TECHNISCHE UNIVERSITÄT DRESDEN

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

Utjecaj ojačanja vlaknima na ponašanje asfaltnih mješavina glede zamora i kolotraženja

Effects of fibre reinforcement on the fatigue and rutting performance of asphalt mixes

Dr.-Ing. Christiane Weise

Međunarodni seminar ASFALTNI KOLNICI 2017
International seminar ASPHALT PAVEMENTS 2017
Opatija, 05.–06. 04. 2017.

Research cooperation

Two research projects since January 2012 were funded by

ZIM
impulse für wachstum
Zentrales Innovationsprogramm Mittelstand

Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages

Research cooperation

Technische Universität Dresden
Chair of Pavement Engineering

Institut Dr.-Ing. Gauer, Regenstauf

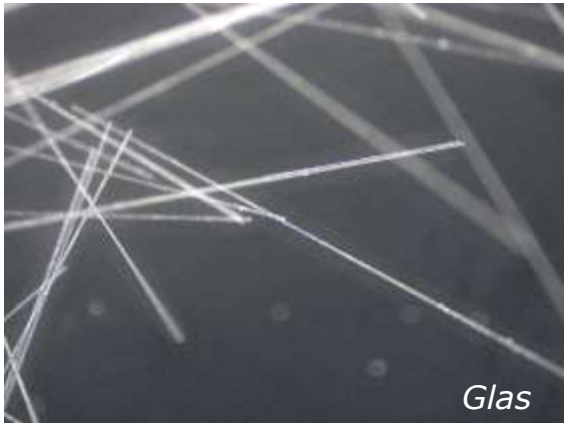
Wolf Straßen- und Tiefbau GmbH, Reinsdorf

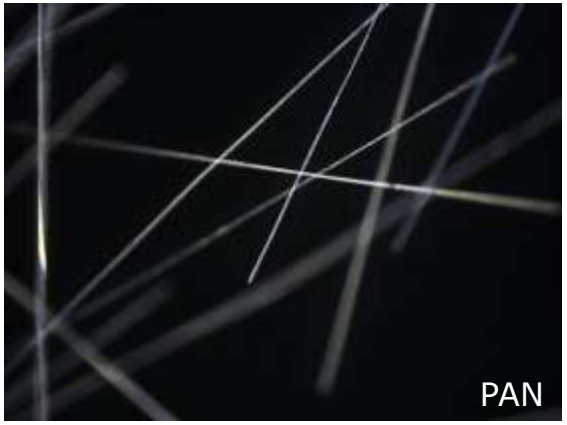
Thuringian Institut of Textile and
Plastics Research, Rudolstadt

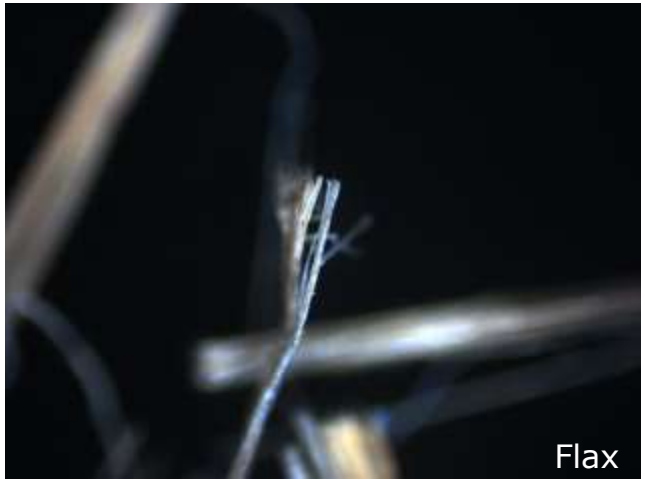
Outline

- Fibres
- Overview of the investigated asphalt mixes
- Laboratory test methods and results for stiffness and fatigue performance
- Results of the calculative pavement design
- Rutting performance of the wearing courses
- Conclusion and outlook

Fibres – organic and anorganic







Cellulose fibres

Cellulose fibres

fivefold enlargement

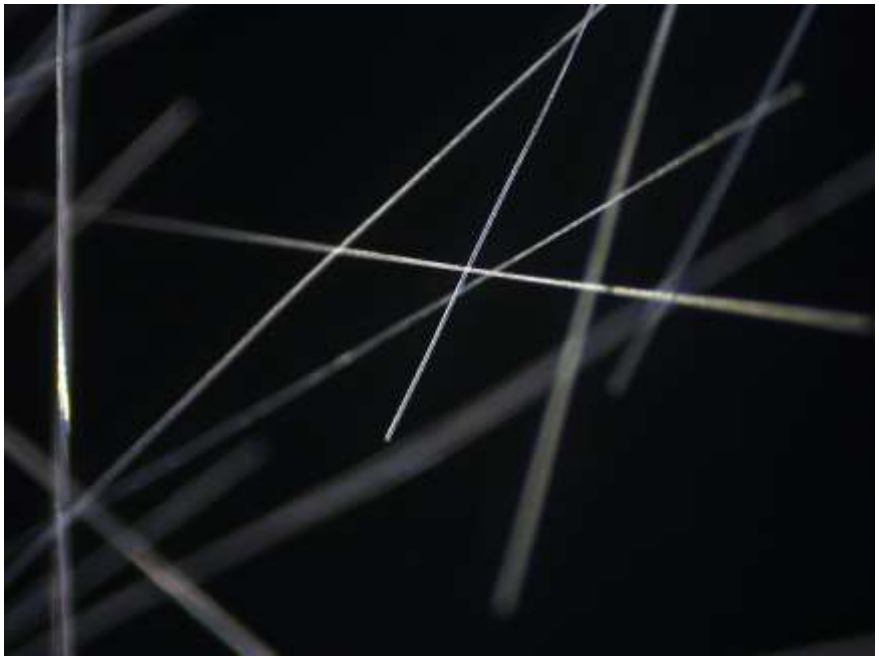
Fibre length between
0.3 mm and 1.4 mm

hundredfold enlargement

Polyacrylnitril fibres (PAN)

