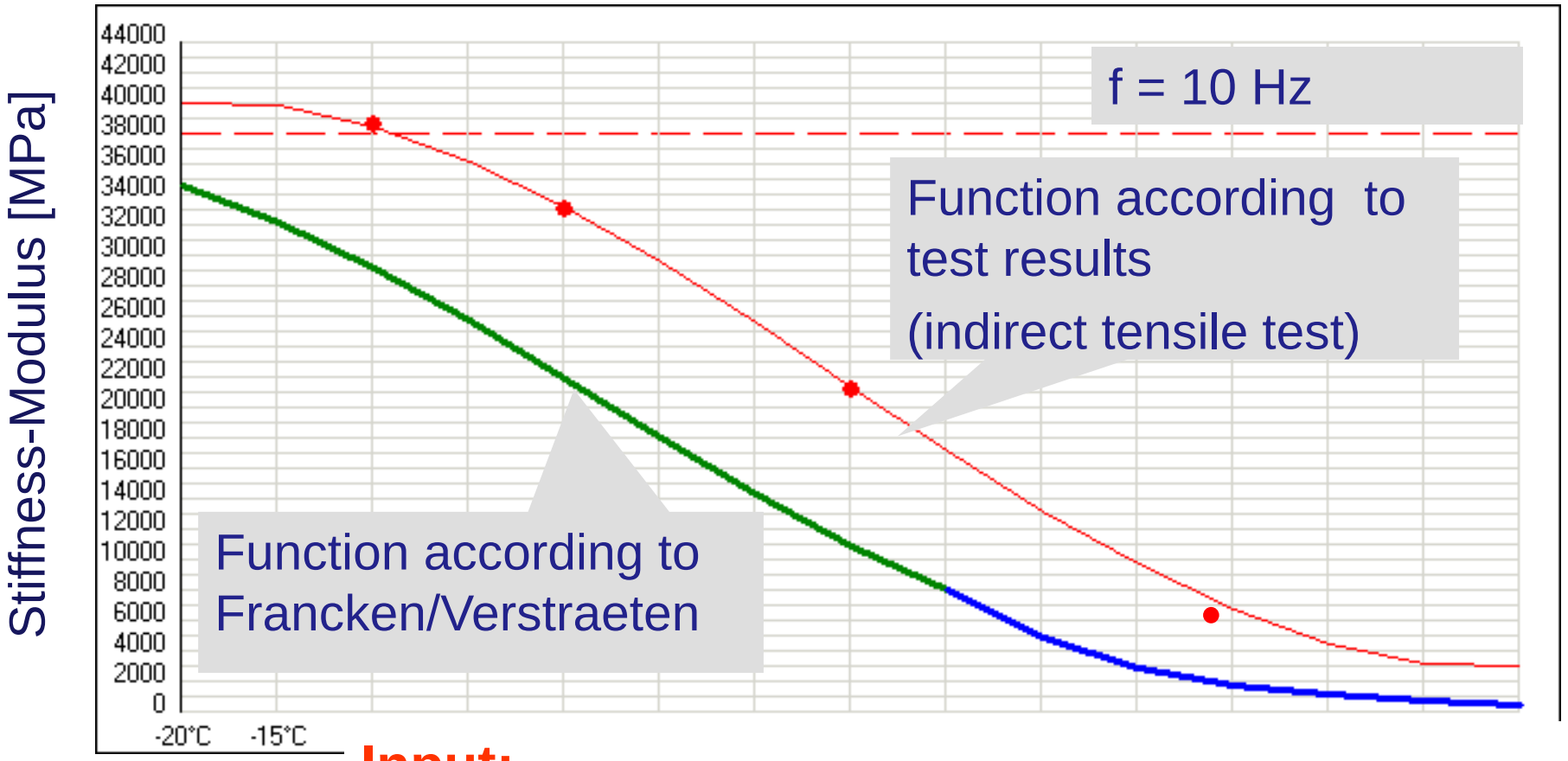
-simple to make the sample (laboratory + in situ!)

-low effort for sample preparation



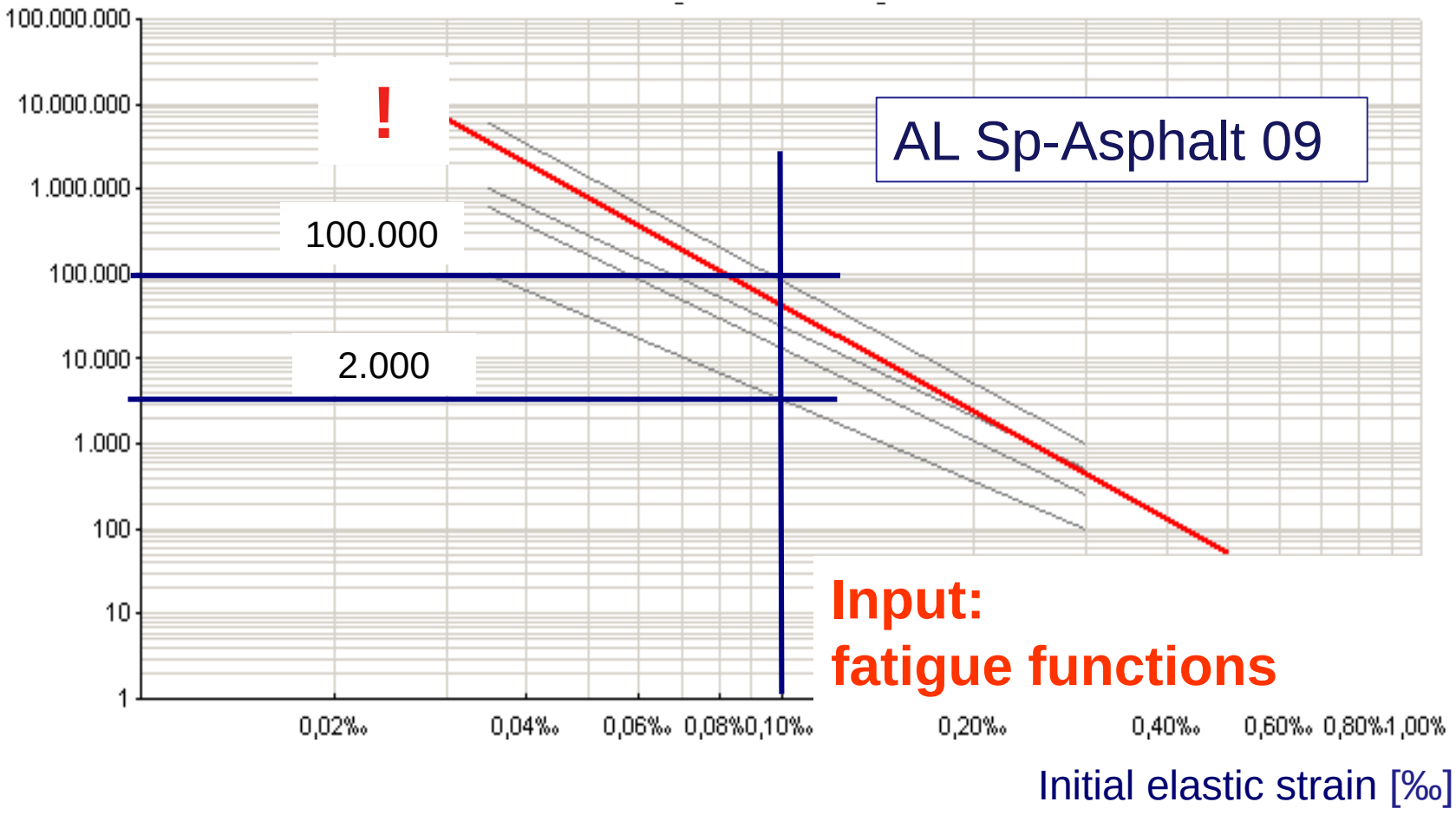


Stiffness



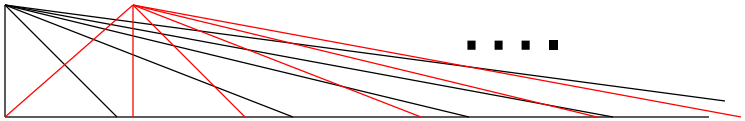
Input:
Stiffness modulus - temperature functions

Fatigue functions



Calculation

13 temperature conditions I II III IV V…XIII



10...20 load classes I II III IV V … X

13 (...200) * 10 (10...20) = 130 (4000) strain conditions

evaluation: permitted N = F(calculated ε) per condition

accumulation: Miner's law

Accumulation of damages

(test results)

per N = f (exp σ,γ)

(input data's)

exp N

$$\sum_{Miner} = \frac{\exp N_1}{perN_1} + \frac{\exp N_2}{perN_2} + \ldots + \frac{\exp N_n}{perN_n} \leq 1$$

