Testing the limits

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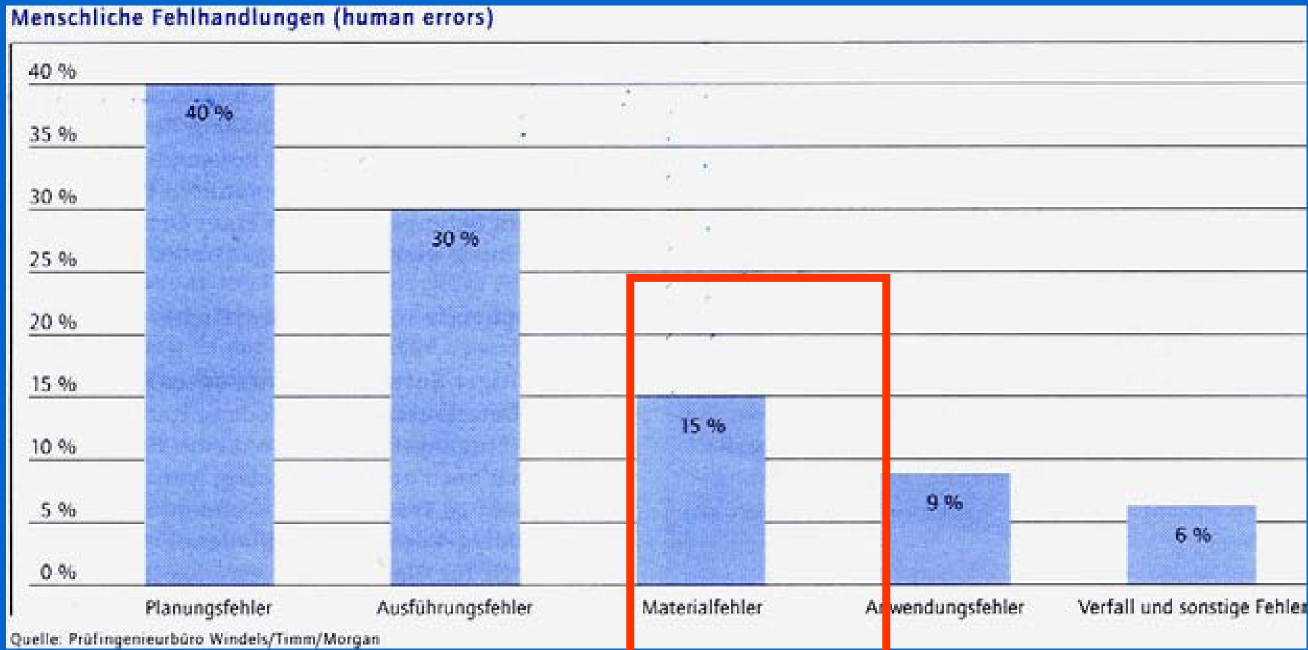
University of Applied Sciences Münster
TBU, Greven

avoid material failure by testing

Who is responsible



Design construction material application
40 % 30 % 15 % 9 %

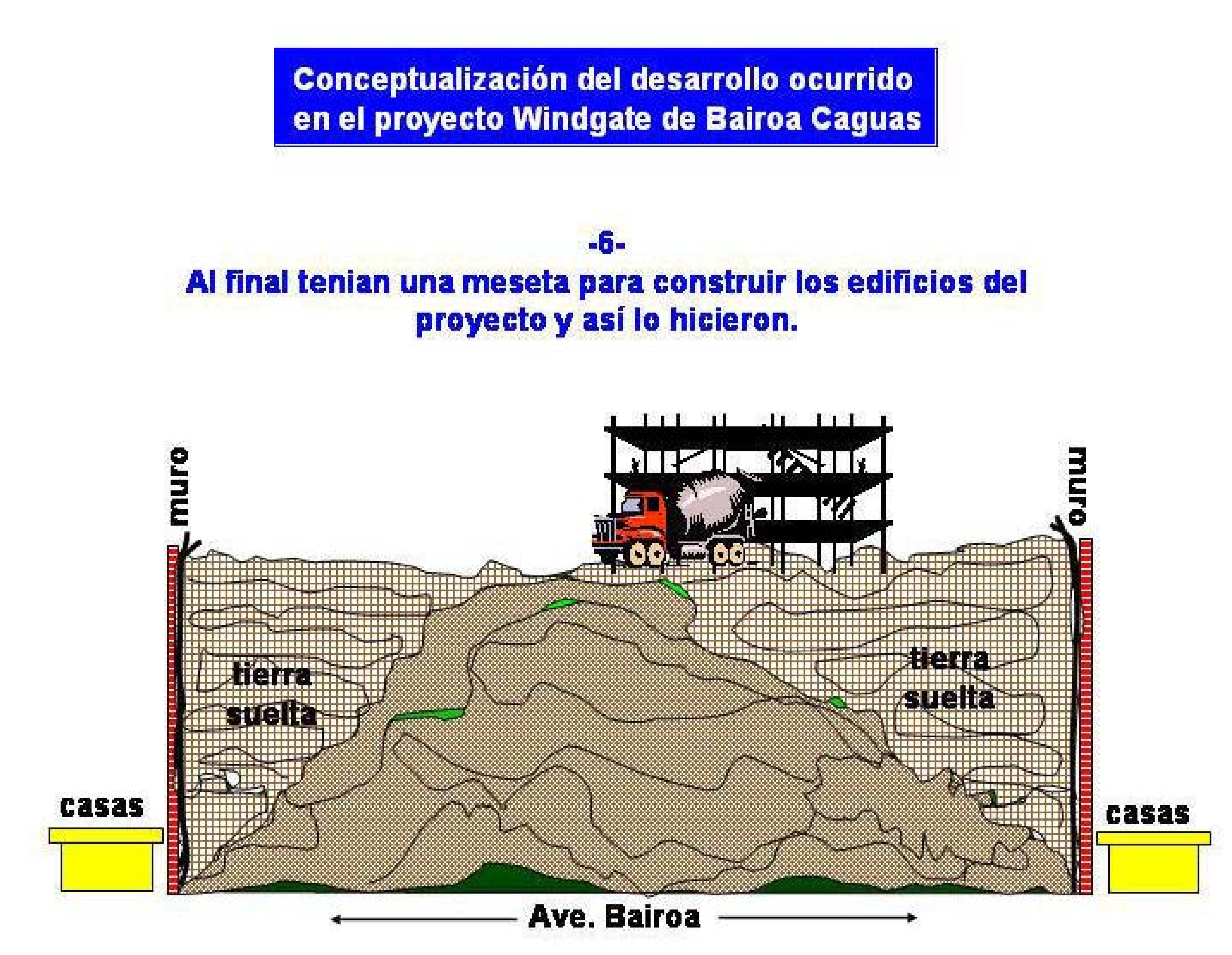
Prüfingenieurbüro Windels/Timm/Morgan in Gerling Ing.-Letter 1/00

Example of a desaster(design failure)

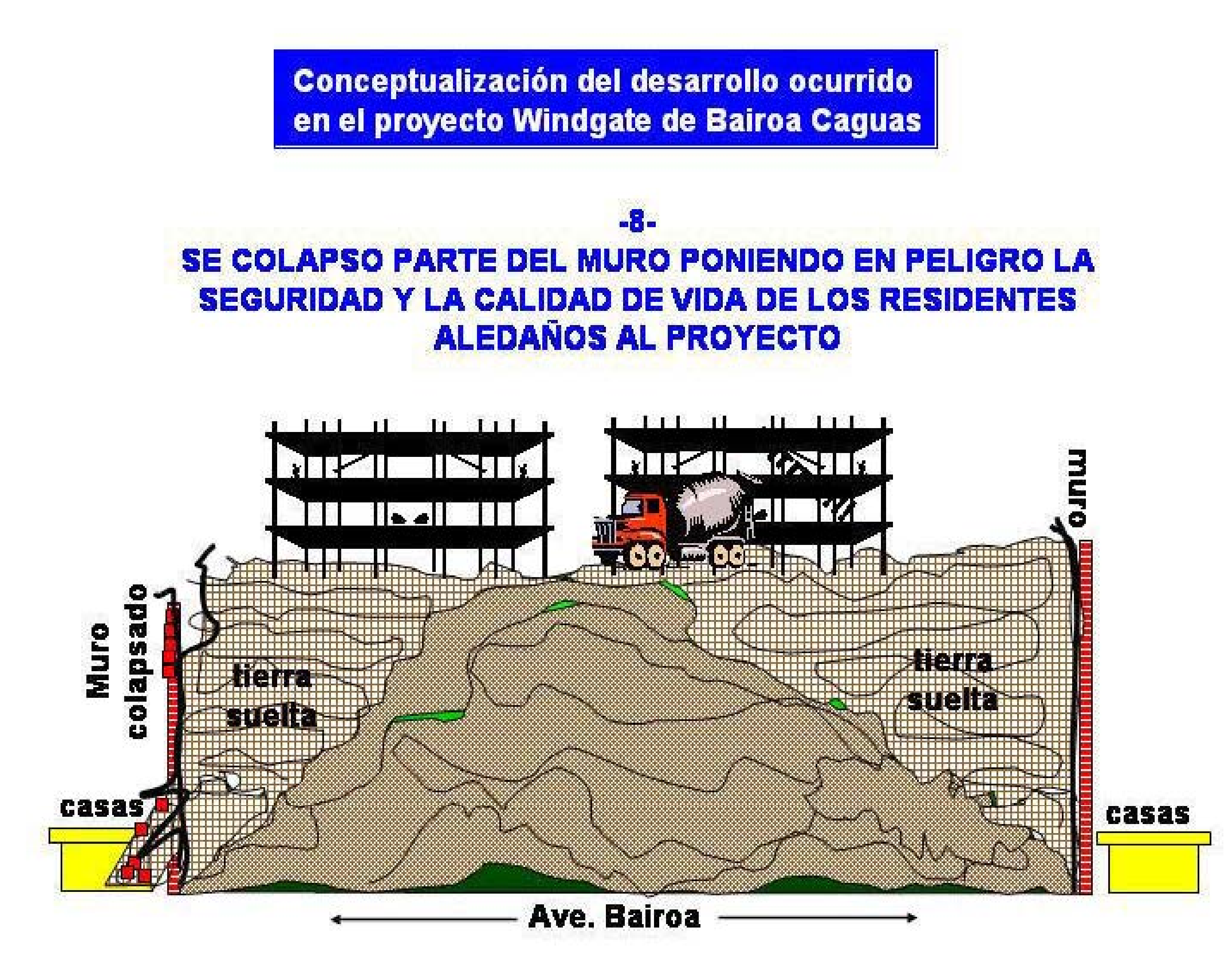
Example of a desaster

Example of a desaster

Example of a desaster



Example of a desaster



Concrete is brittle and
sensitive to
flexion,
splitting tensile stress

Brittle failure
of concrete

Very optimistic:
Silicon against broken concrete

Announcing
fatal
failure
 concrete blocks initiate
the collaps

It is not failure of the geosynthetic

Final fatal failure

not of the geosynthetic!