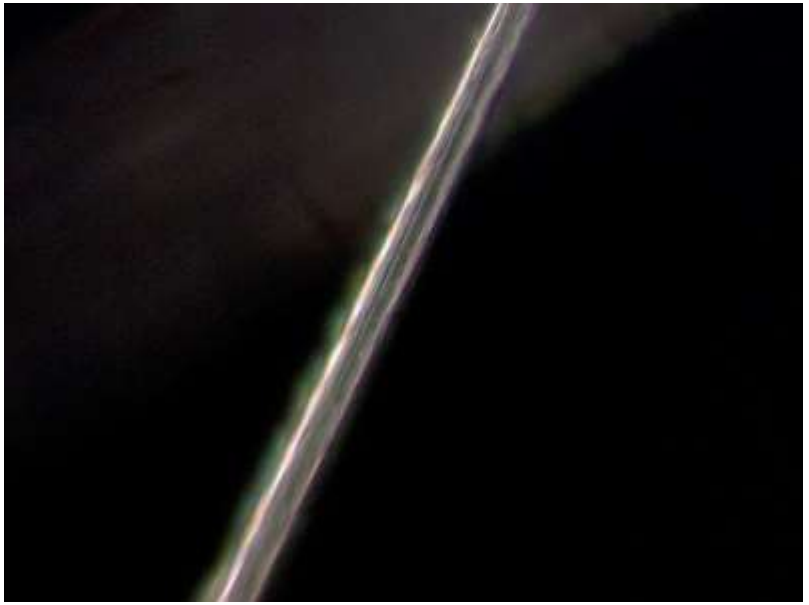
At temperatures above 250°C occur health hazardous gases.
-> asphalt production !!!???

Polyacrylnitril fibres (PAN)



fivefold enlargement

Fibre length 6.0 mm

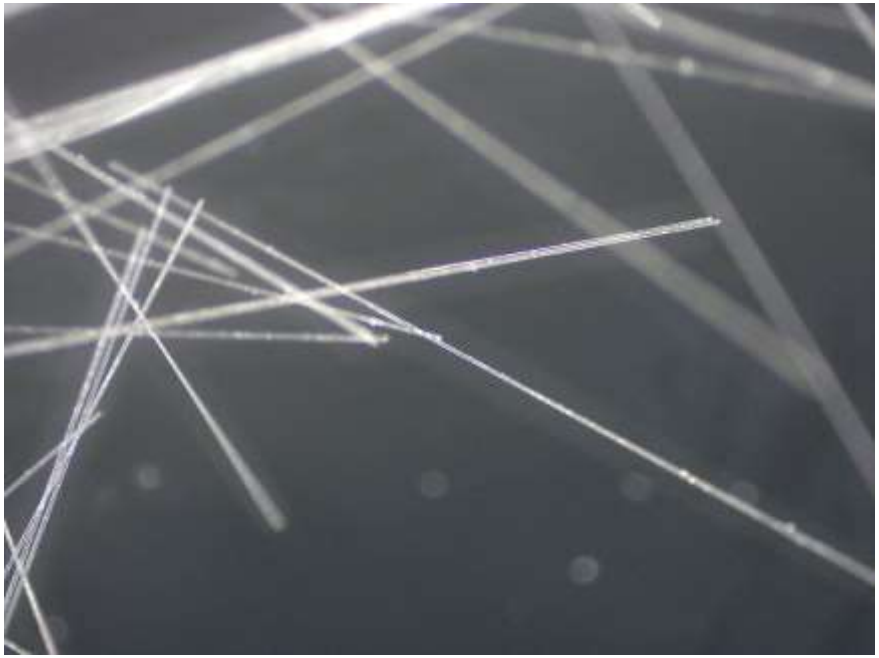


hundredfold enlargement

Glas fibres

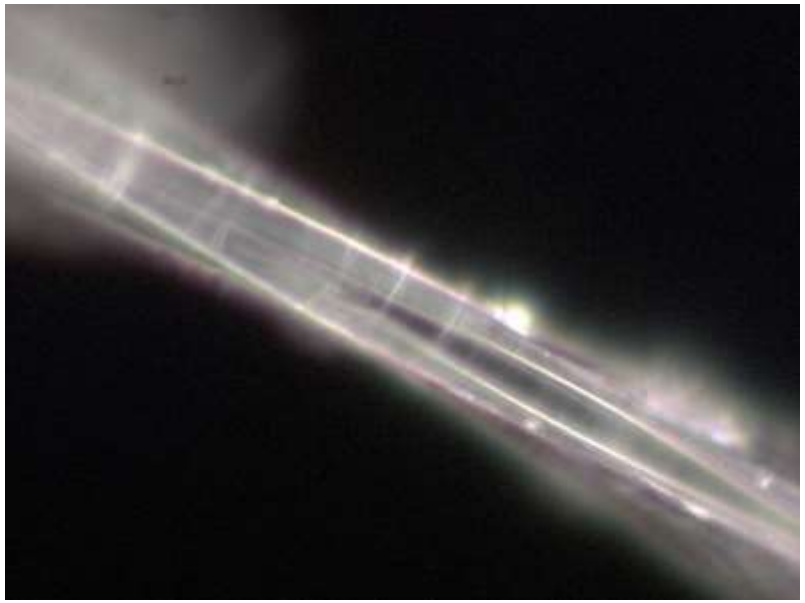
Developed for the use in automotive engineering or in wind power plant building.

Glas fibres



fivefold enlargement

Fibre length 4.4 mm



hundredfold enlargement

Fibres characteristics

		Cellulose	*PAN*	*Glas*
cut length	[mm]	0,3-1,4	6	4,4
density	[g/cm³]	~ 1,5	1,18	2,6
E modulus	[MPa]	3000	5030	2807
tensile strength	[MPa]	55	615,9	3400

The tensile strength of asphalt base mixes at 20°C is approximately 1 MPa.