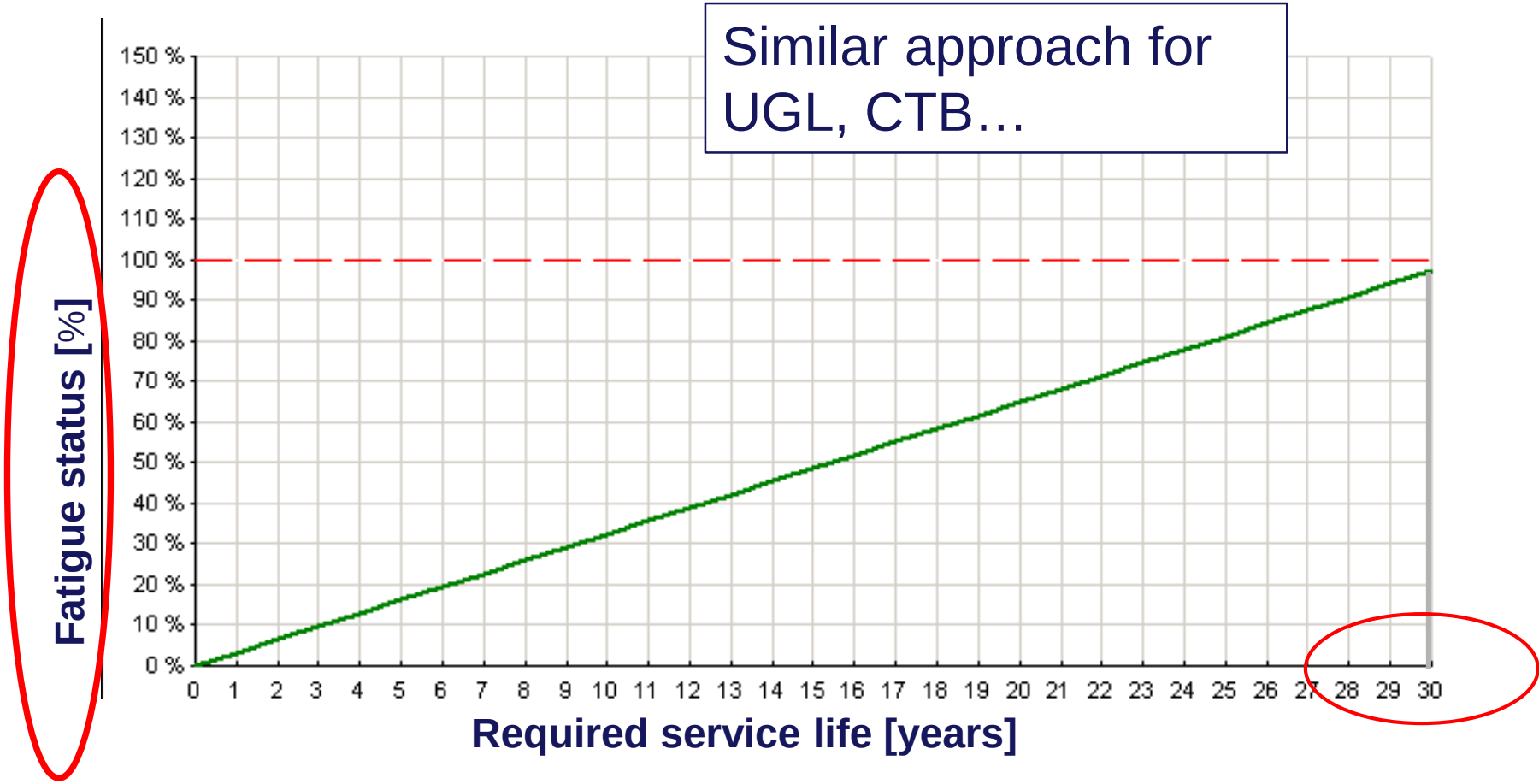
Miner‘s law

exp – expected

per - permitted

1*100 = 100% = „Fatigue status“

Similar approach for UGL, CTB…

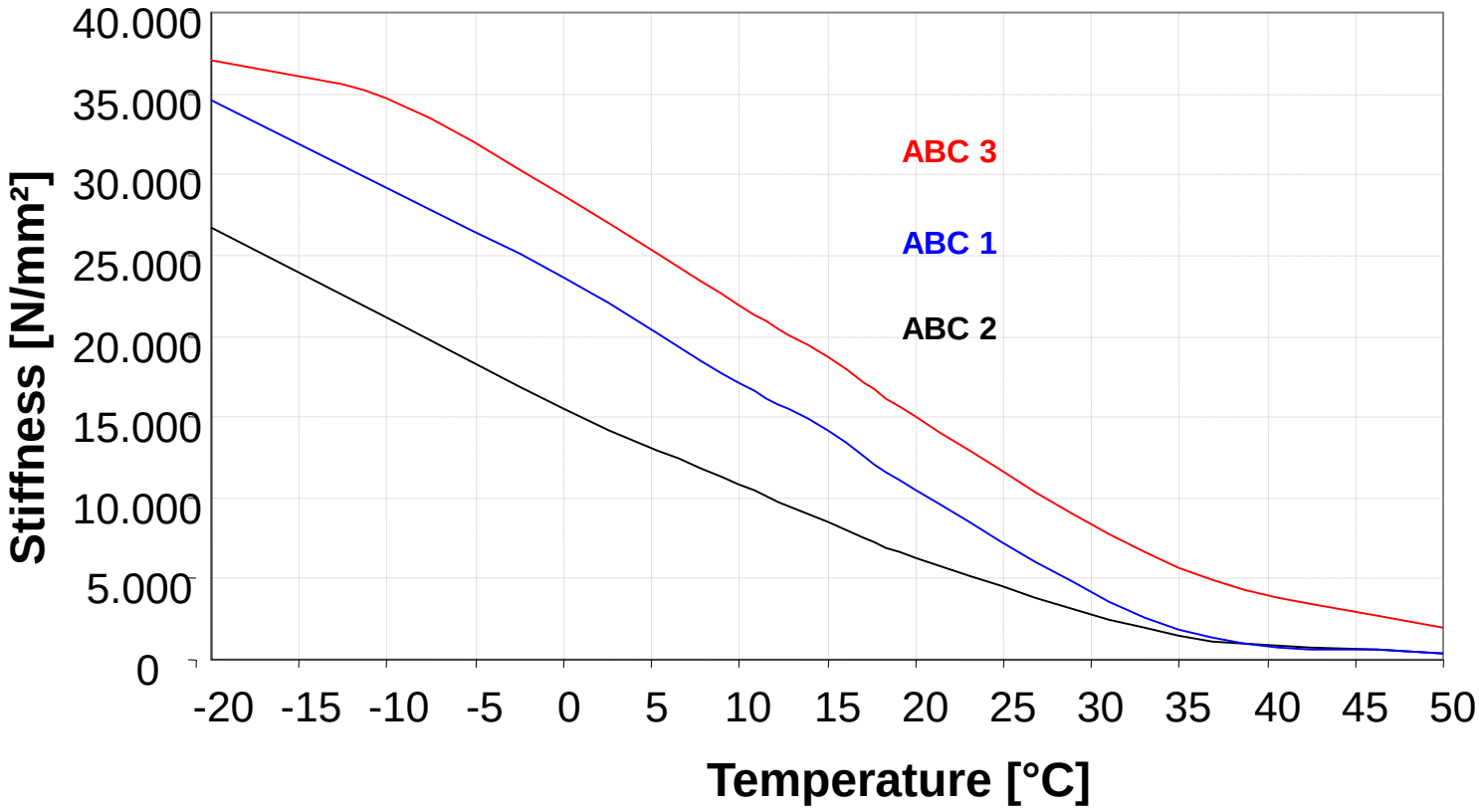


Design criterion

„Fatigue“

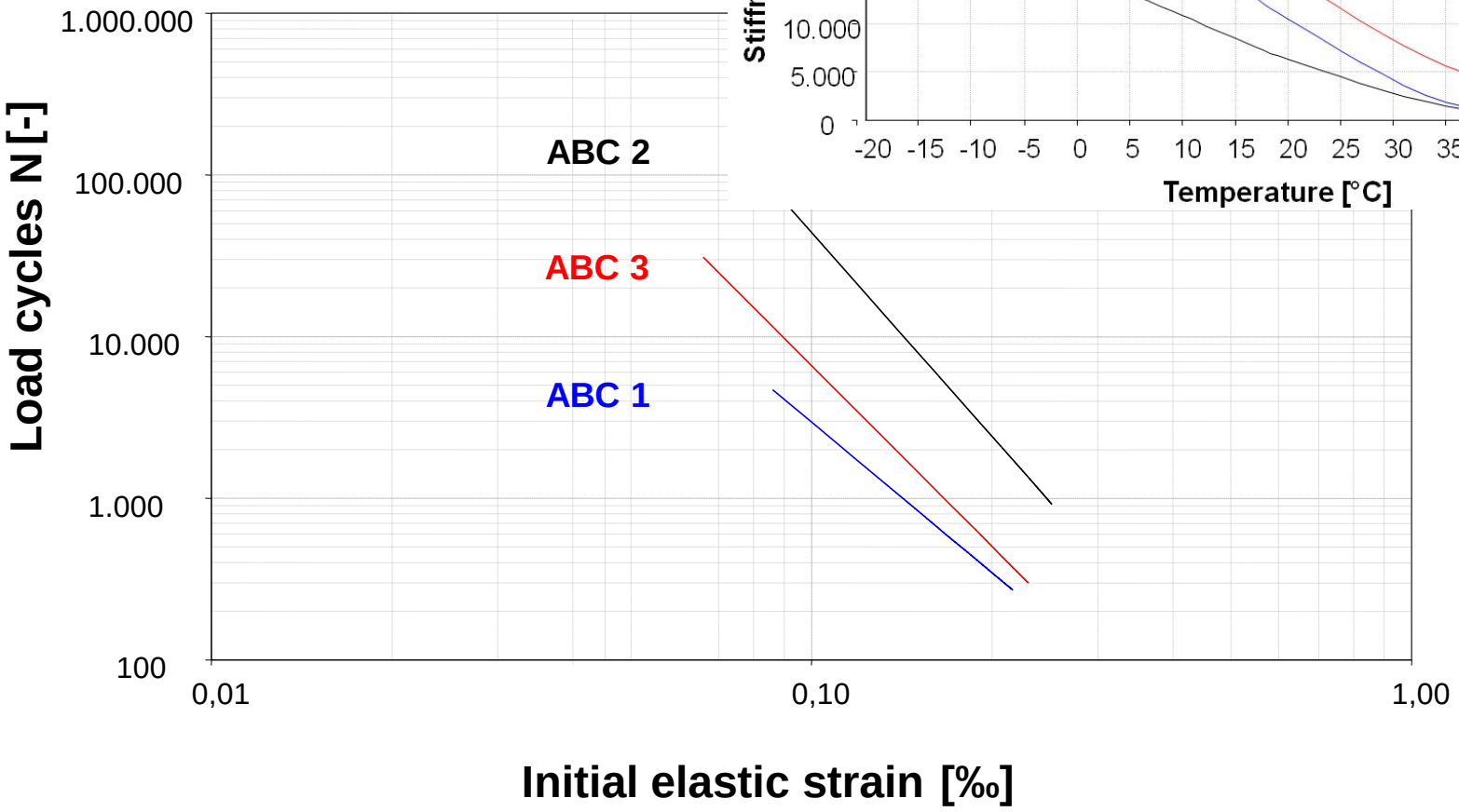
Example 1 - material behaviour

Stiffness – determined by indirect tensile test