Exceeding deformation limits

THE CIVIL ENGINEER IN SOUTH AFRICA
DIE SIVIELE INGENIEUR IN SUID-AFRIKA

Registered at the Post Office as a newspaper. By die Poskantoor as 'n nuusblad geregistreer R9 (incl)

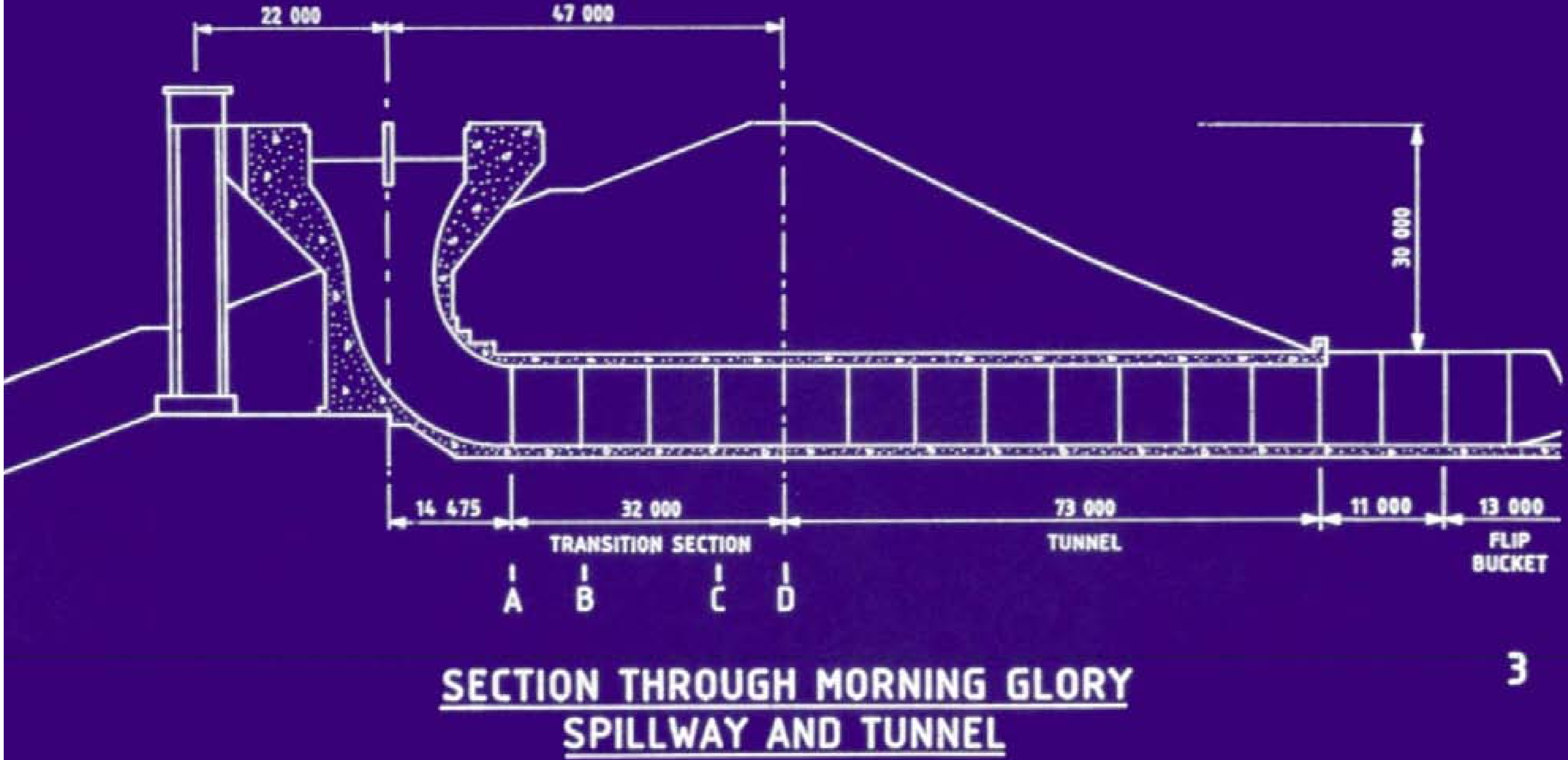
December 1992

Morning glory spillway, Zoeknog Dam

Report on Regional Urbanization Worksh

Source: K.Legge

Erosion along tunnel



Source: K.Legge

Source:
K.Legge

Source:
K.Legge

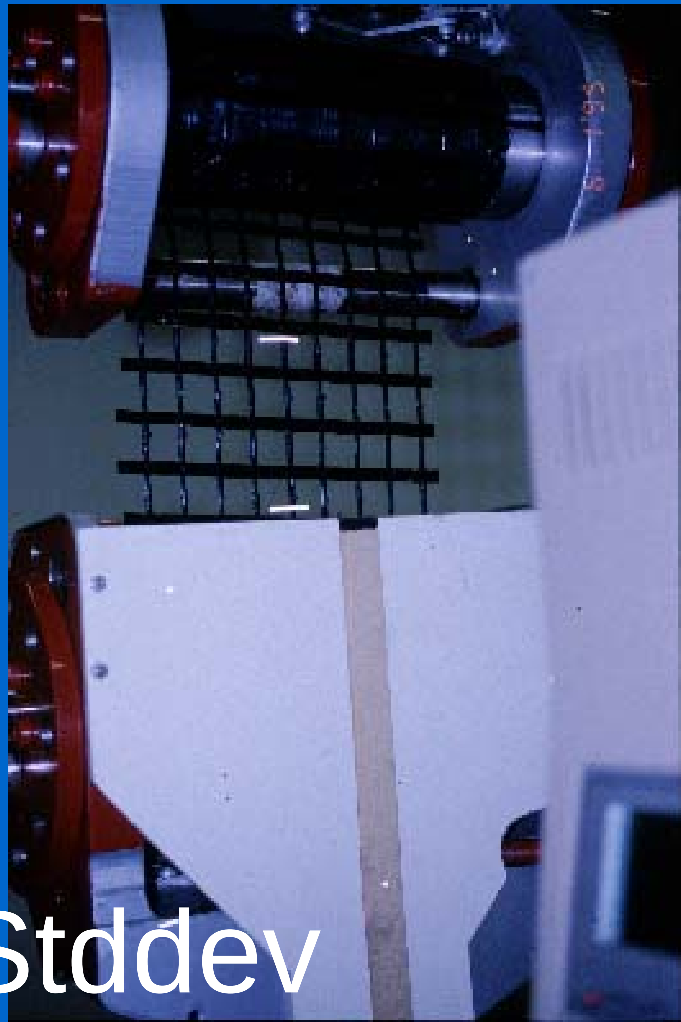
Source:
K.Legge

Design of Reinforcement

$$F_d = F_k / A_1 \cdot A_2 \cdot A_3 \cdot A_4 \cdot A_5 \cdot \gamma$$

F_d Design Force of GSY
F_k Characteristic strength of GSY
A_1 Reduction factor for longterm (creep rupture, creep)
A_2 Reduction factor for damage during installation
A_3 Reduction factor for connections, seams, joints
A_4 Reduction factor for environmental exposition as weather, chemistry
A_5 Reduction factor for cyclic loading
γ Partial factor of safety (1.1…1.4)

Characteristic strength F_k



$F_k = F_{5\%} = \text{mean} - 1{,}645\ \text{Stddev}$

Characteristic strength F_k

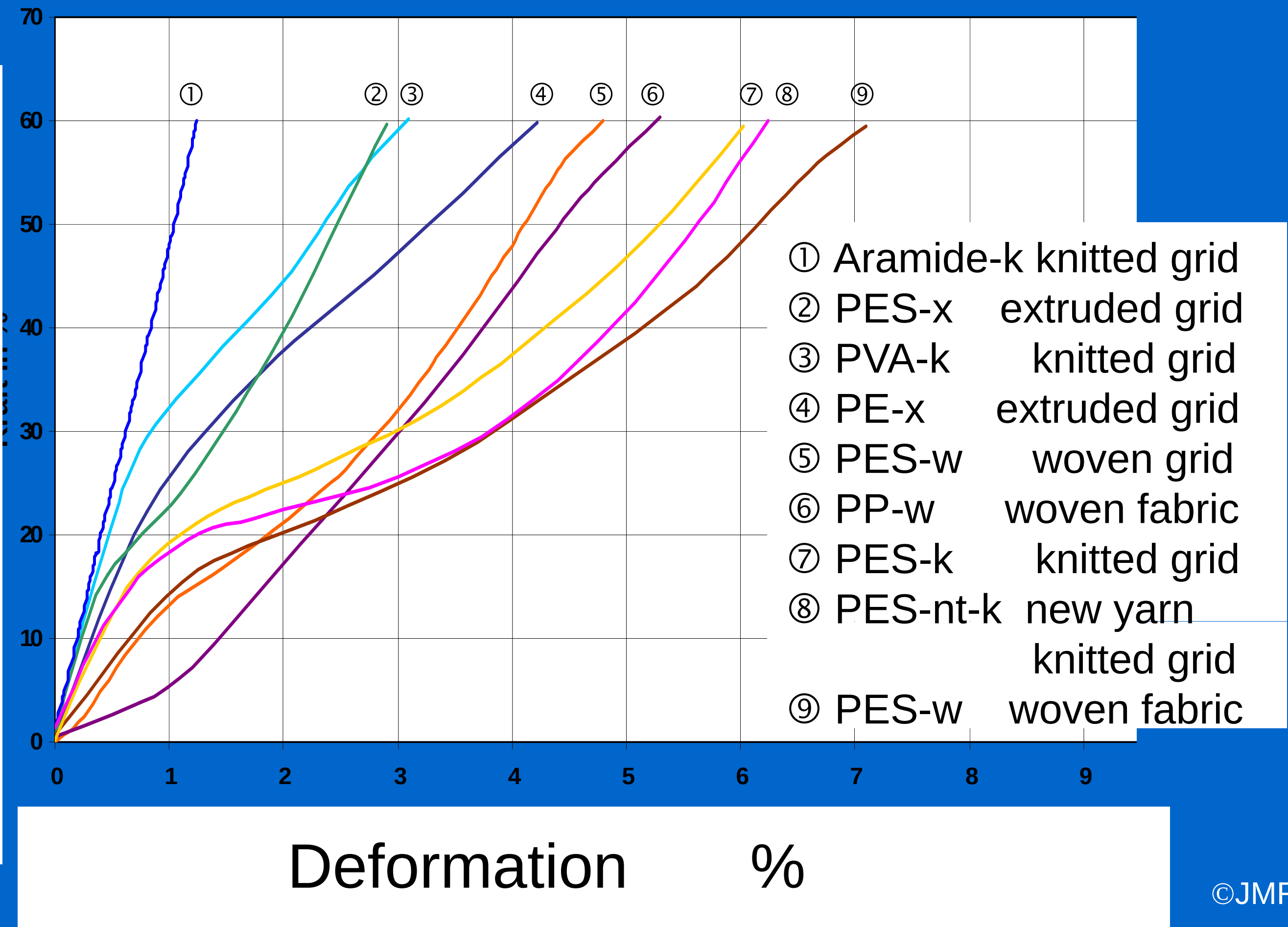
$F_k = F_{5\%} = \text{mean} - 1{,}645\ \text{Stddev}$