Investigated asphalt mixes

Asphalt Base mixture - AC 22 T S

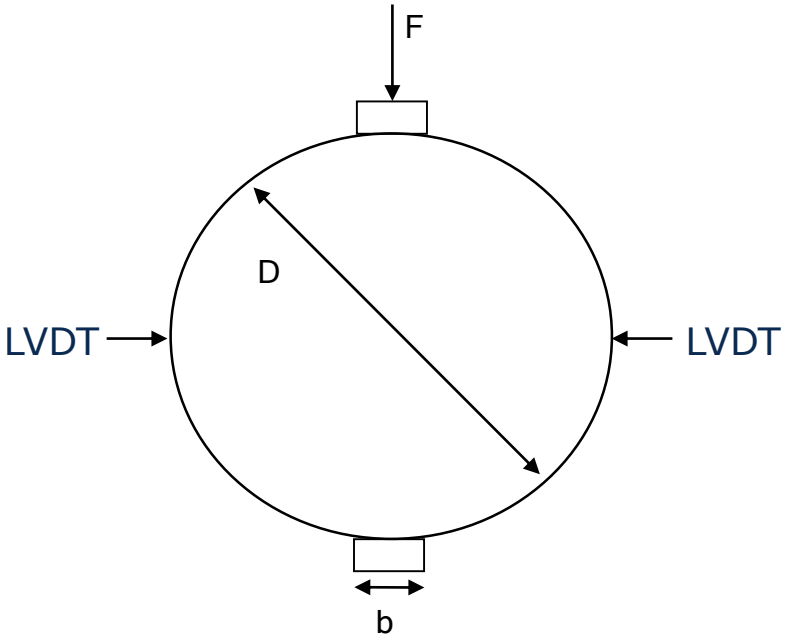
	Bitumen	Bitumen content [mass-%]	Fibre type	Fibre content [mass-%]
TM0	50/70	4.7	-	
TMC	50/70	4.7	Cellulose	0.5
TMP	50/70	4.7	PAN	0.5
TMG	50/70	4.7	Glas	0.6

Investigated asphalt mixes

Stone mastic asphalt - SMA 8 S

	Bitumen	Bitumen content [mass-%]	Fibre type	Fibre content [mass-%]
SM0 1 SMP 1	50/70	7.3	Cellulose PAN	0.3
SM0 2 SMP 2	50/70	7.3	Cellulose PAN	0.5
SM0 3 SMP 3	50/70	7.6	Cellulose PAN	0.7
SMP 4	25/55-55A	7.3	PAN	0.3
SMP 5	25/55-55A	7.3	PAN	0.5

Laboratory Test – Cyclic Indirect Tensile Test (CITT)

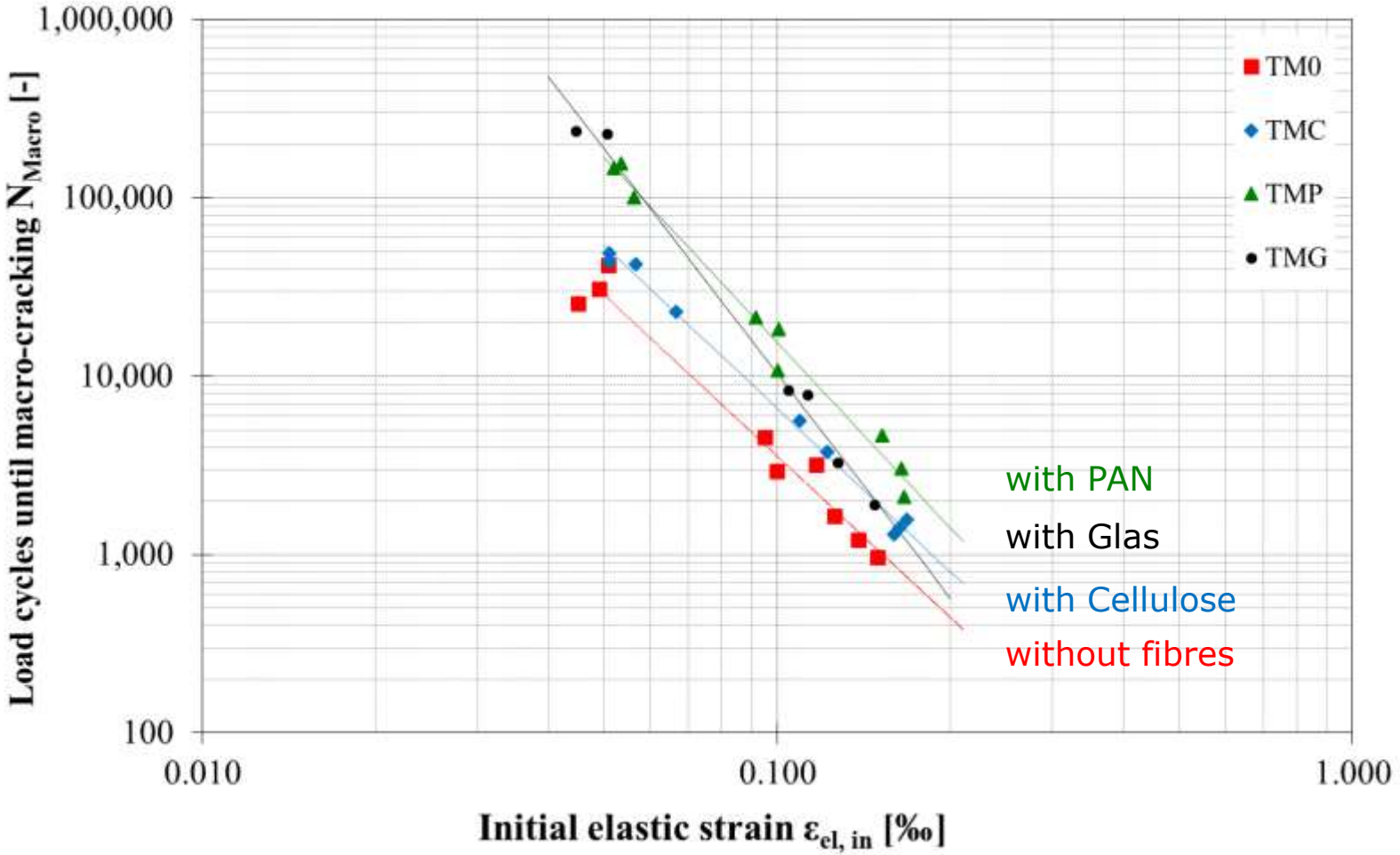


prEN 12697-24 Annex F – Resistance to Fatigue (2015)

prEN 12697-26 Annex F – Stiffness (2015)