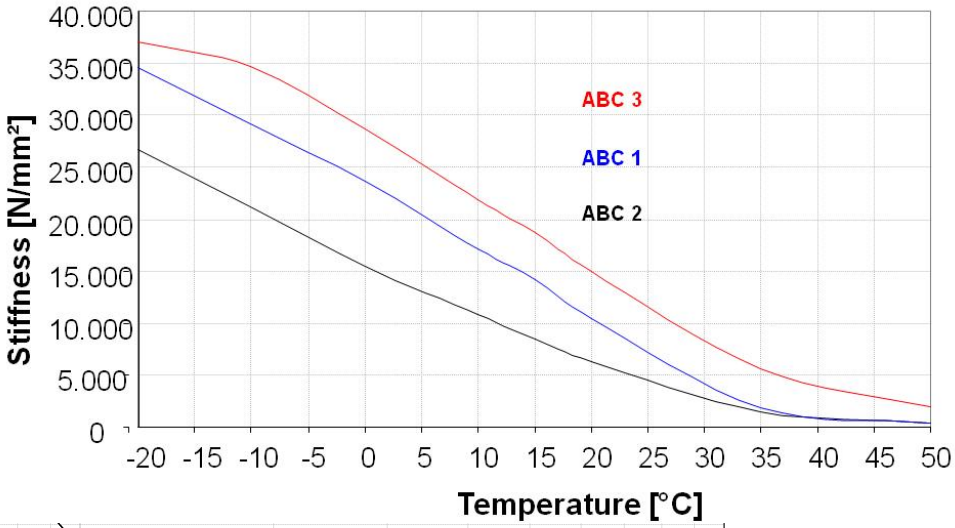


Example 1

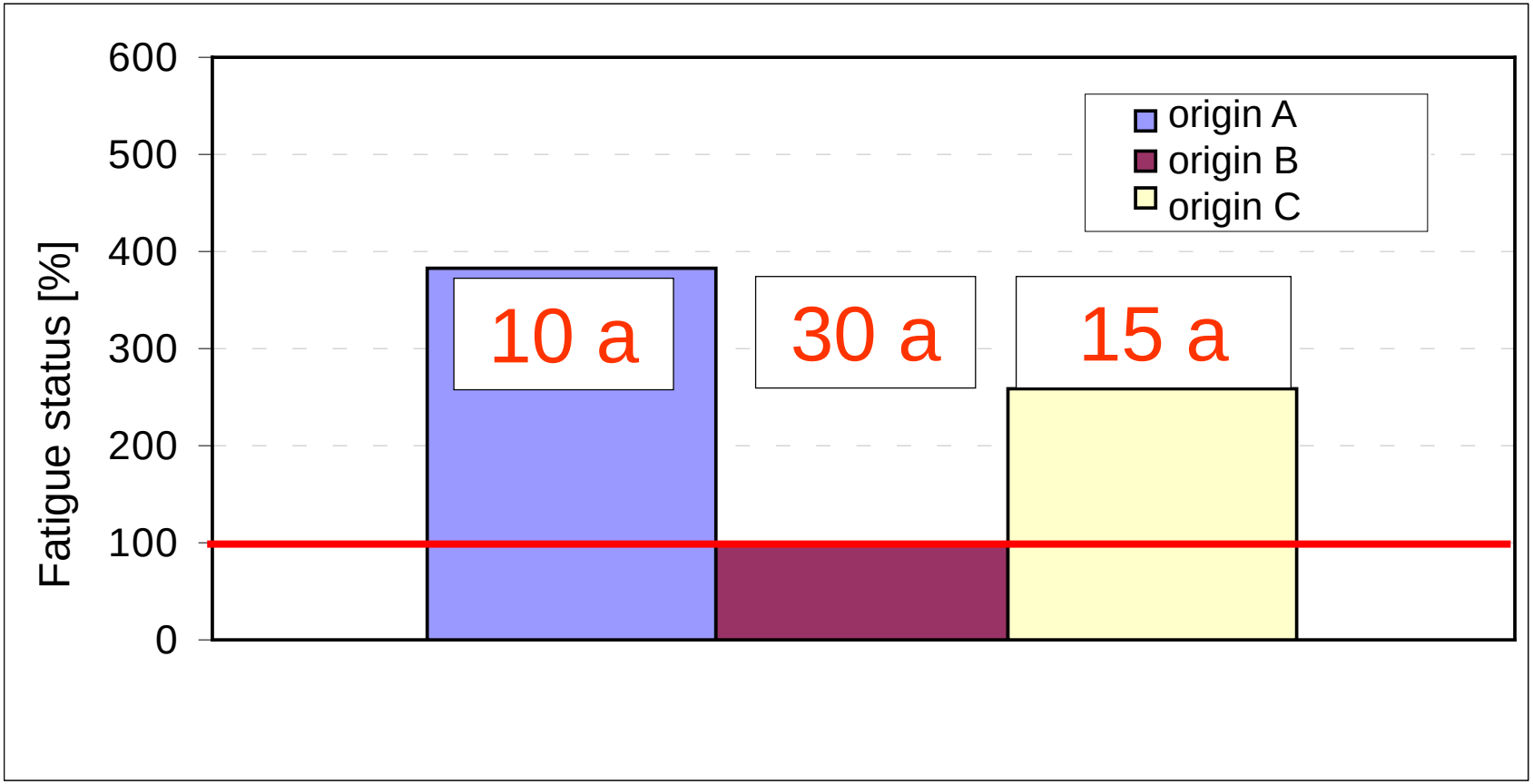
Fatigue functions - determ



Stiffness – determined by indirect tensile test

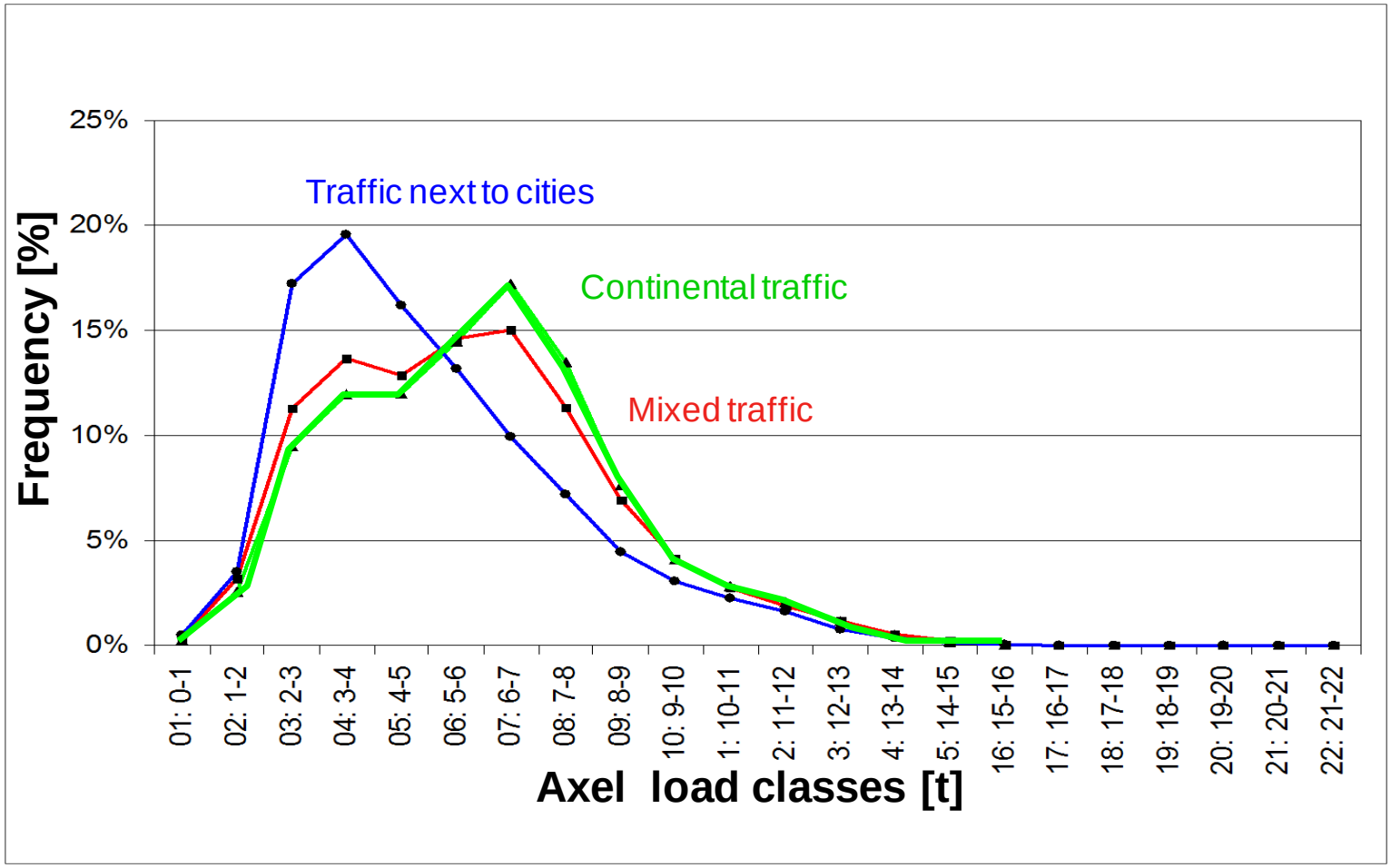


Effect of material behaviour



Level of fatigue of asphalt base course material with the same stone material and sieving curve and Bitumen 50/70 with different origin