High Strength Geosynthetics

normalised by

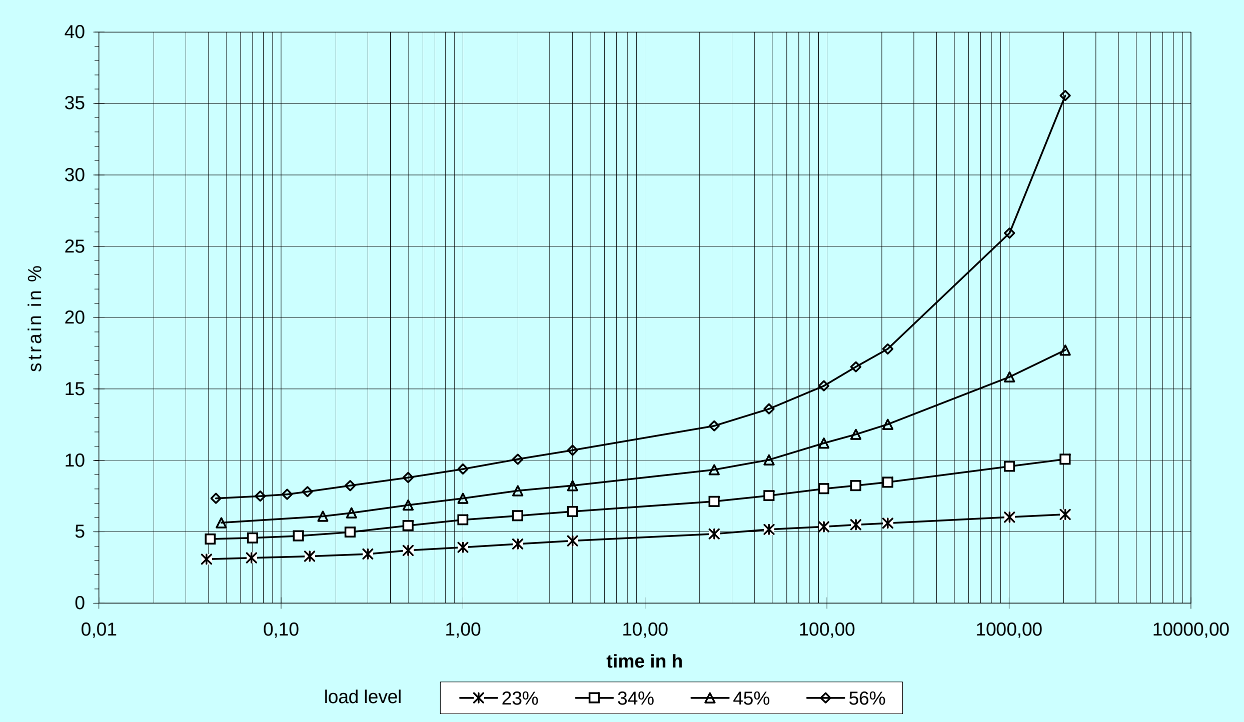
100 Fi
Fm

deformation measurement by clip on gages with very high accuracy (normally used for elastic deformation of steel

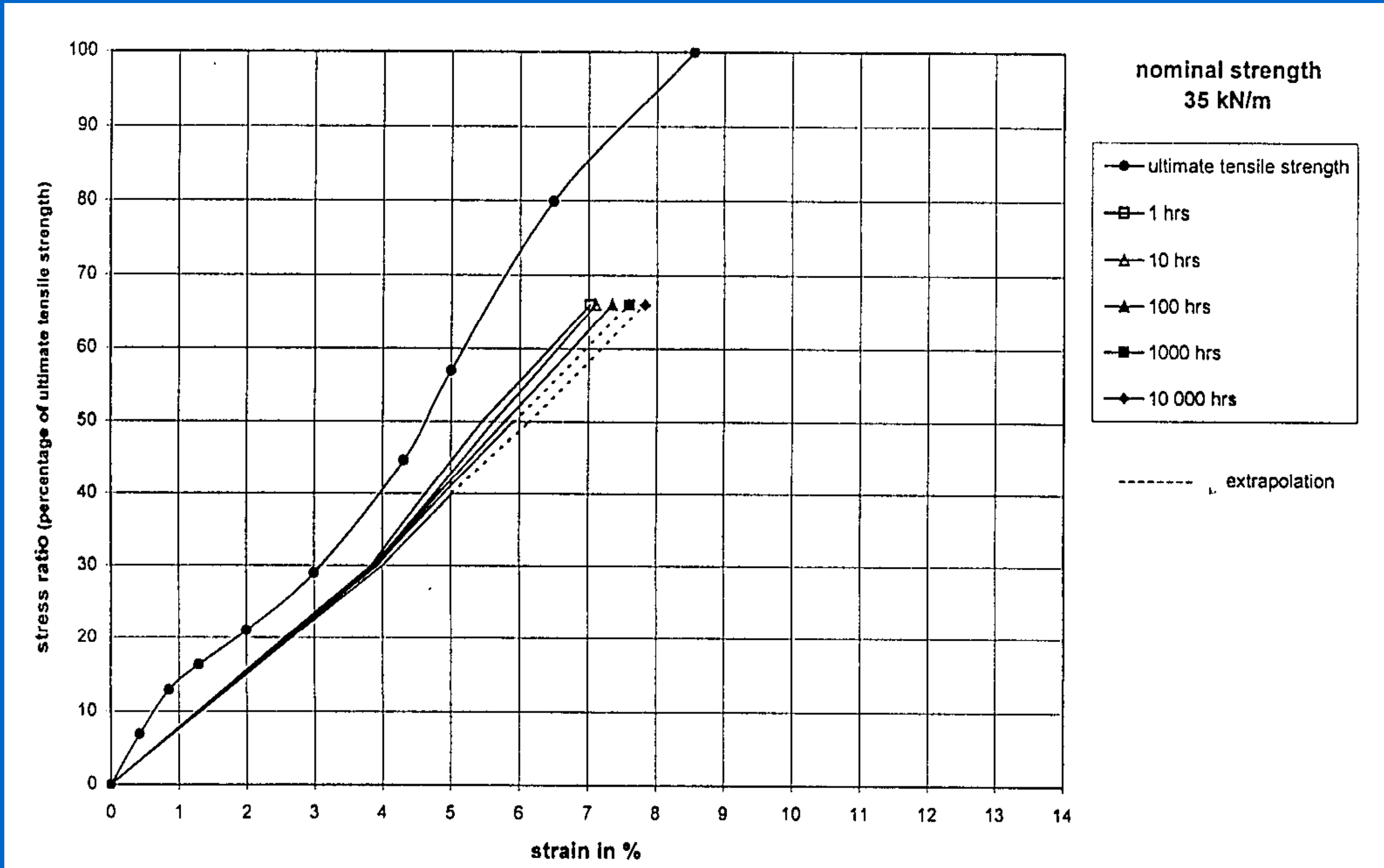


A_1 –longterm creep

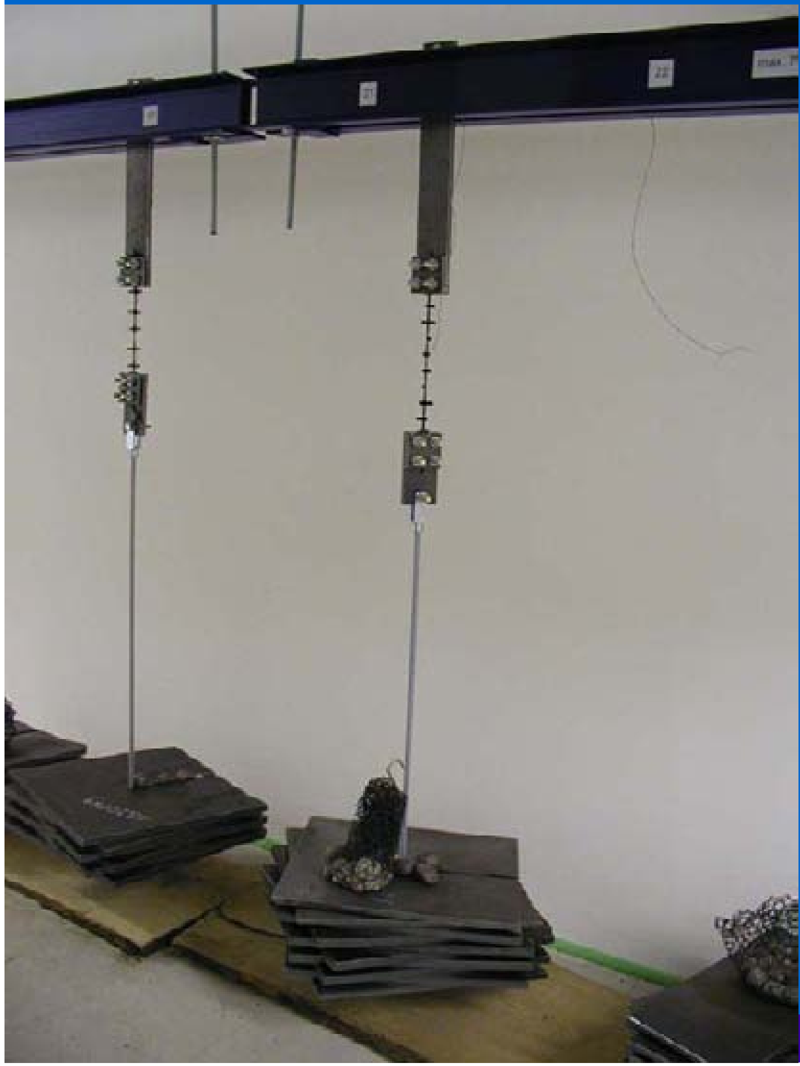
EN ISO 13433
1000h creep as index-test,
mostly 10 000 h requested