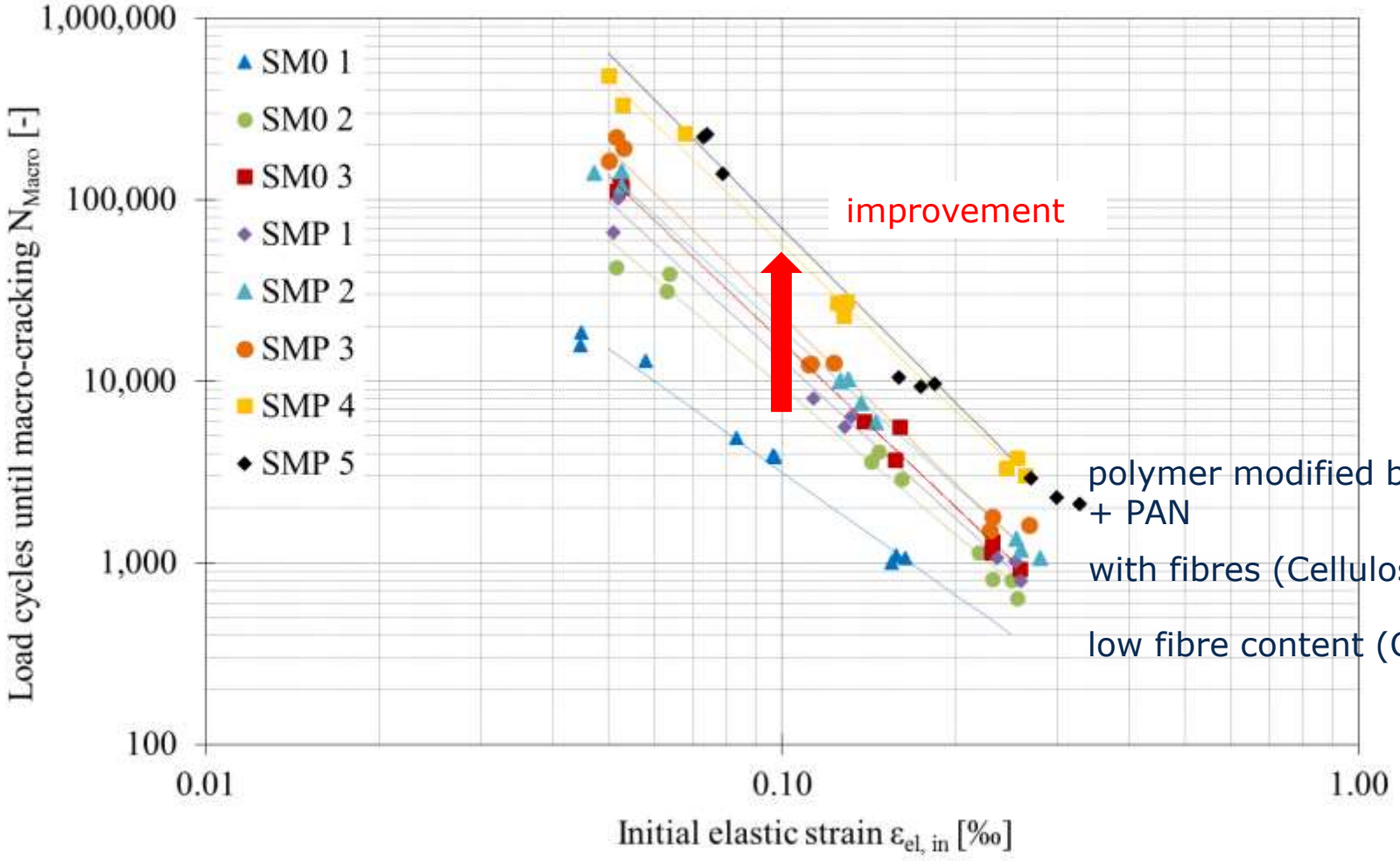
Test results – Fatigue performance

$$N_{Macro} = a \times \varepsilon_{el,in}^{\ b}$$



Test results – Fatigue performance

$$N_{Macro} = a \times \varepsilon_{el,in}^{\ b}$$