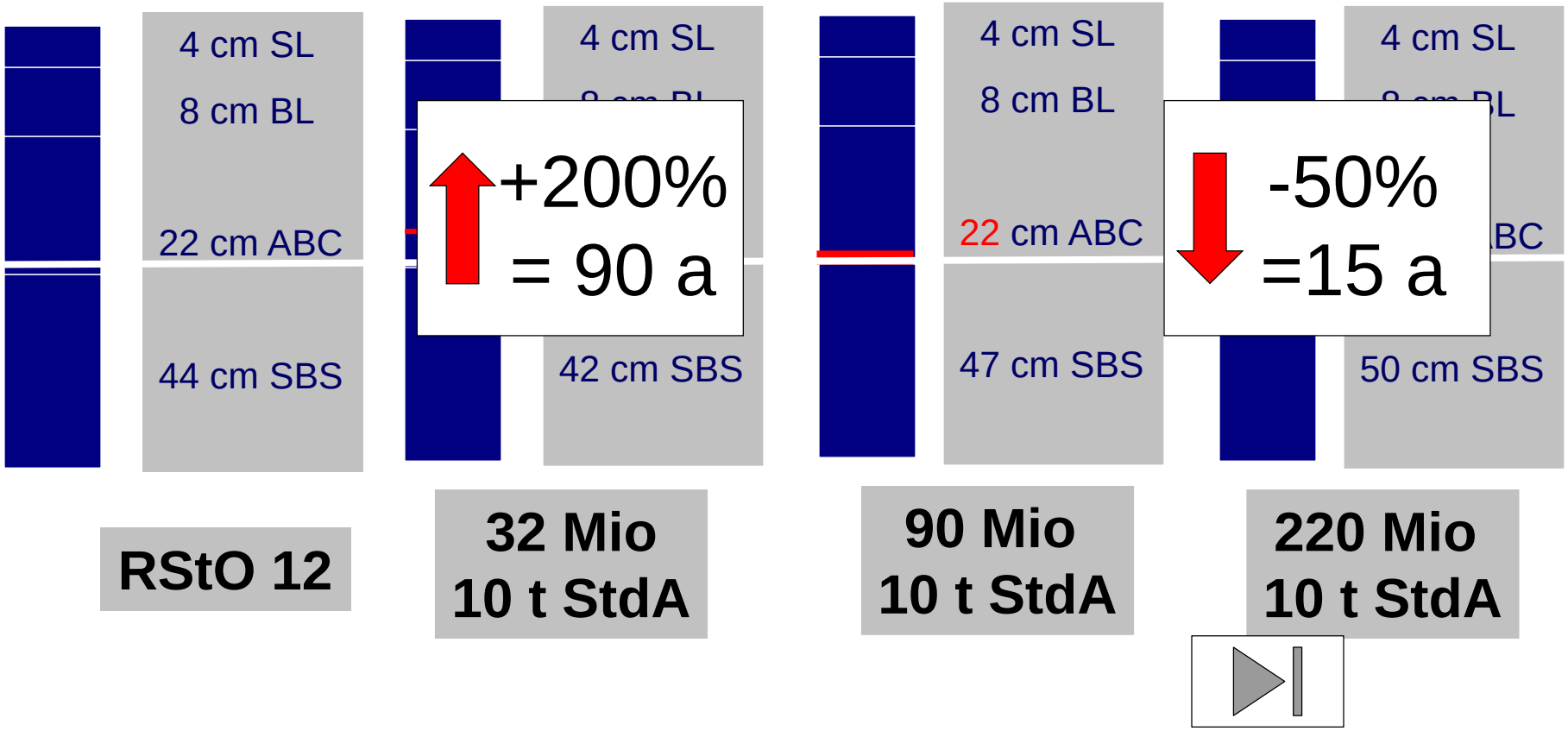
Example 2 – traffic load



Example 2 – traffic load

Effect on service life?