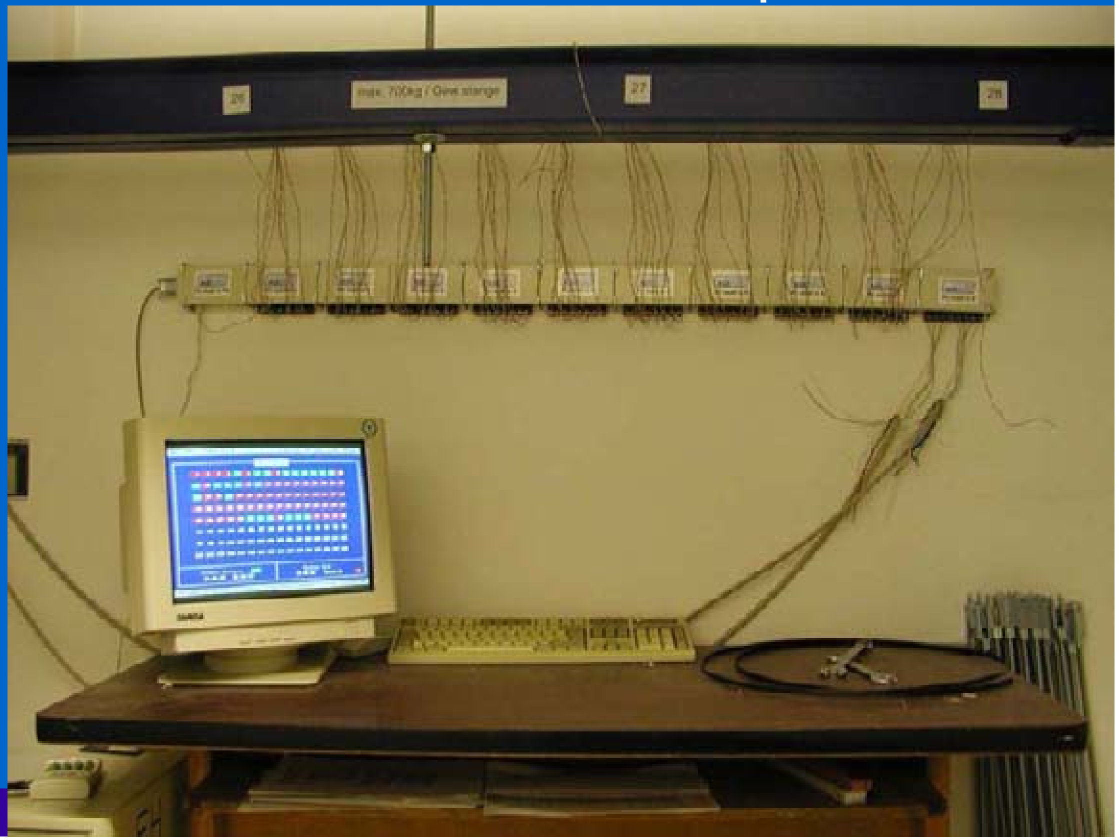
A_1 – isochronous stress-strain curve



A_1 –longterm creep rupture

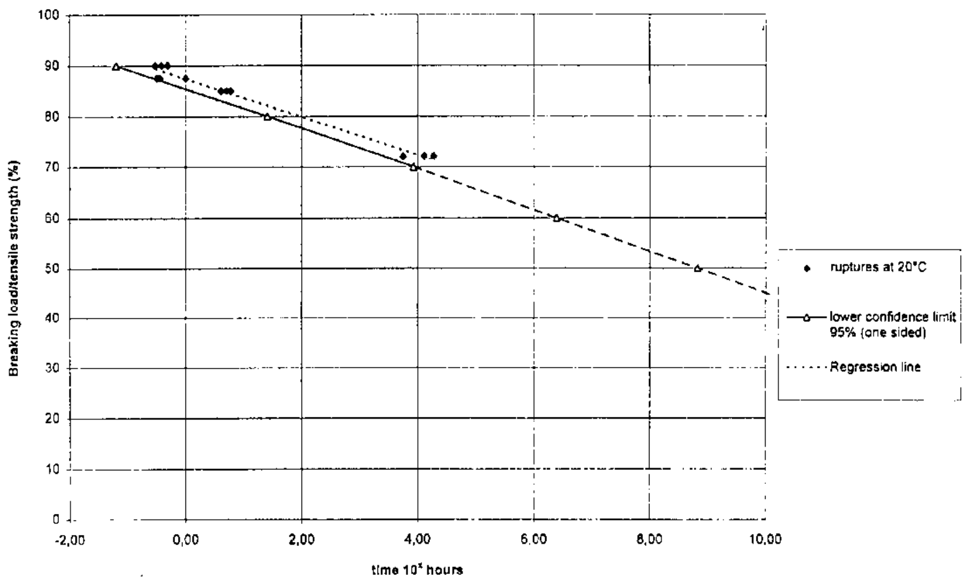


EN ISO 13433
one value in the area
of 10 000 h requested



A_1 –longterm creep rupture

EN ISO 13433
one value in the area
of 10 000 h requested



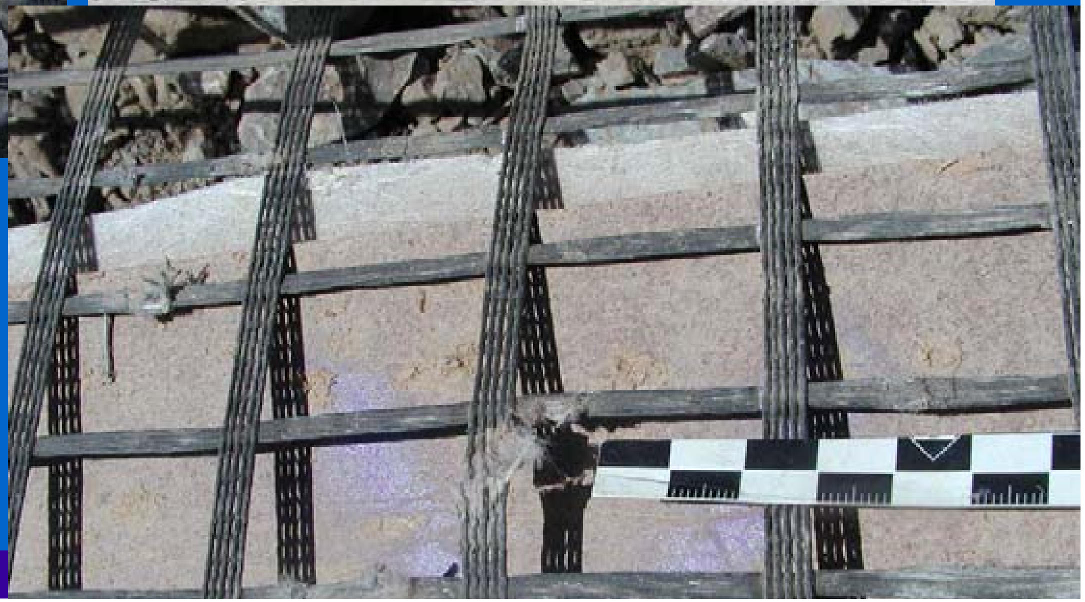
Earthfall B180

Event occurred larger than estimated

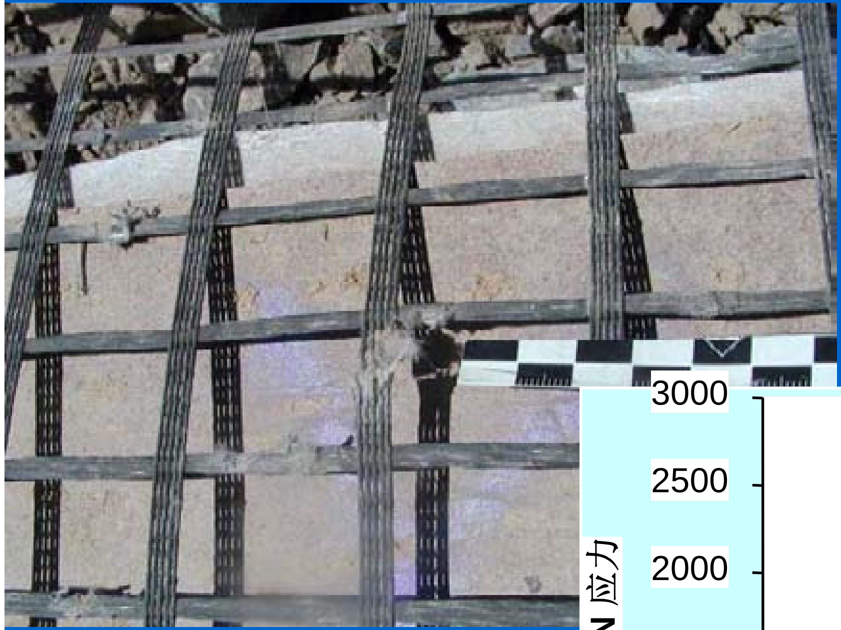
A_2 – damage during installation

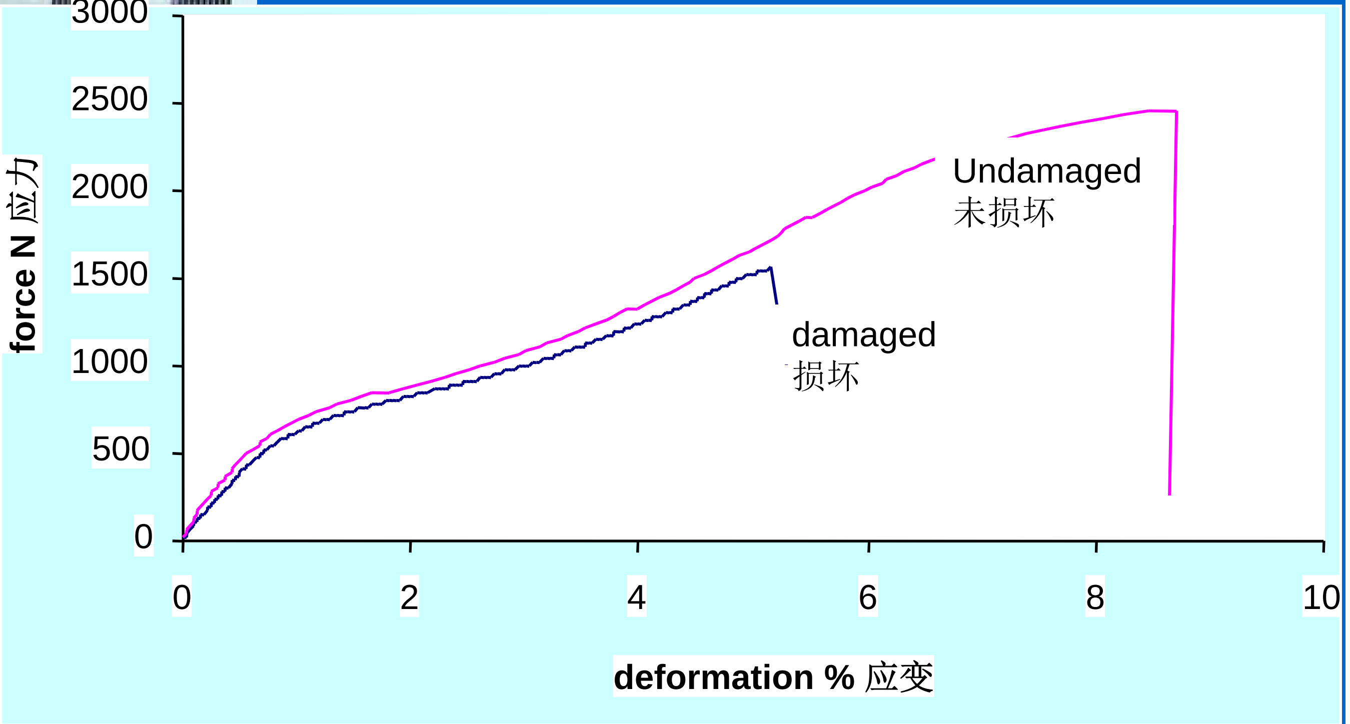
A_2 – damage during installation