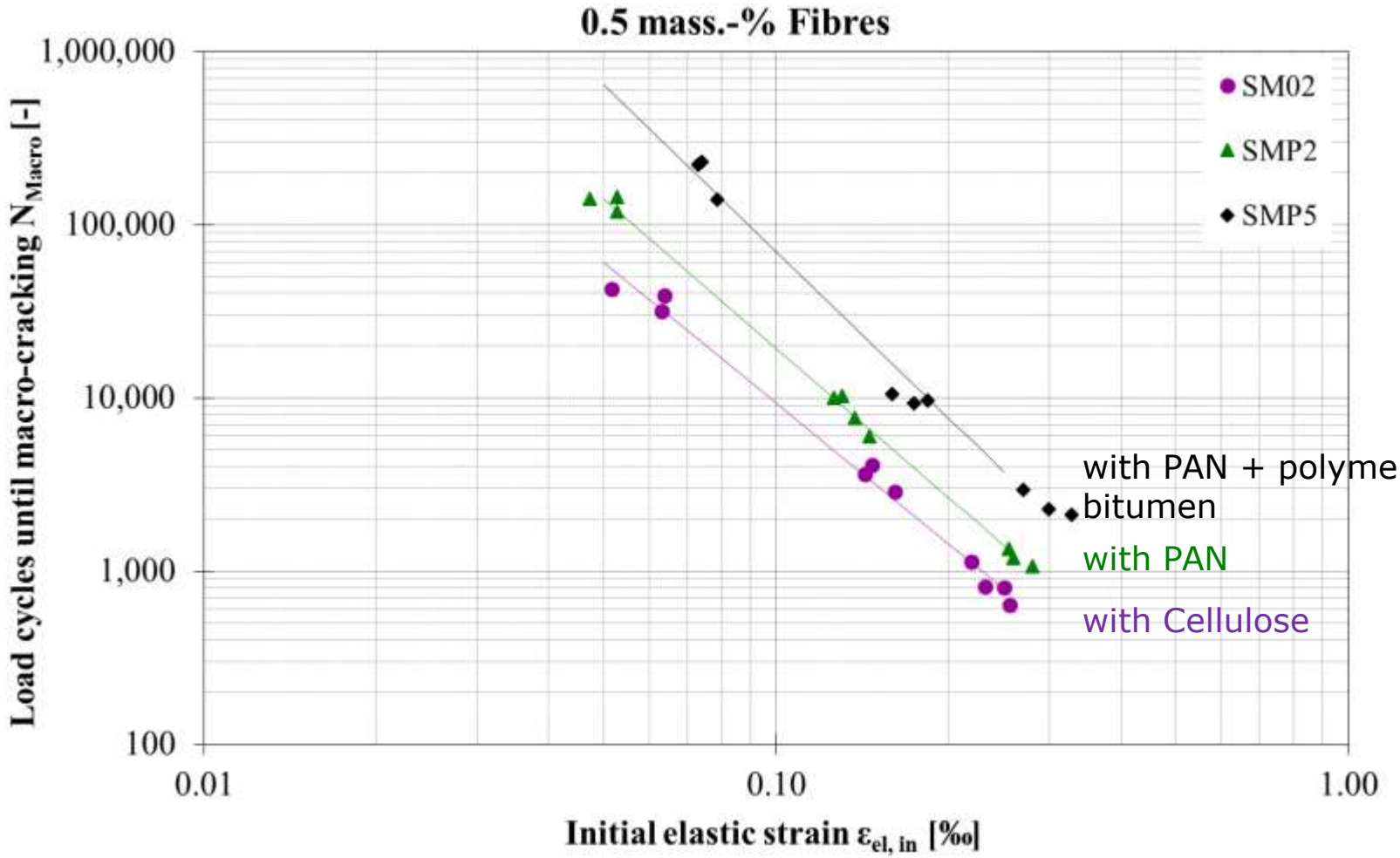


polymer modified bitumen + PAN

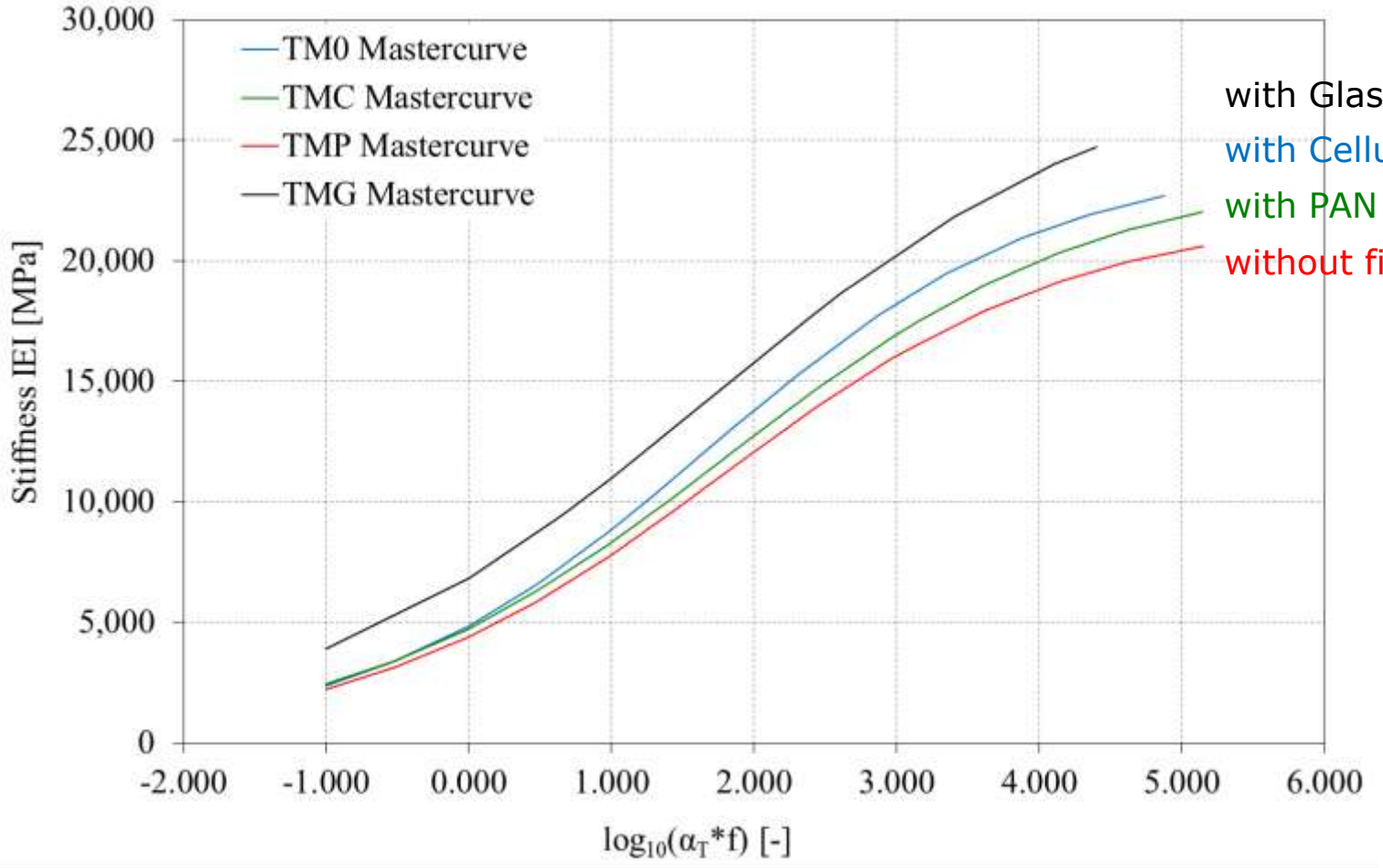
with fibres (Cellulose or PAN)

low fibre content (Cellulose)