B ≥ 32 Mio 10 t StdA	±0 cm	±0 cm	±0 cm



RStO 12	32 Mio 10 t StdA	90 Mio 10 t StdA	220 Mio 10 t StdA

Example 3

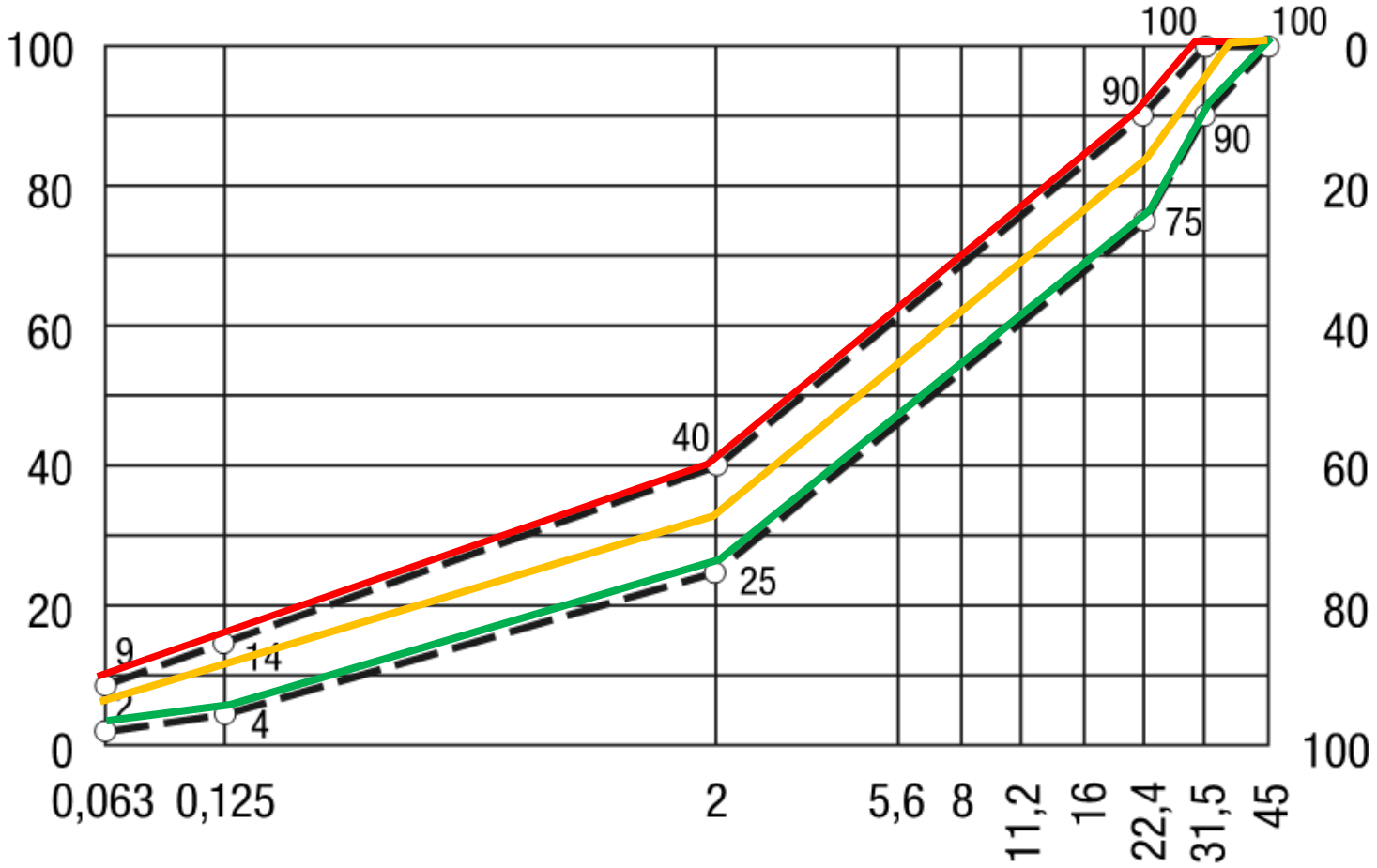
Performance based mix design method

- Number of asphalt mixes -

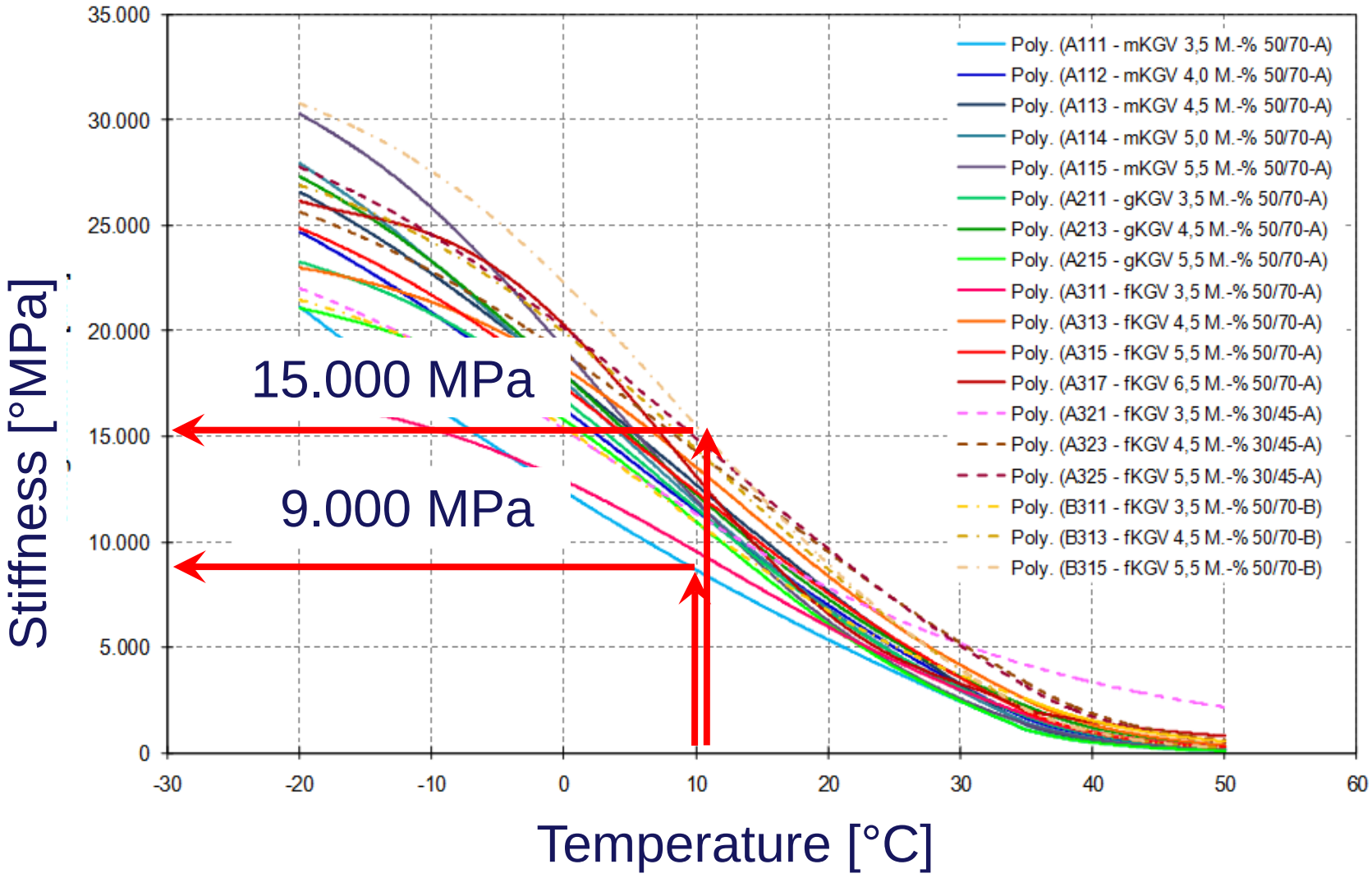
Grading curve	Bitumen	Producer	No. of Bitumen content
medium	50/70	A	5
coarse			3
fine			4
	30/45		3
	50/70	B	3
		∑ Asphalt mixes	18

Grading curve (asphalt base course)

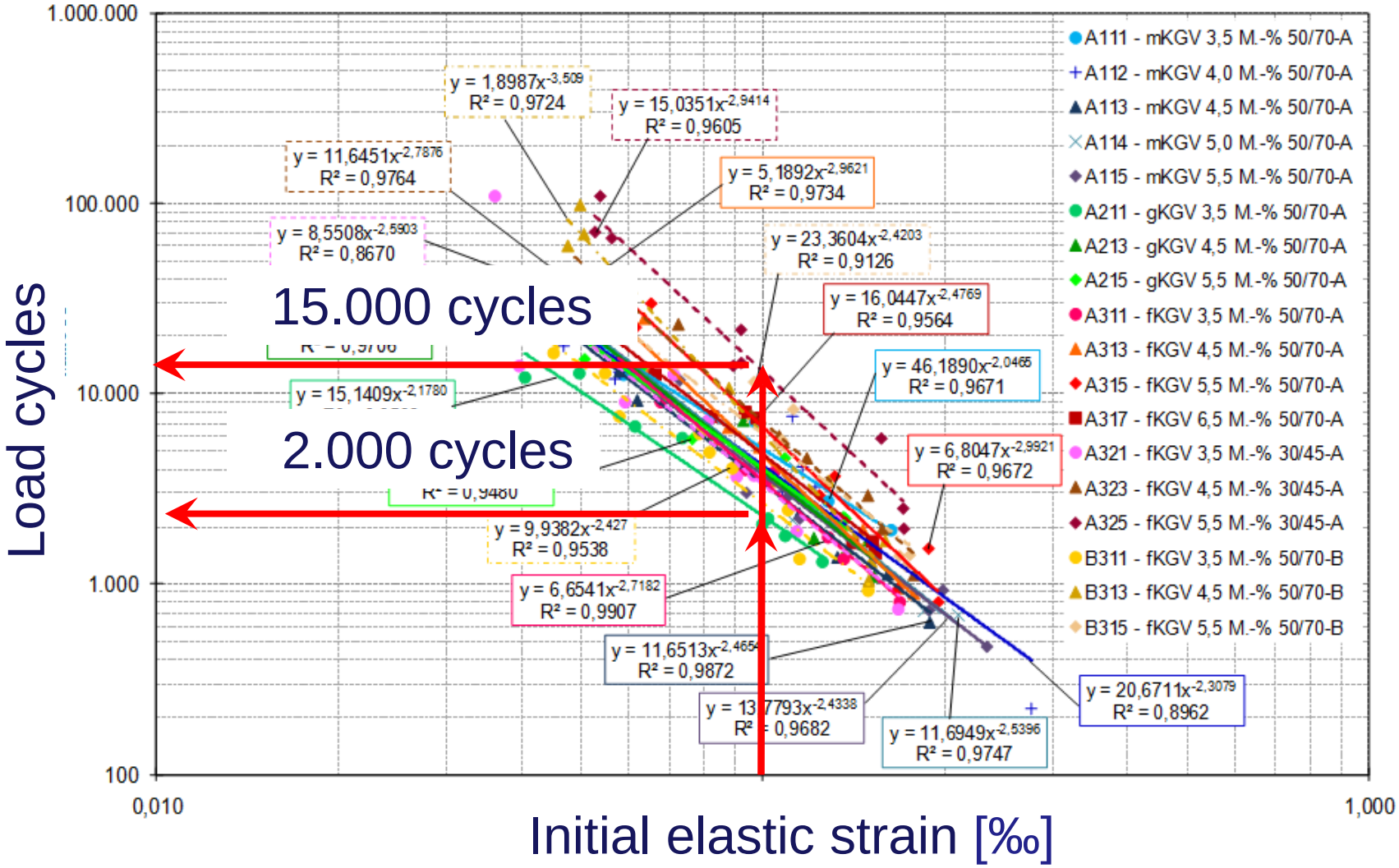
„fine“ „medium“ „coarse“



Stiffness-Temperature-Function

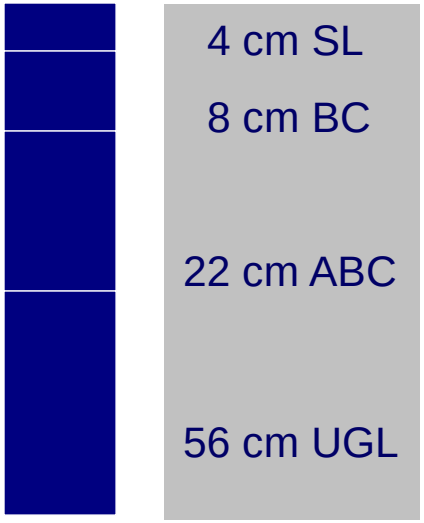


Fatigue function



Calculation according to “RDO Asphalt 09”