A_2 – damage during installation

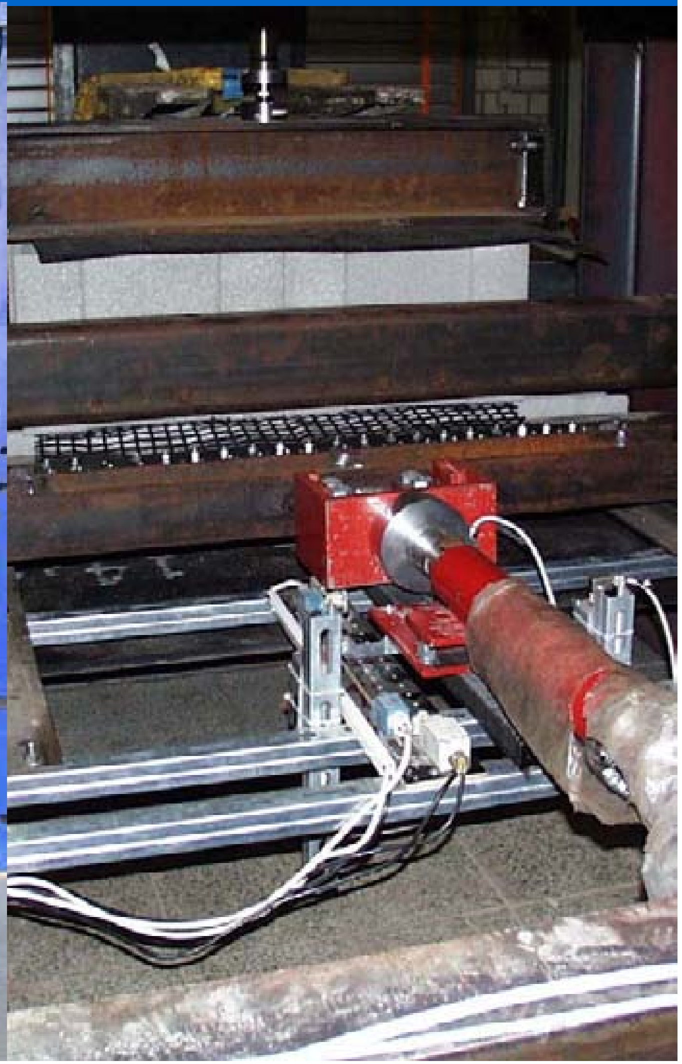


A_2 – damage during installation

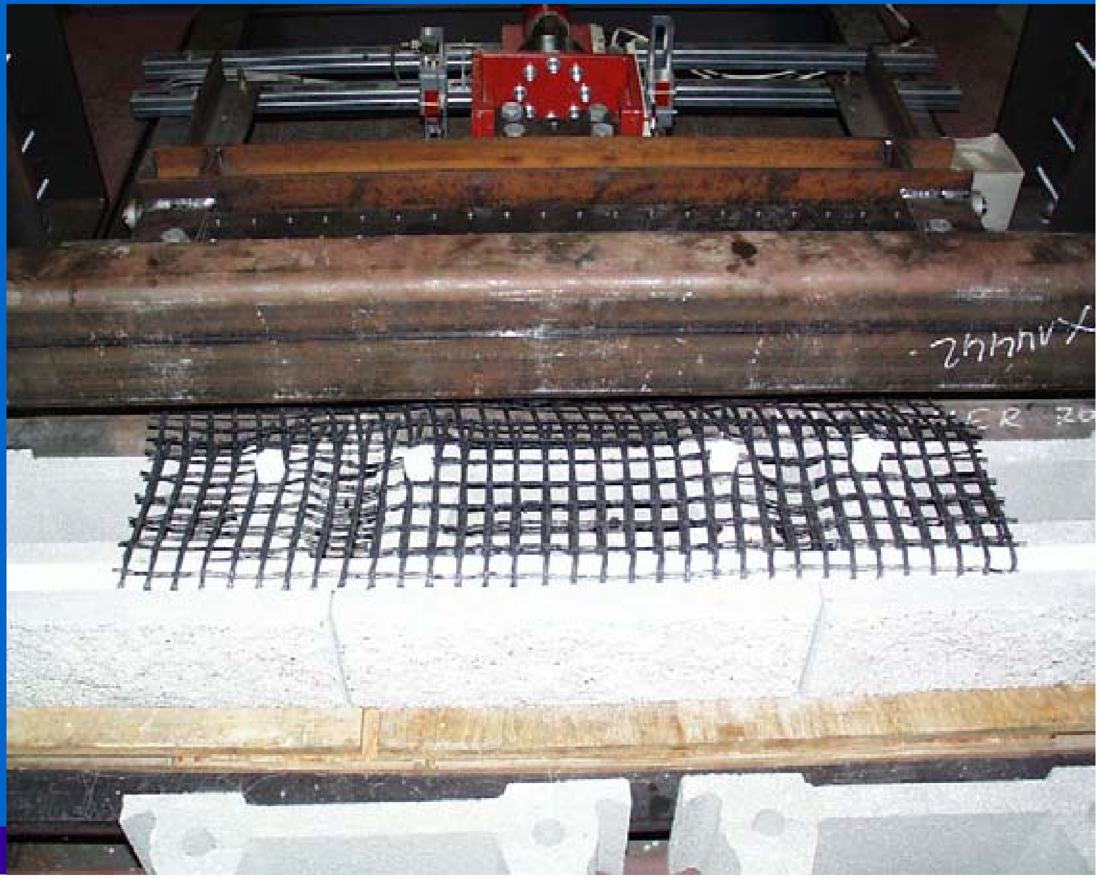




A_3 – connections, seams, joints



A_3 – connections, seams, joints

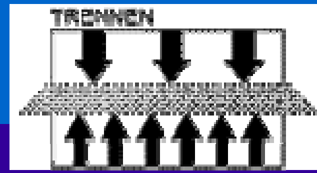


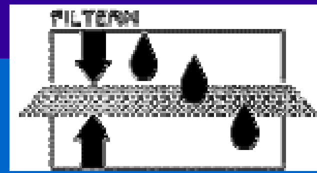
Environment A_4

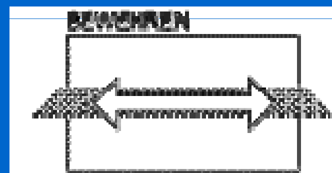
Chemical resistance

A_5 – cyclic loads

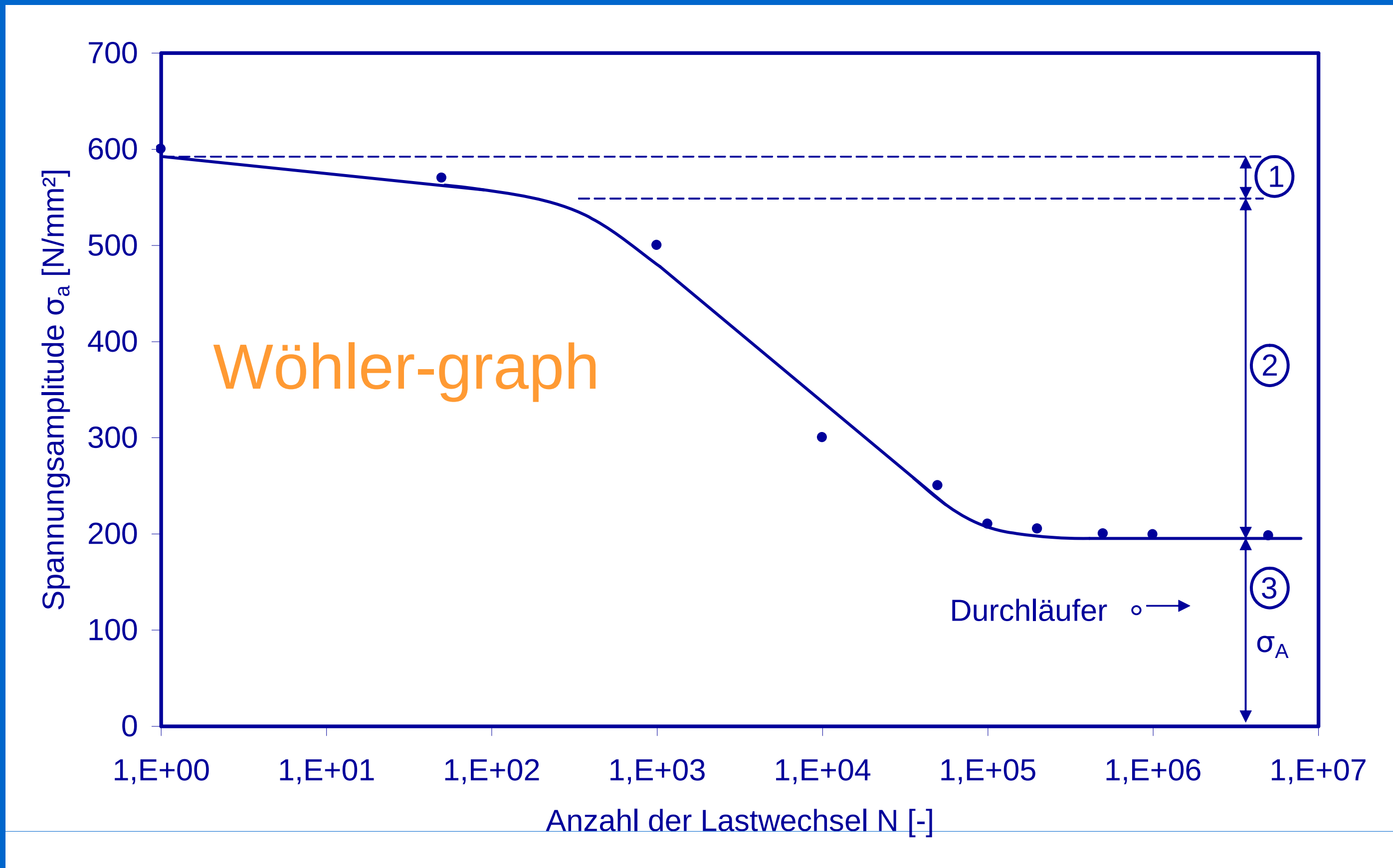
Cyclic, dynamic loading







Fatigue behaviour of metallic materials

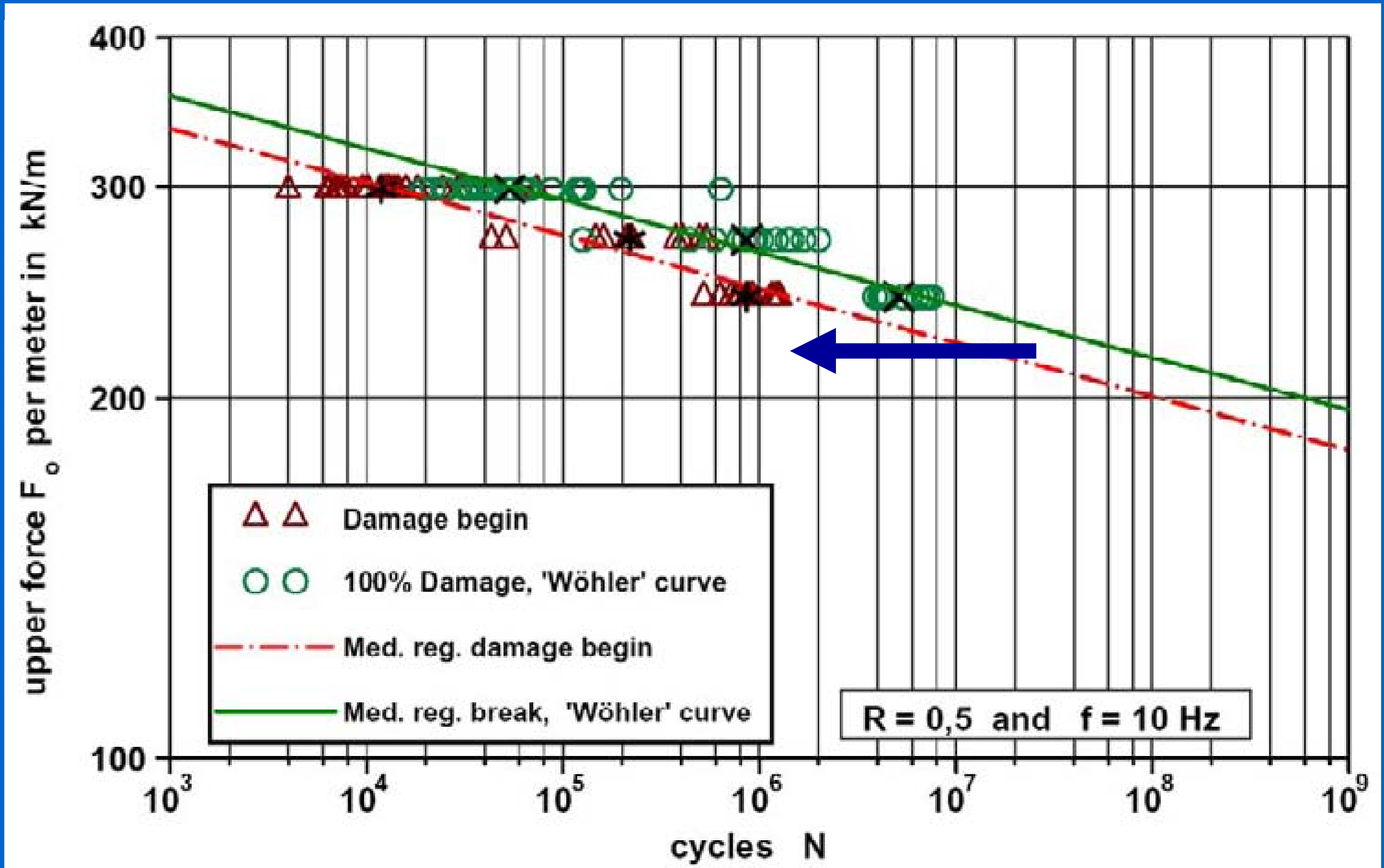