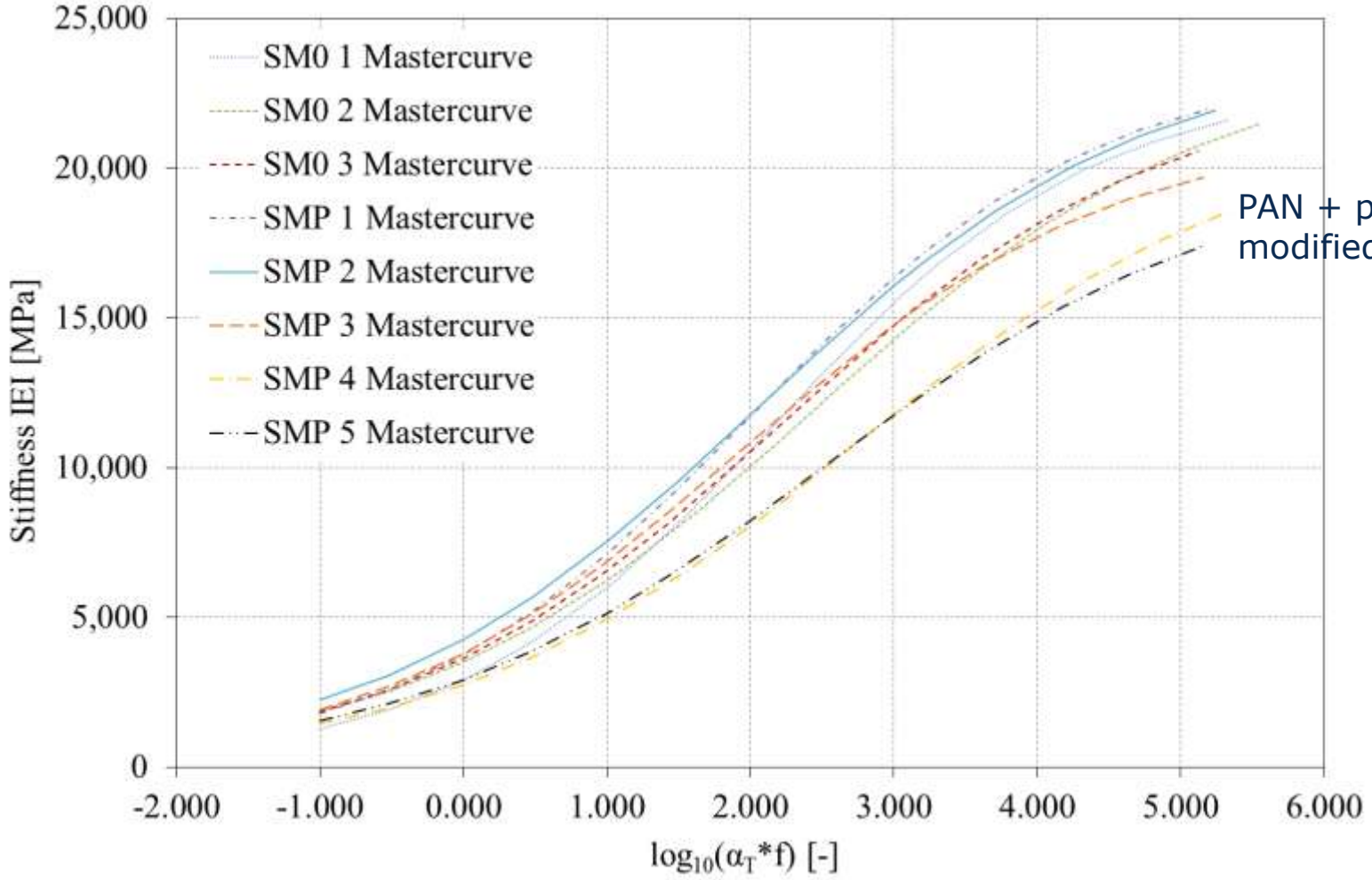
Test results – Fatigue performance



Test Results – Stiffness performance

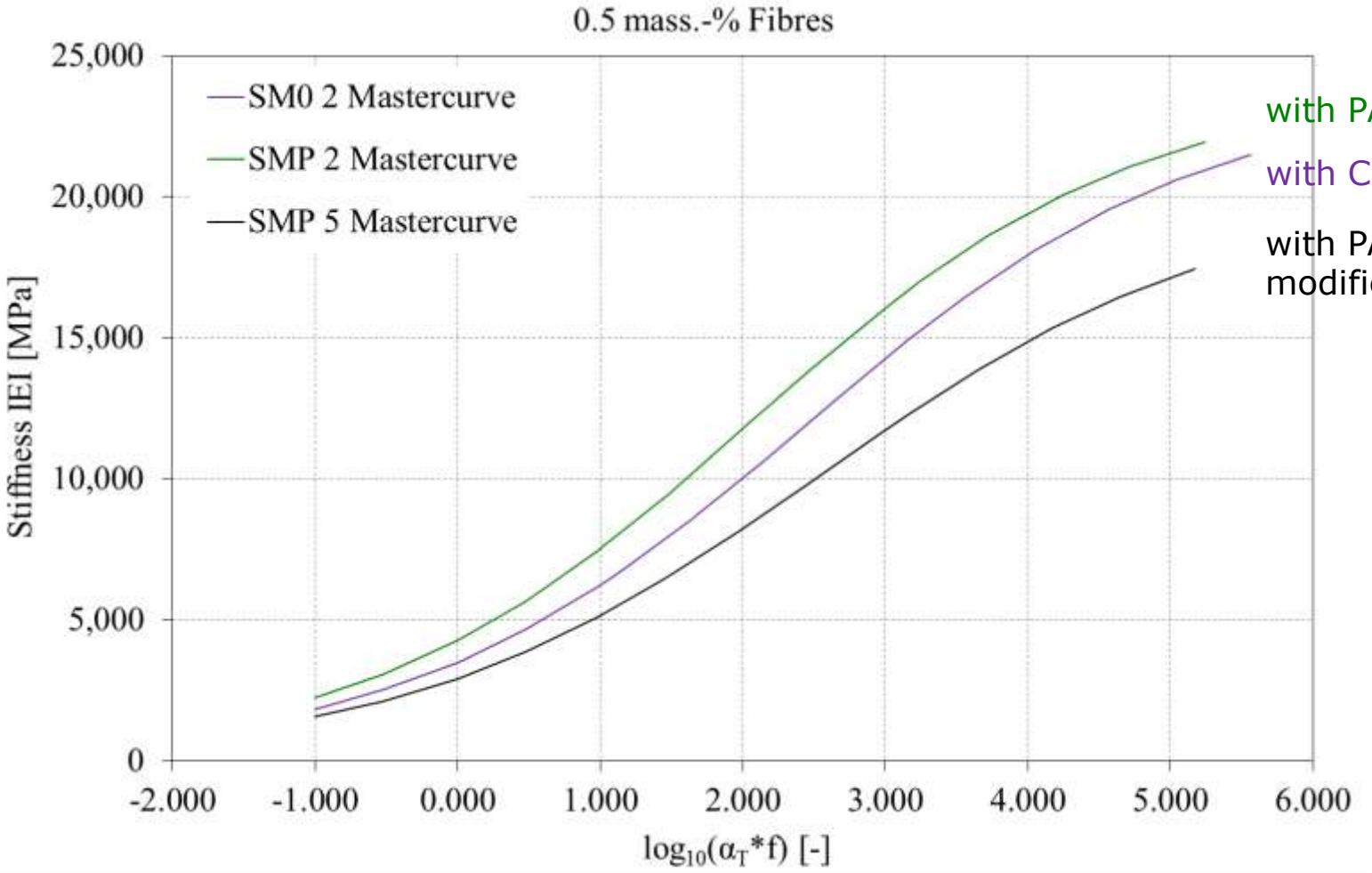


Test Results – Stiffness performance



PAN + polymer modified bitumen

Test Results – Stiffness performance



with PAN

with Cellulose

with PAN + polymer modified bitumen

Pavement Design

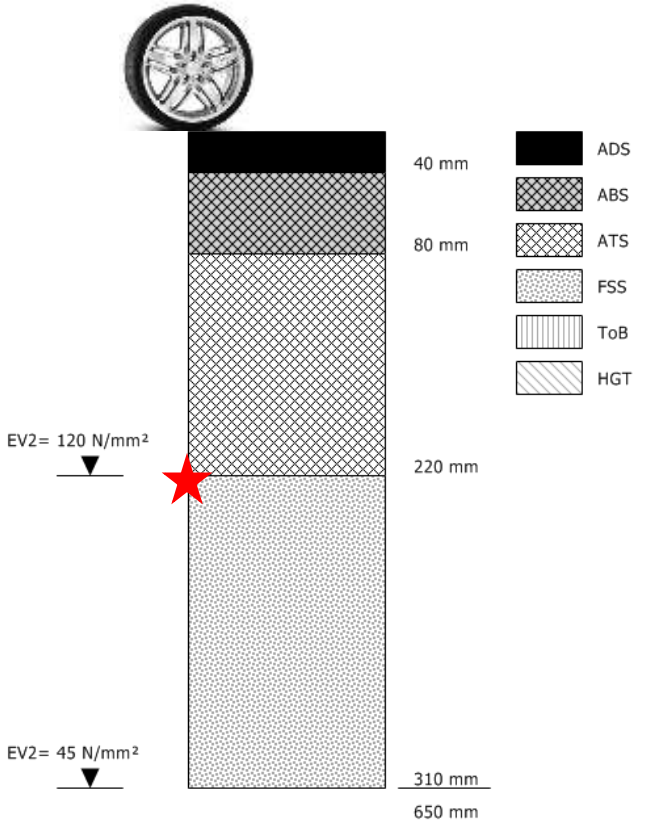
Layer structure

40 mm Wearing course

80 mm Intermediate course

220 mm Asphalt base course

310 mm Frost protecting layer



Calculated for a service life of

30 years.

Pavement Design - Results

	TM0	TMC	TMP	TMG
	increase	**saving**		
	[cm]			
SM0 1	1.0	1.0	5.5	8.0
SM0 2	1.0	1.0	5.5	8.0
SM0 3	1.0	1.0	5.5	8.0
SMP 1	0.5	1.0	5.5	8.0
SMP 2	0.5	1.0	6.0	8.0
SMP 3	1.0	1.0	5.5	8.0
SMP 4	0.5	0.5	5.0	7.5
SMP 5	0.5	0.5	5.5	7.5

Economic calculation

Material	Price in EUR
AC 22 T S 50/70 (asphalt base mix)	50.00 / t
AC 22 T S 50/70 (asphalt base mix with high Bitumen content)	63.00 / t
Paving of 8-10 cm asphalt base mix	3.00 / m²
FSS 0/32 (frost protecting layer)	9.00 / t
Paving of 30 cm frost protecting layer	4.10 / m²
Cellulose	1.00 / kg
PAN	5.50 / kg
Glas	1.50 / kg