B = 32 Mio ESALs



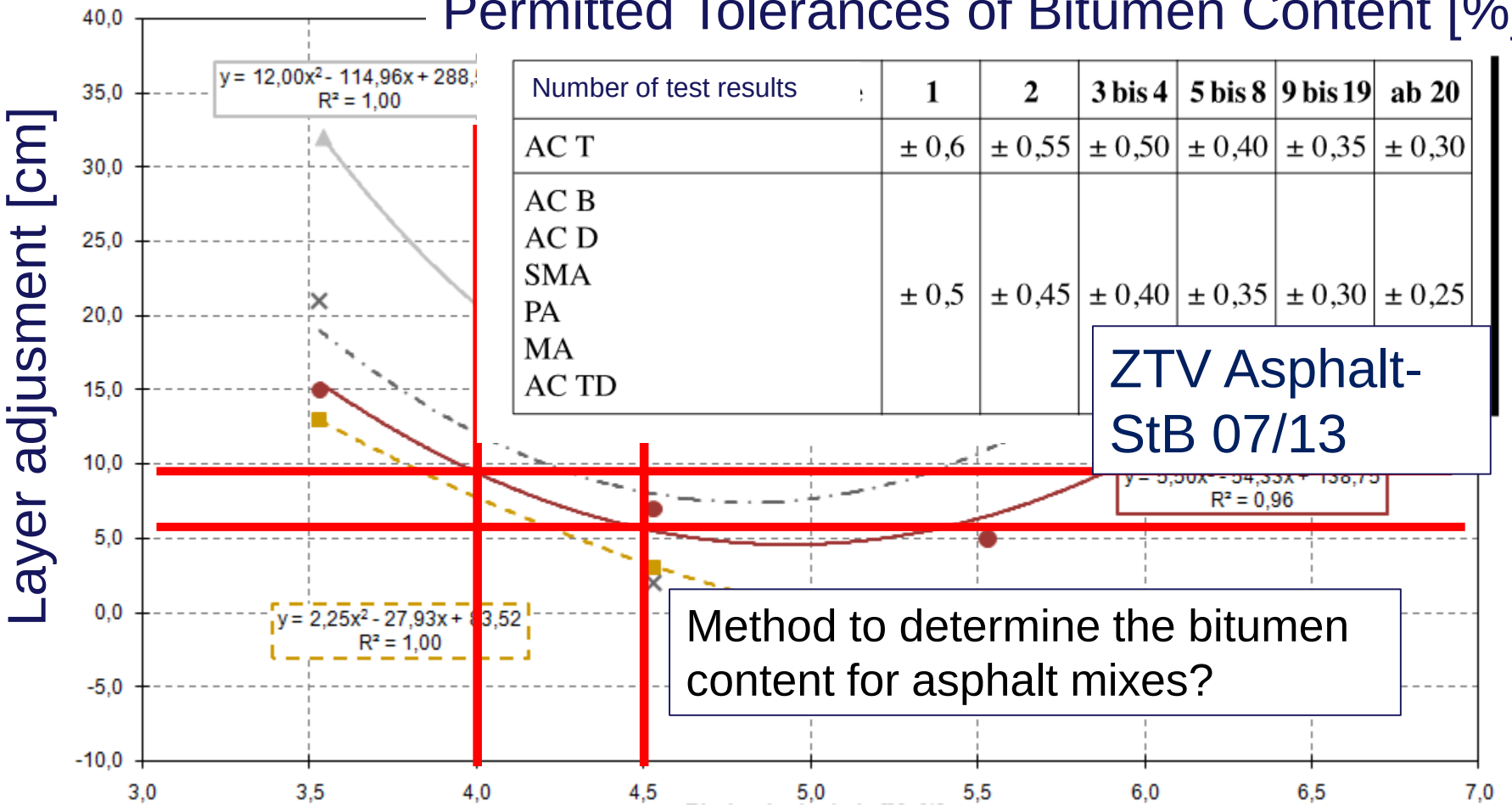
RStO 12

Layer thickness ⇔ Binder content

Permitted Tolerances of Bitumen Content [%]

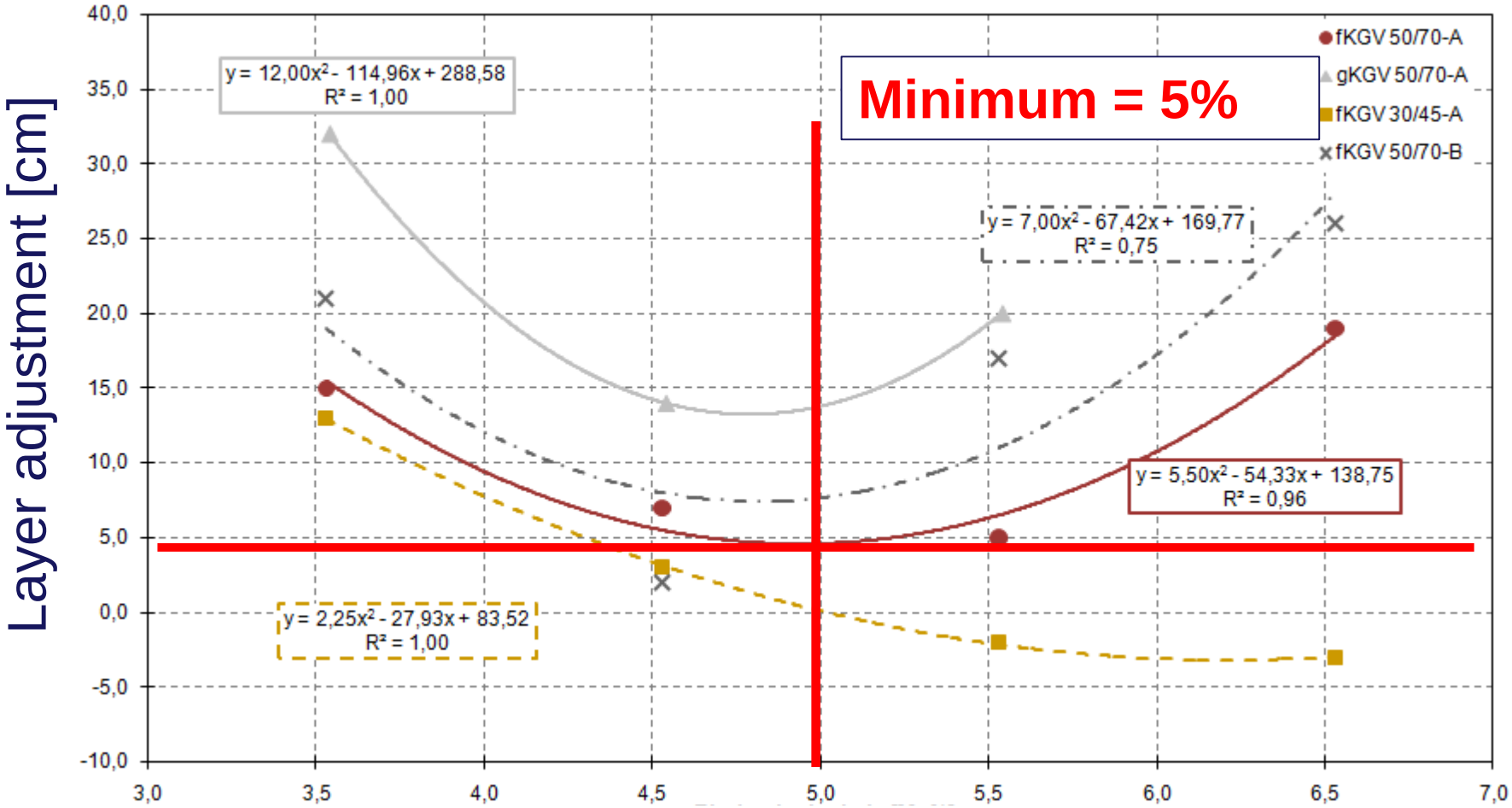
Number of test results	1	2	3 bis 4	5 bis 8	9 bis 19	ab 20
AC T	± 0,6	± 0,55	± 0,50	± 0,40	± 0,35	± 0,30
AC B AC D SMA PA MA AC TD	± 0,5	± 0,45	± 0,40	± 0,35	± 0,30	± 0,25

ZTV Asphalt-StB 07/13

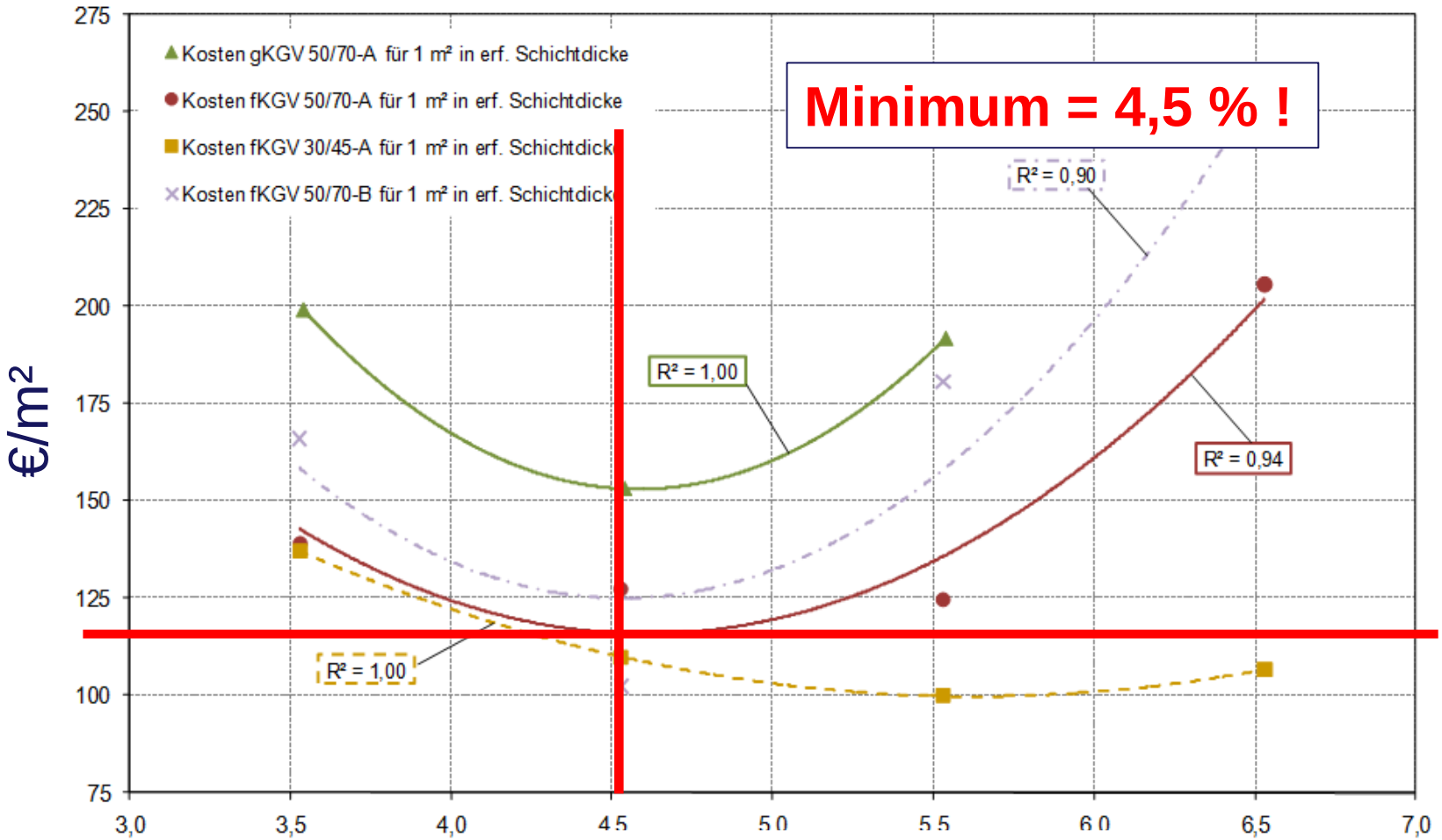


Method to determine the bitumen content for asphalt mixes?