1LCF

2HCF

3endurance limit

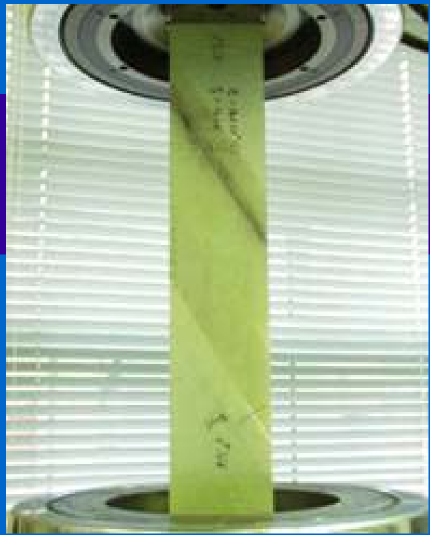
Wöhler graph and begin of damage line

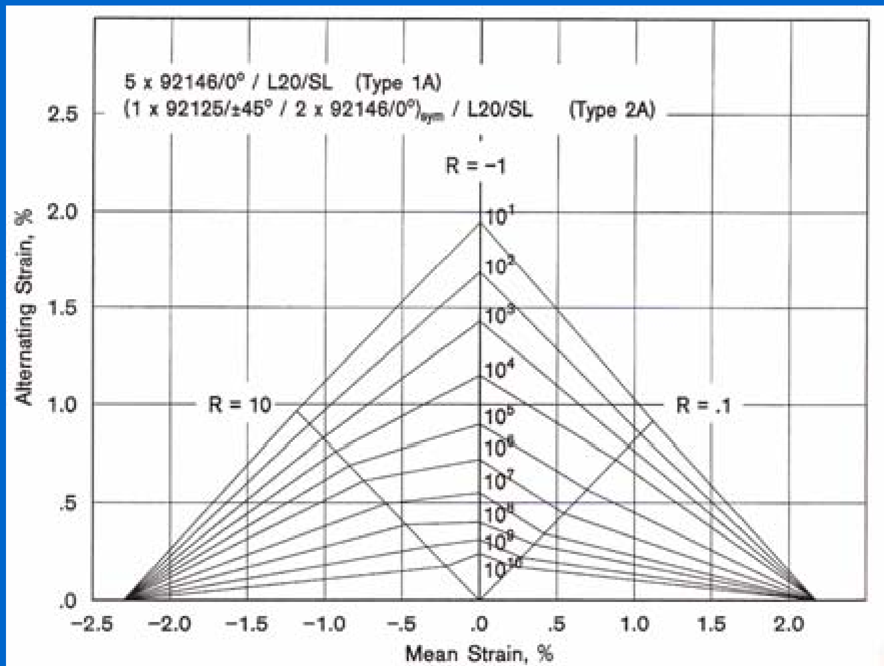


Zanzinger 2006

Spider web graph

common for fibre reinforced plastics (FRP)





Kensche et. al 1996

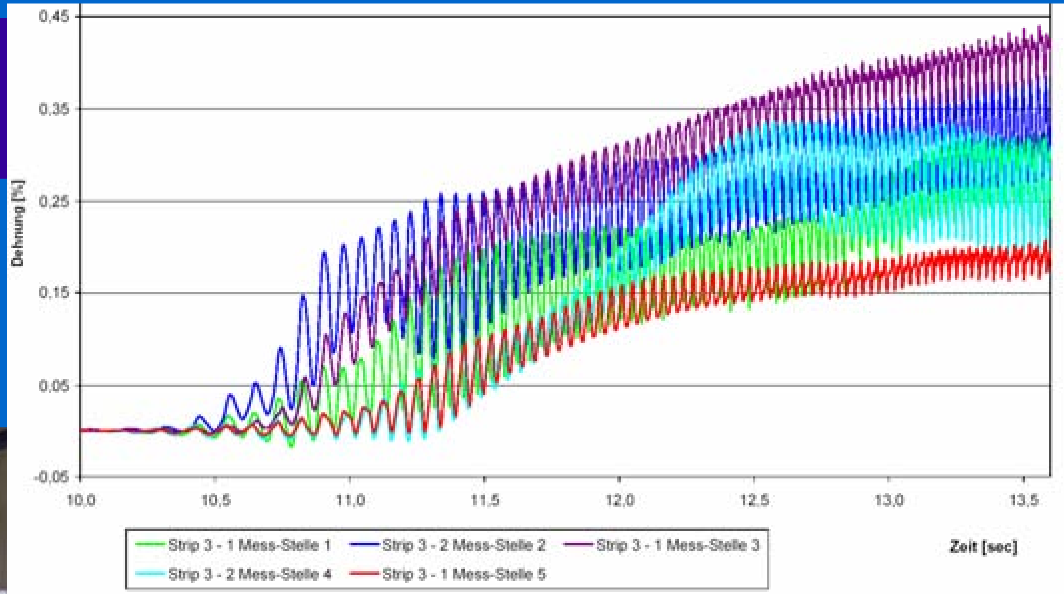
Labormessungen

Herold et al. 2006

H = 4,00 m

L = 3,00 m

f = 0 bis 36 Hz



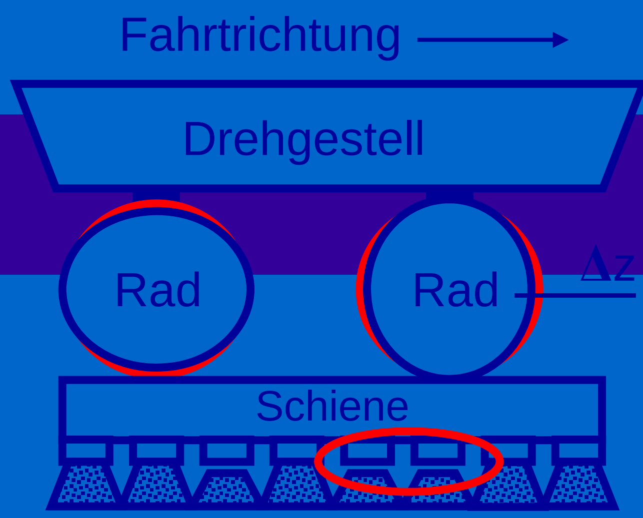
Large scale labtests by Herold & Pachomow at the BTU Cottbus

Calculations from strain to Force lead to

R = 0,66 √

Auersch et al.