Prices are examplary for small contract sections

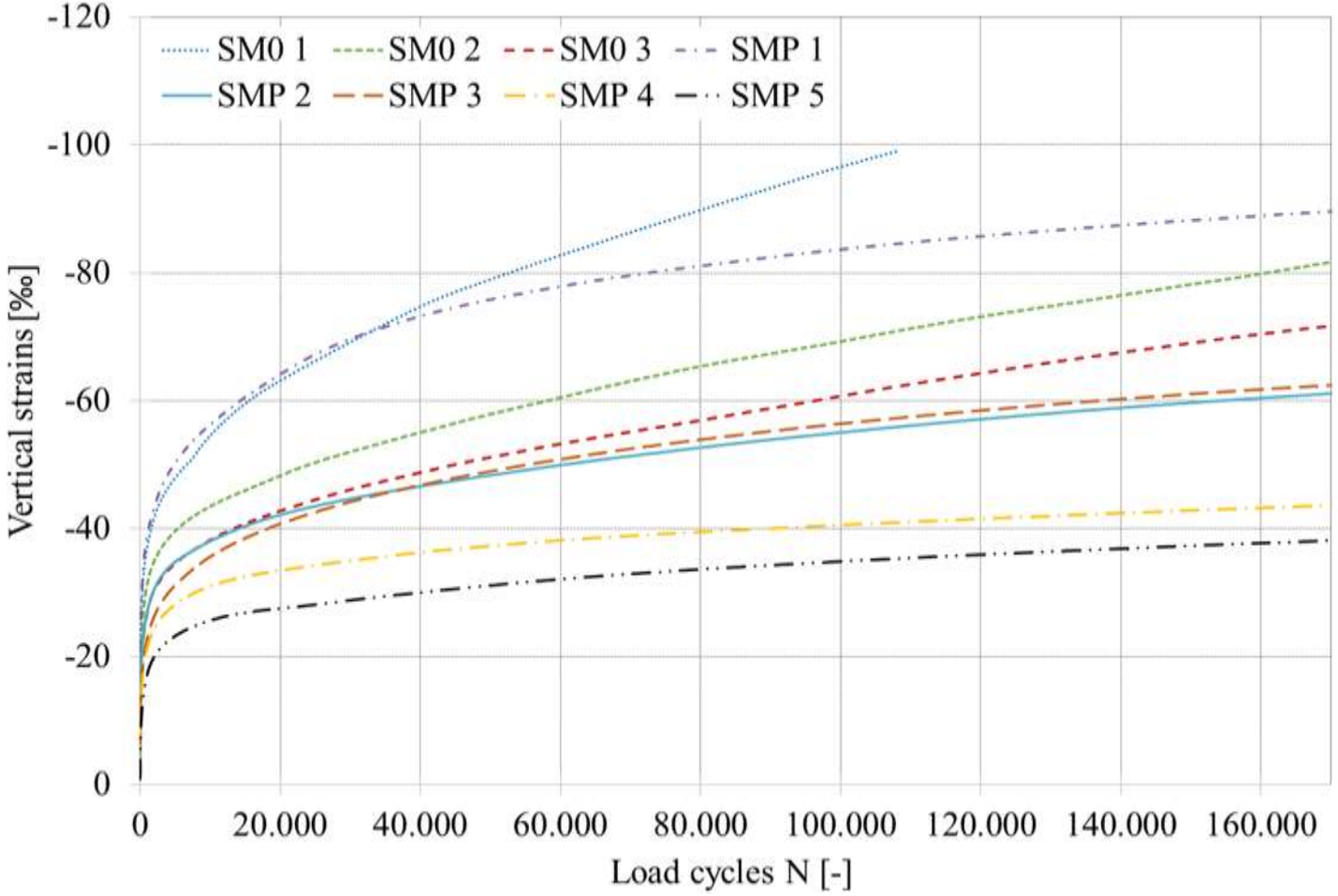
Economic calculation

Asphalt base	Asphalt base				Frost protecting layer			Overall costs pro m²
	Layer thickness [cm]	Costs			Layer thickness [cm]	Costs		
		Material	Fibres	Paving		Material	Paving	
TM0	22	34.65 €	- €	6.00 €	31	6.98 €	4.10 €	51.73 €
	23	36.23 €	- €	6.00 €	30	6.75 €	4.10 €	53.08 €

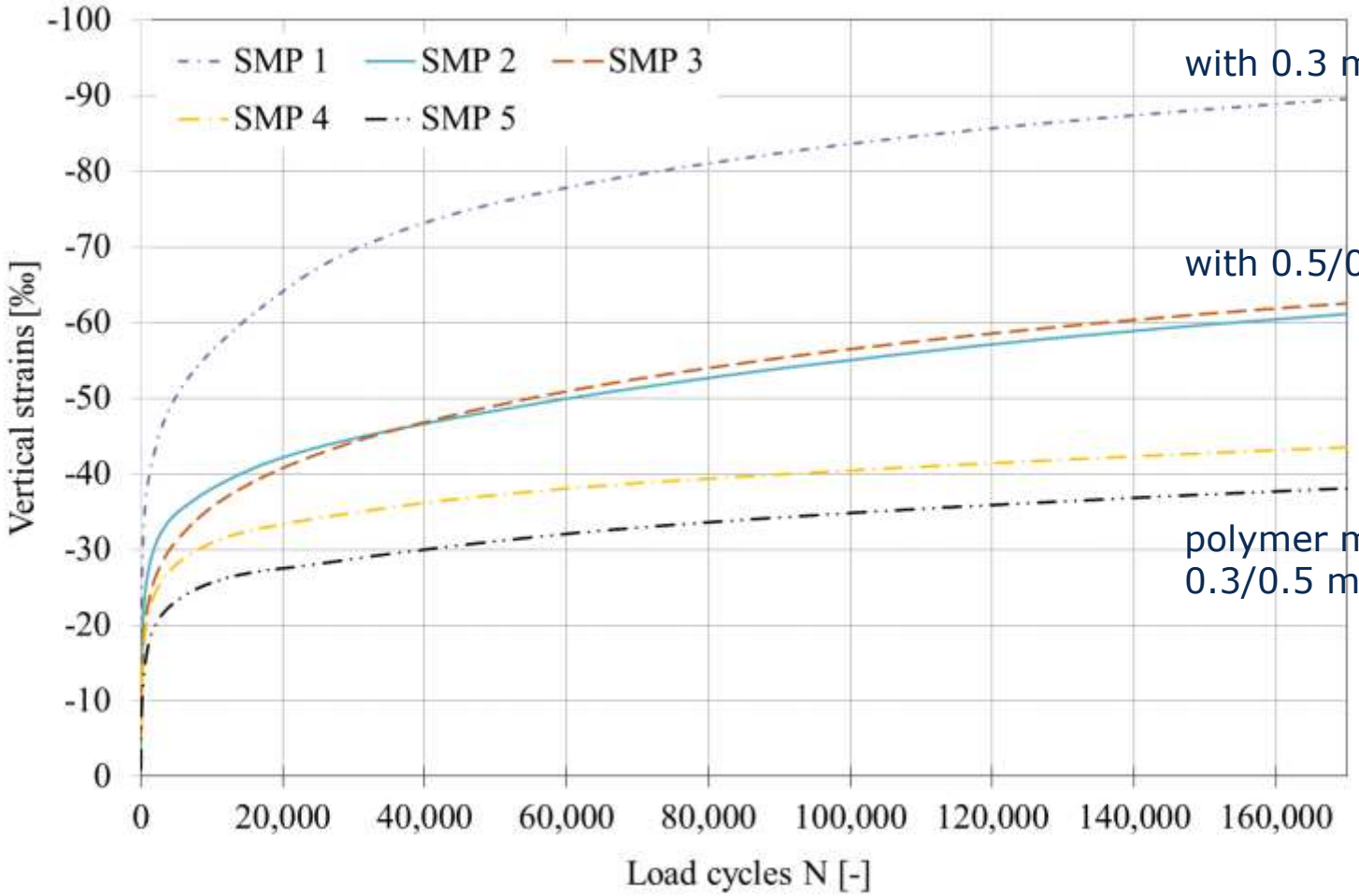
Laboratory Tests – Uniaxial Cyclic Compression Test (UCCT)

- slim specimen: h/D-ratio=2/1
- test temperature: 50°C
- loading form: sinusoidal 10 Hz
- loading:
  minimum stress 0.035 MPa
  maximum stress 0.35 MPa
- end of test:
  after 170,000 load cycles or at the maximum deformation of the specimen

Test results – Rutting performance



Test results – Rutting performance



with 0.3 mass.-% PAN

with 0.5/0.7 mass.-% PAN

polymer modified bitumen + 0.3/0.5 mass.-% PAN

Conclusion and outlook

- The use of PAN or glas fibres improves the fatigue and stiffness characteristics significantly.
- Saving approx. 6 cm of the asphalt base using PAN fibres does not cause a monetary advantage due to the costs of the fibres.
- Saving approx. 8 cm of the asphalt base using low cost fibres like glas fibres result in economical benefits.
- The rutting performance / vertical plastic deformation can be reduced up to 40% depending on the used fibre type and quantity.
- The use of fibres together with RAP must be investigated because recycling is state of the art.

Thank you!

Christiane.Weise@tu-dresden.de

International Seminar
Asphalt Pavements
5th and 6th of April 2017