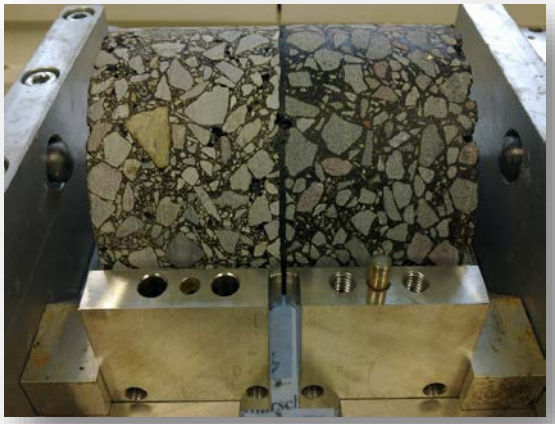
Layer thickness ⇔ Binder content

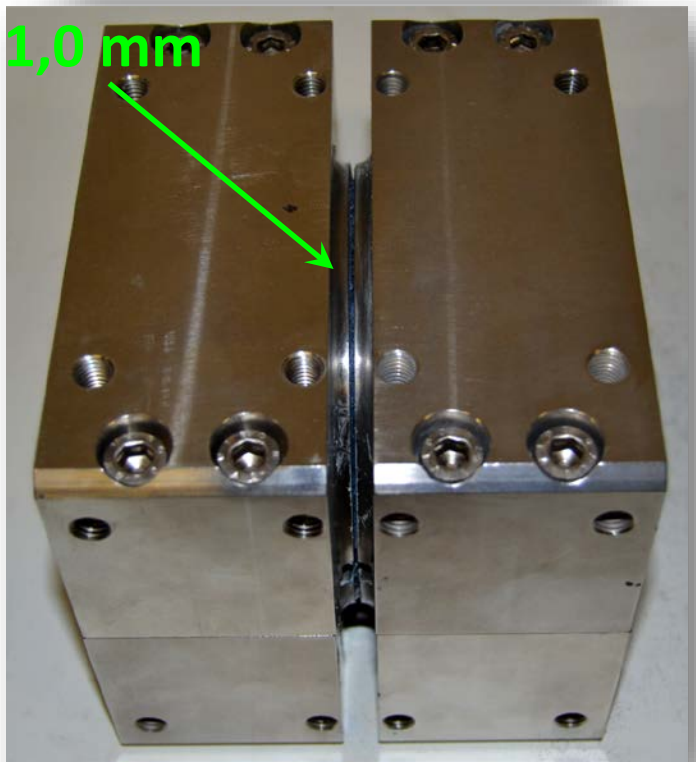


Expenses [€/m²] ⇔ Binder content [%]