Measurement on railroads



$\Delta z \leq 0{,}3$ mm

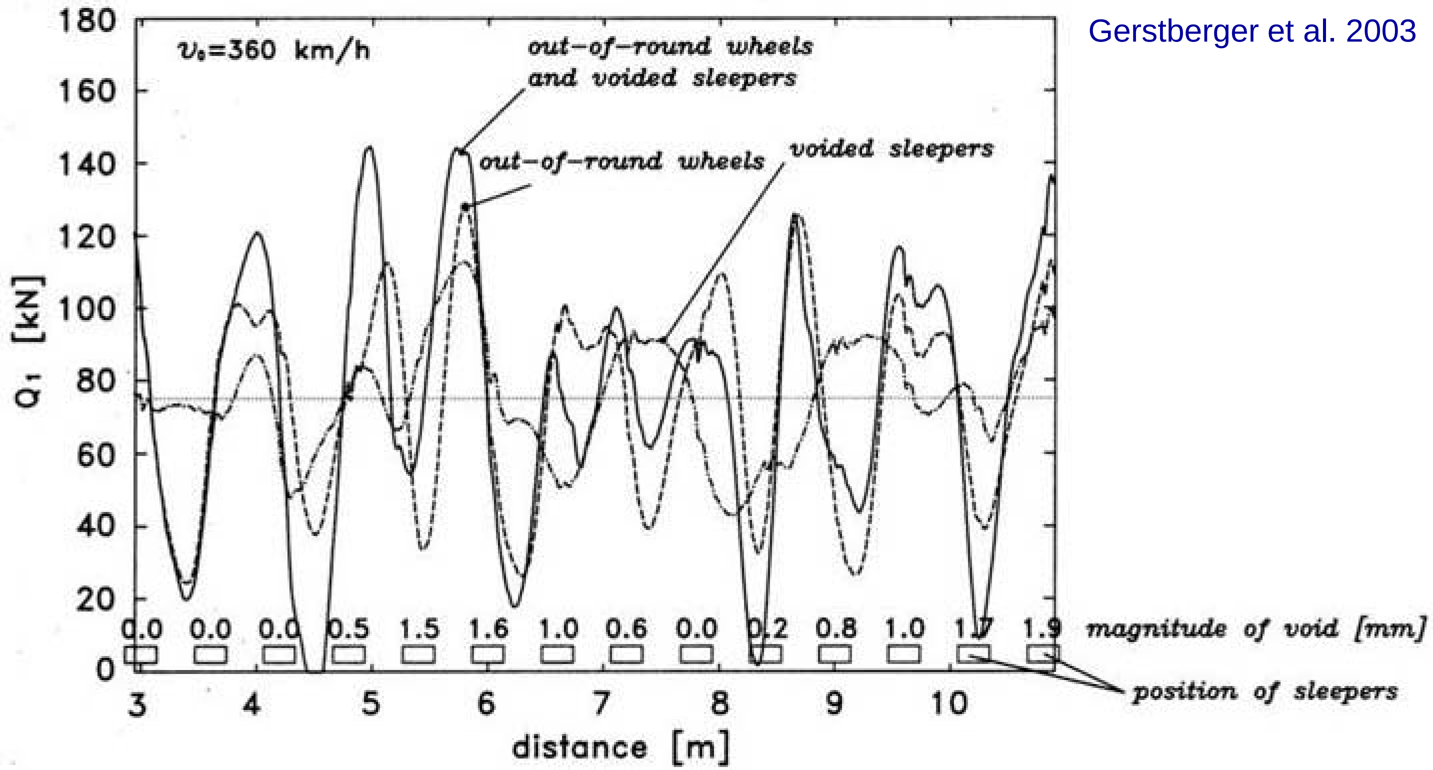
Cause of dynamic loads	**dynamic load/ Static load**	**Ratio min F/ maxF**
Traffic under ideal conditions	15 %	0,87
Unevenness of wheels	30 bis 50 %	0,66 bis 0,77
Shock loads	200 bis 300 %	0,33 bis 0,50

Frequency

- single wheel 180 Hz
- wheelcouples ca. 8 bis 12 Hz
- Frequencies > 65 Hz not measured in soil
- maximum of deformation in soil < 20 Hz

f = 10 Hz

Gerstberger et al. 2003



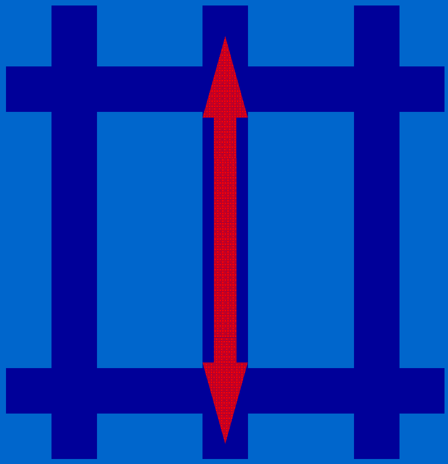
Loading parameters

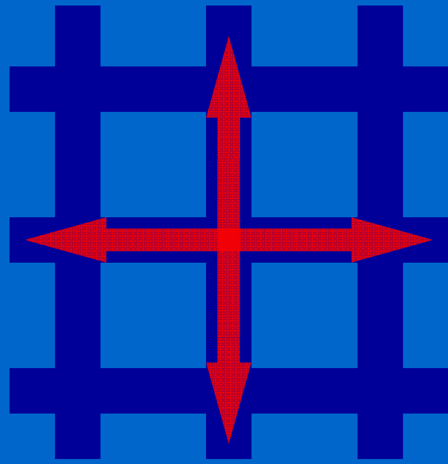
parameter	value
Number of load cycles N	$N = 10^7$
frequency f	$f \leq 10$ Hz
dynamic ratio R	$R \leq 0{,}66$

Materials under investigation

uniaxial (anisotrope) Geogrid

biaxial (isotrope) Geogrid

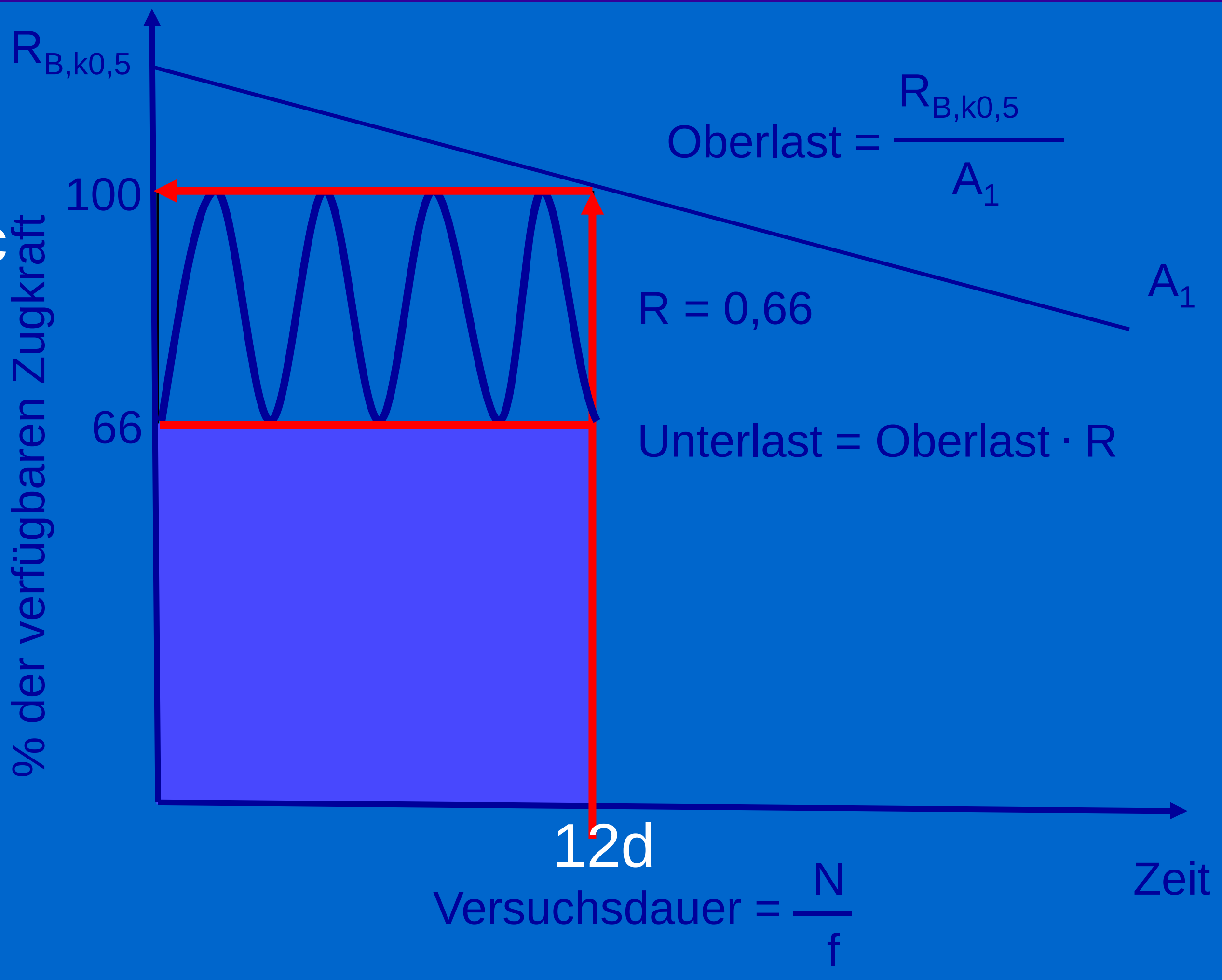




		GG1	GG2	GG3	GG4	GG5
Polymer	-	PET	PET	PP	PP	PEHD
pitch	mm	80	100	40	50	160
$R_{B,k0}$	N	6441	6356	2025	1819	1355
$\varepsilon_{B,k0}$	%	7,2	7,7	7,2	9,6	10,6

Creep rupture curve to determine loads

The maximum sustainable static load for the test-duration was selected as upper load