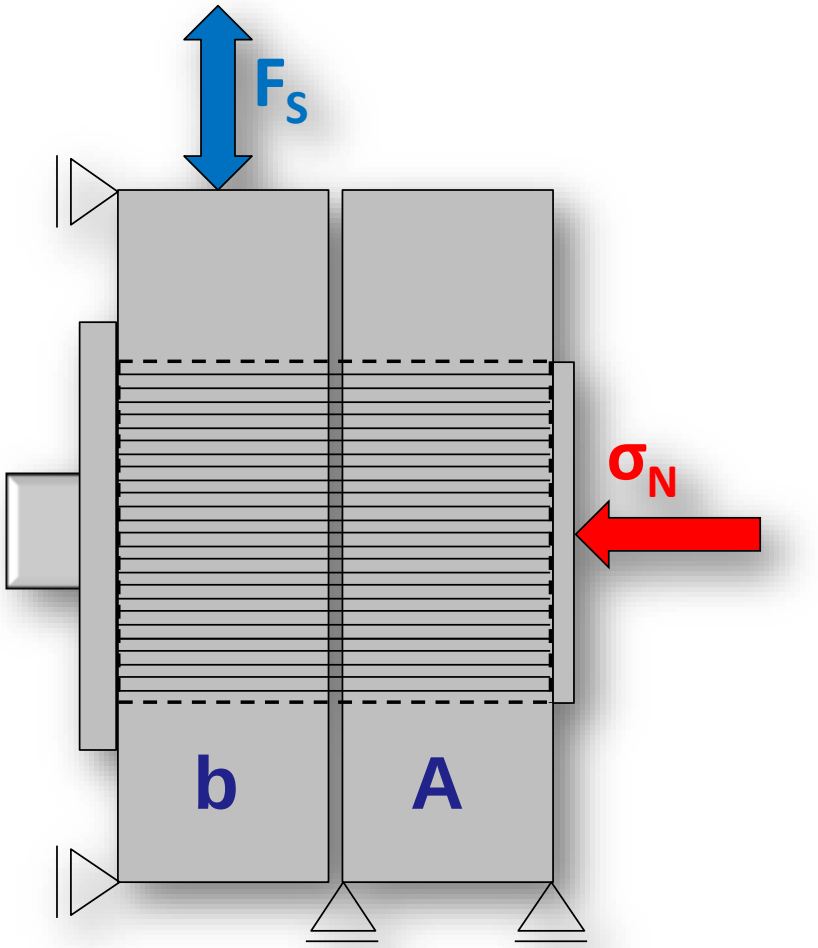


Dynamic shear test

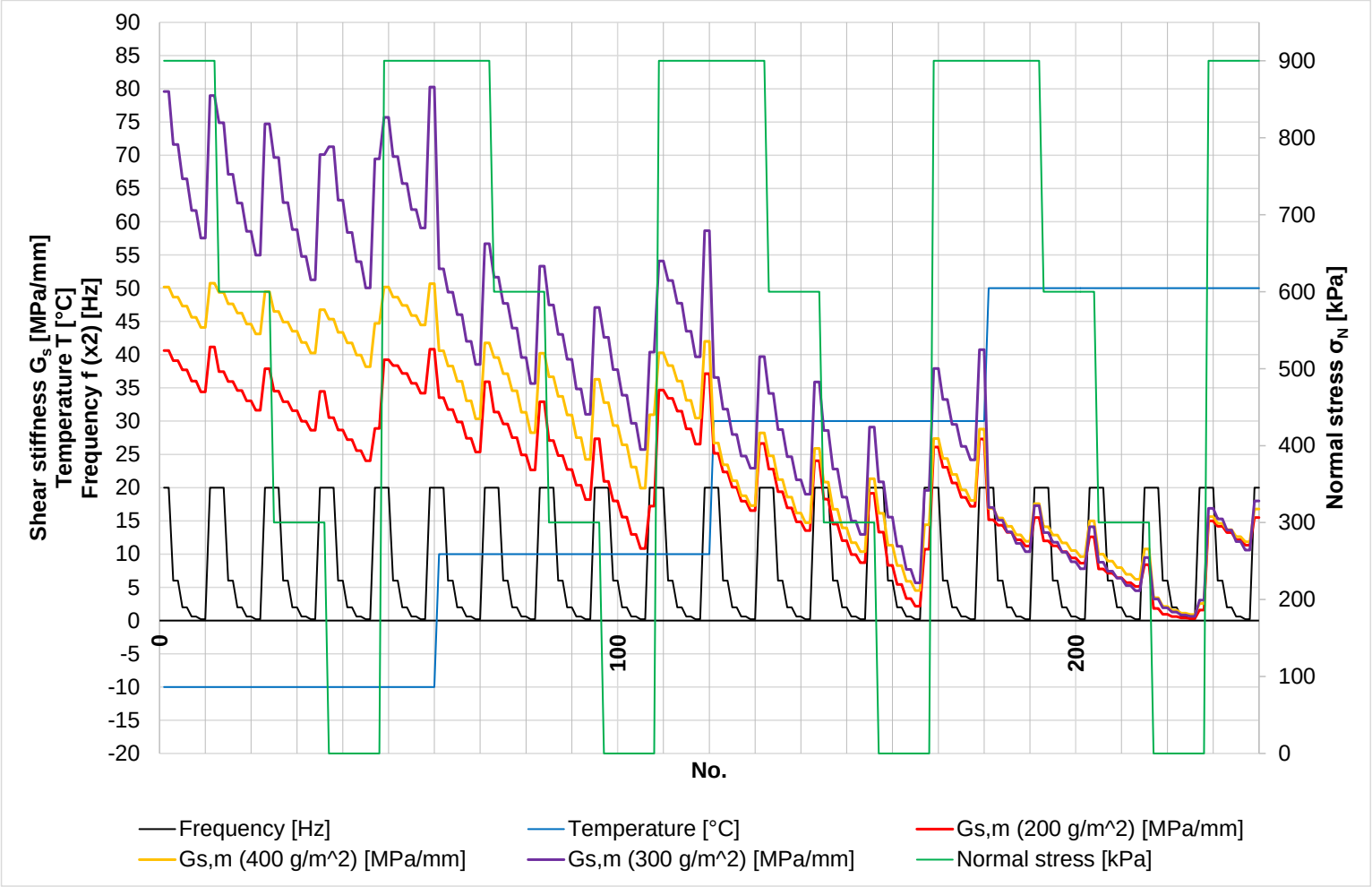




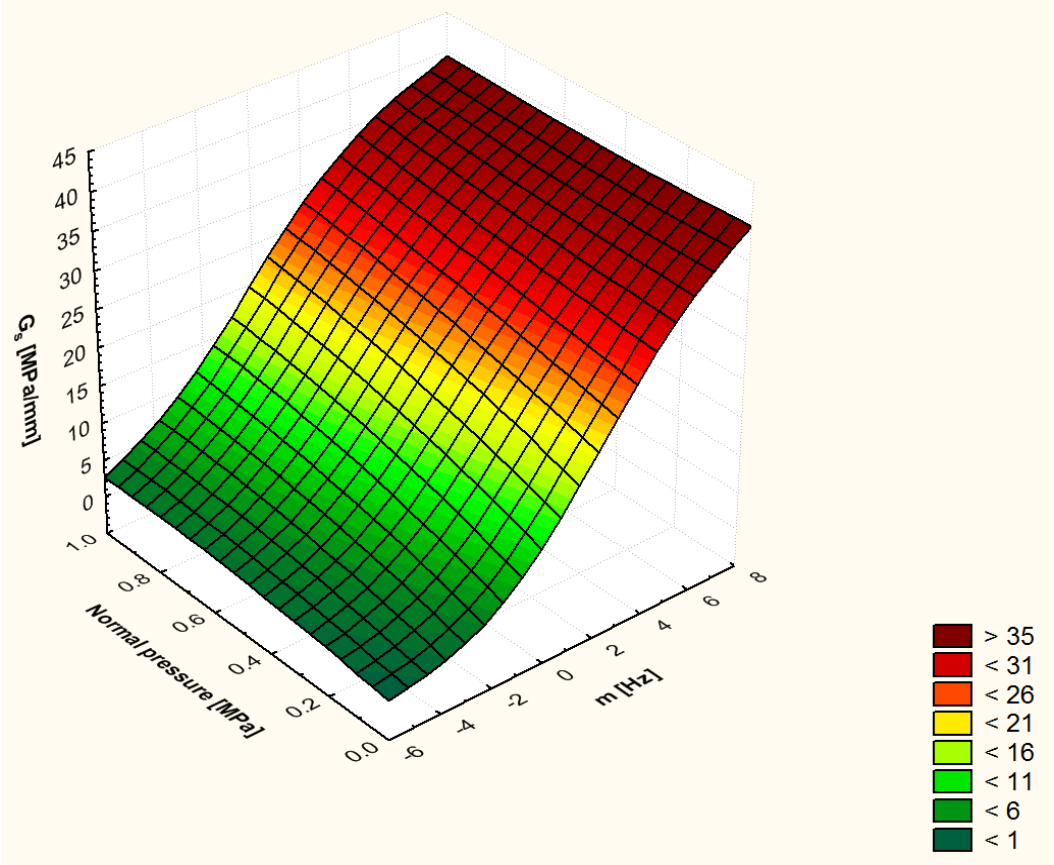
Example 3 - Layer bond



Results – Layer bond



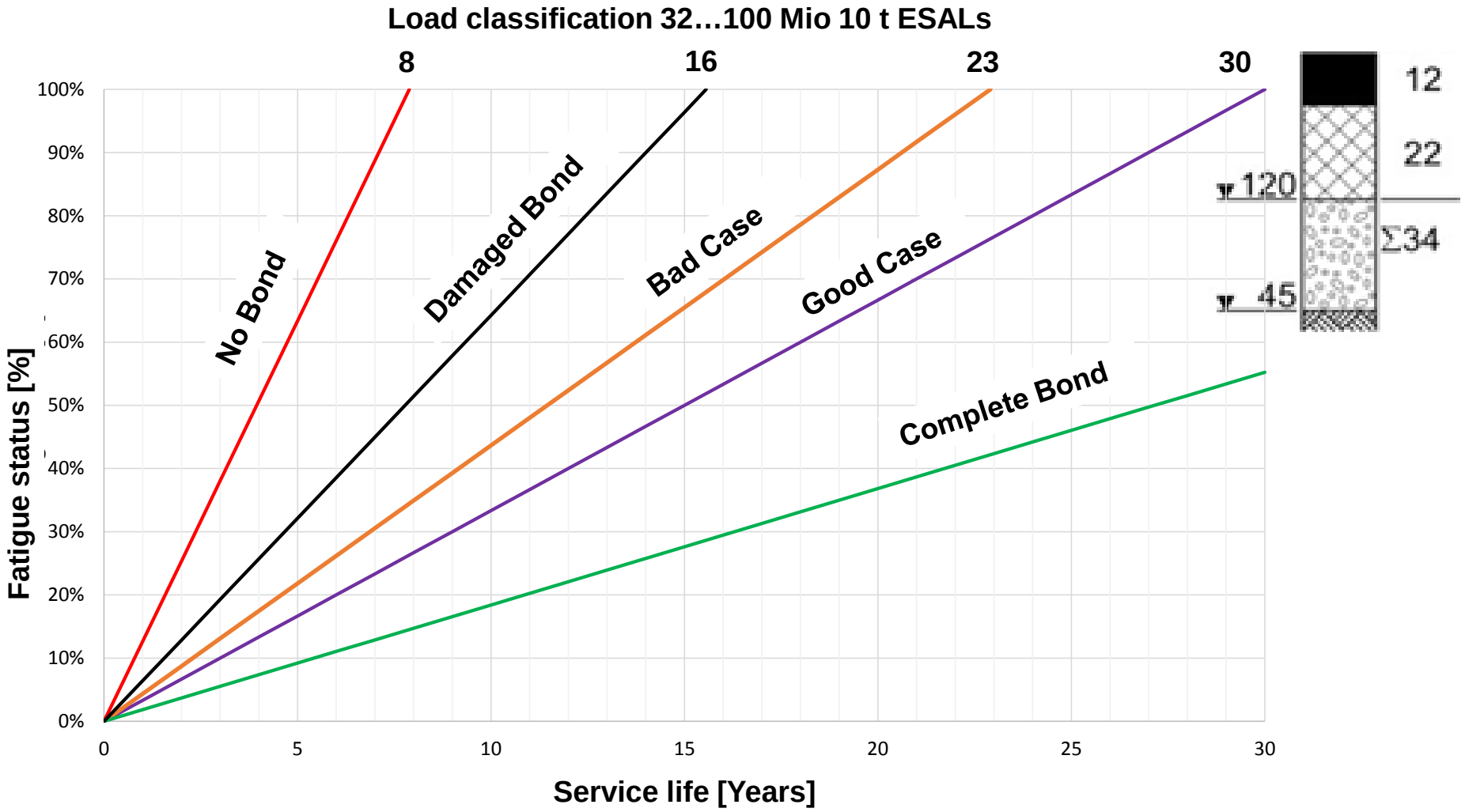
Results – Layer bond



Sigmoidal function

$$G_s = G_{s,min} + \frac{\left(G_{s,max} - G_{s,min}\right)}{1 + e^{[\,m\cdot(\,c\cdot \ln \sigma_N + d\,) + (\,j\cdot\sigma_N + k\,)]}}$$

Example 3 - Layer Bond

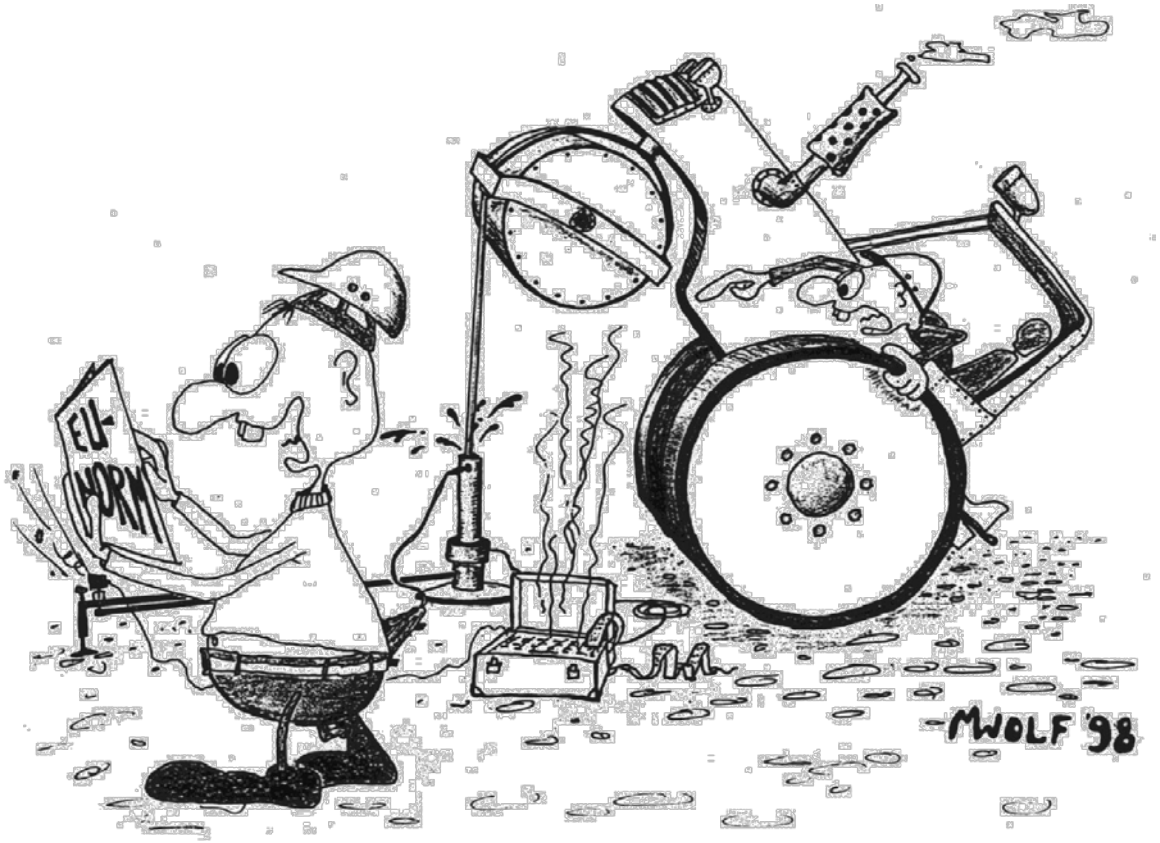


Future ?

Improve the models to describe the material behavior:

- Asphalt: viscos-elastic (complex modulus) + plastic behavior
- Unbound materials: nonlinear-elastic + plastic behavior
- more detailed temperature functions
- Finite element method instead of multi layer theory
- probabilistic instead of deterministic predictions

The End



Thank you for your attention !