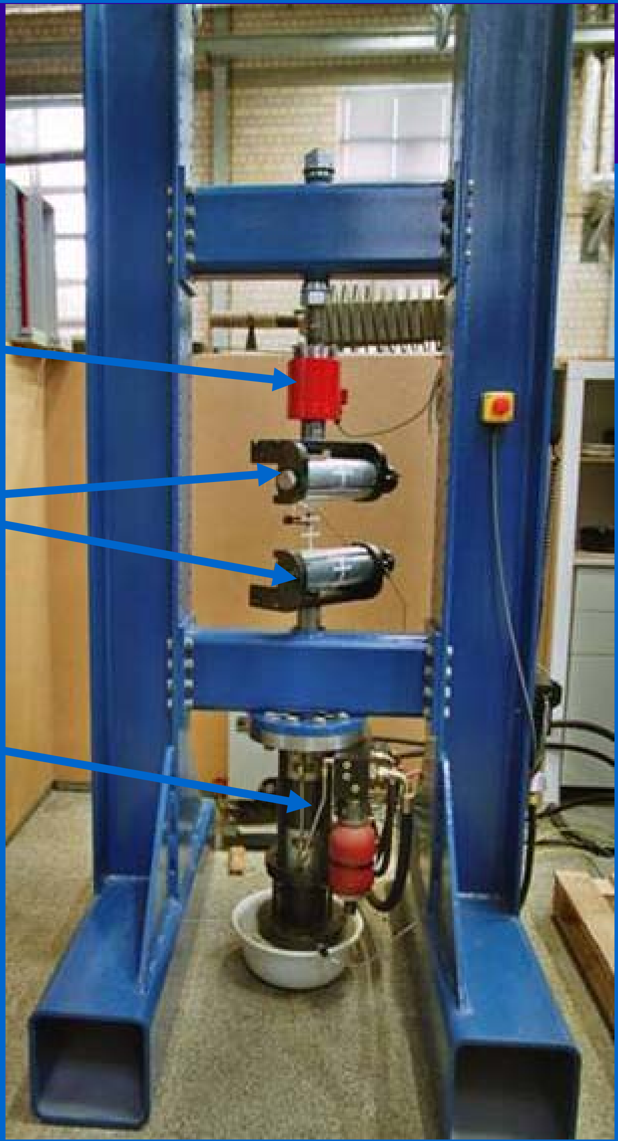


Cyclic testing

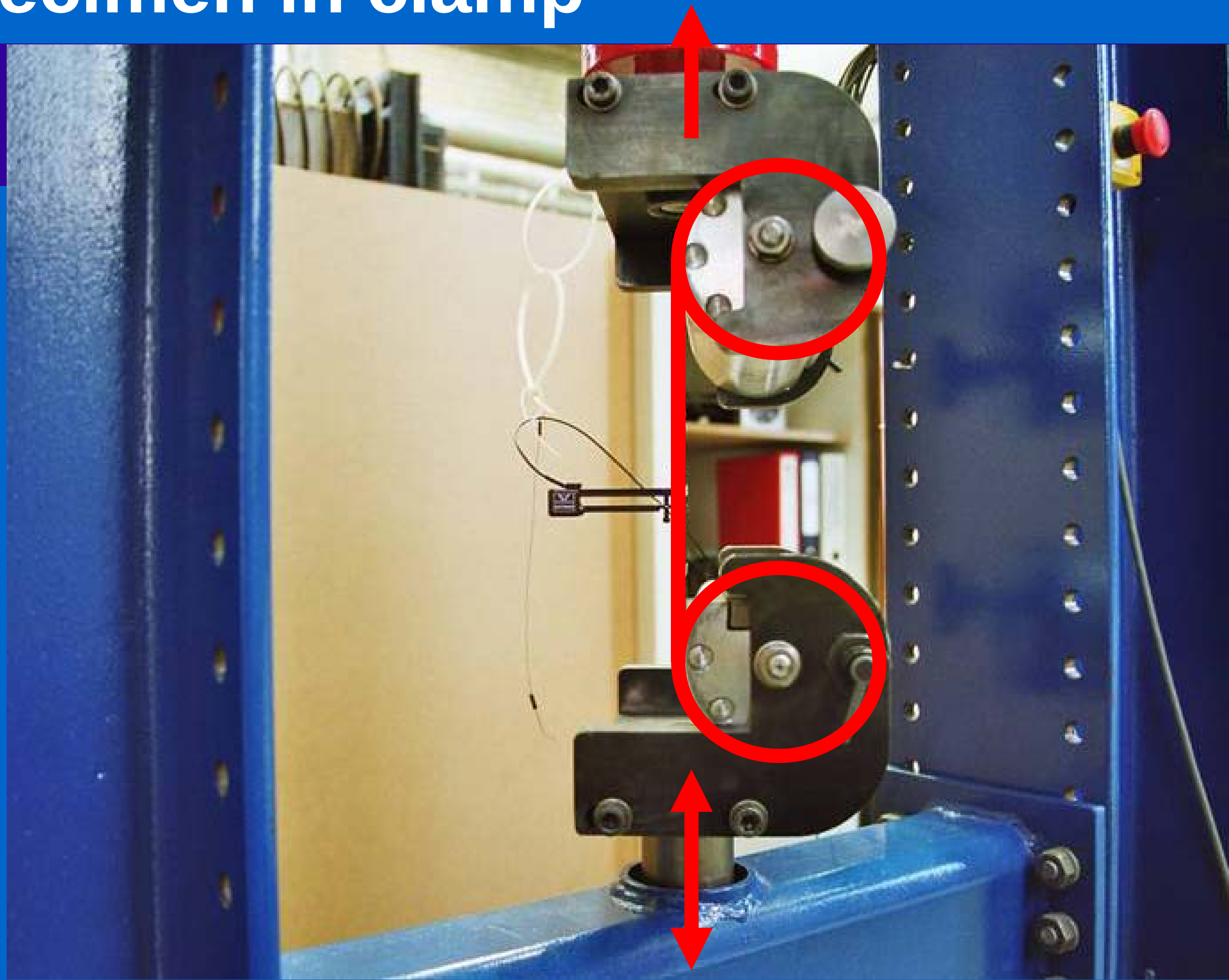
Load cell

Capstan clamps

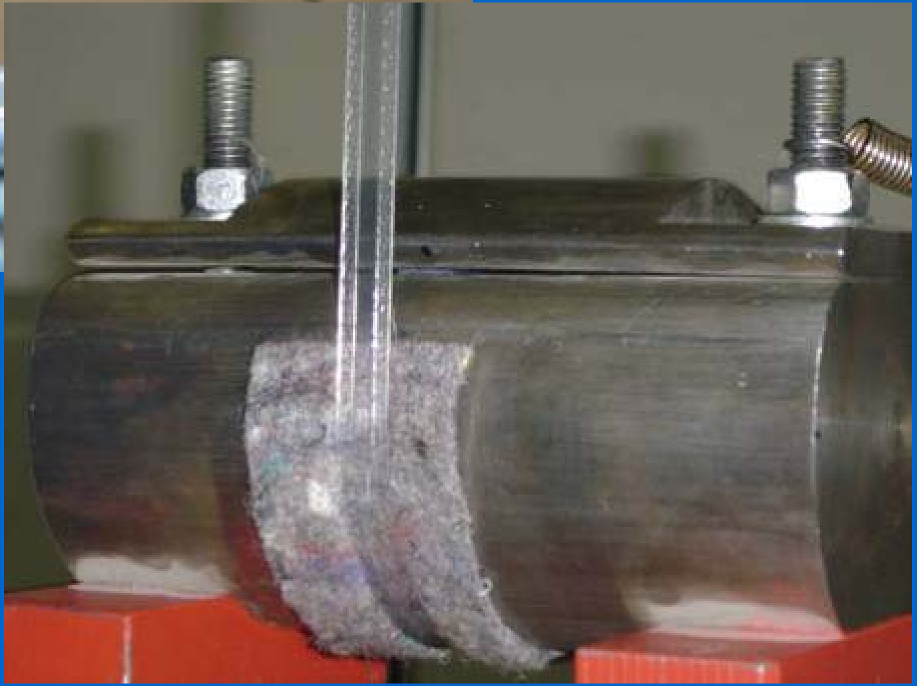
Servo-hydraulic actuator



Specimen in clamp



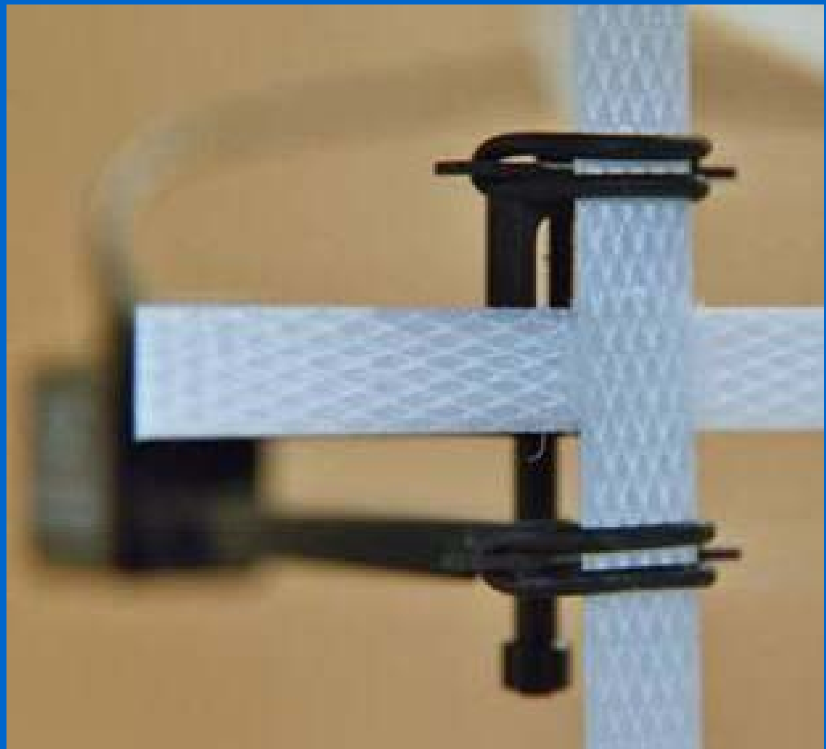
Strain measurement, clamping



Clip on strain gages

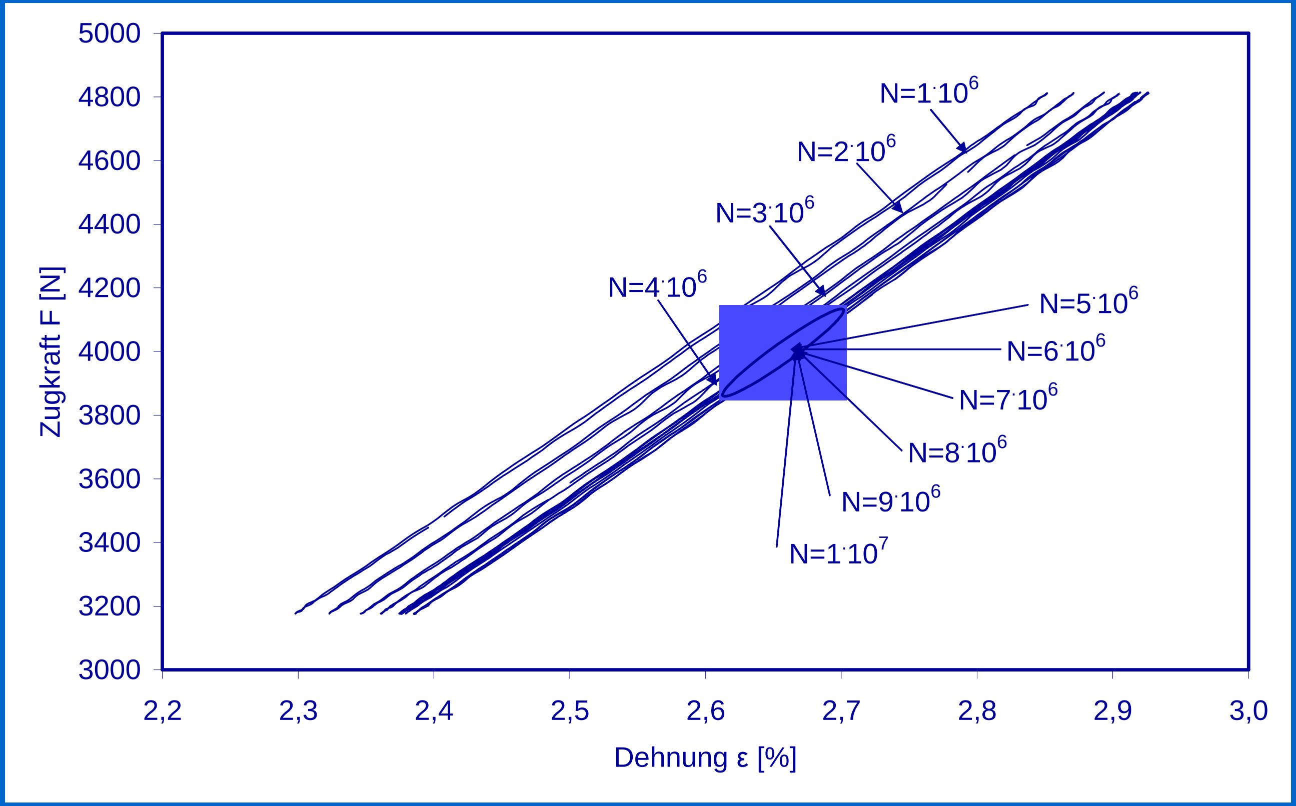
INSTRON
max s: ± 5 mm
$\varepsilon \leq 20$ %

HBM DD1
max s: ± 2,5 mm
$\varepsilon \leq 10$ %



Load strain hysteresis of GG1-PET during 10E7 cycles

Low creep, very low change in stiffness

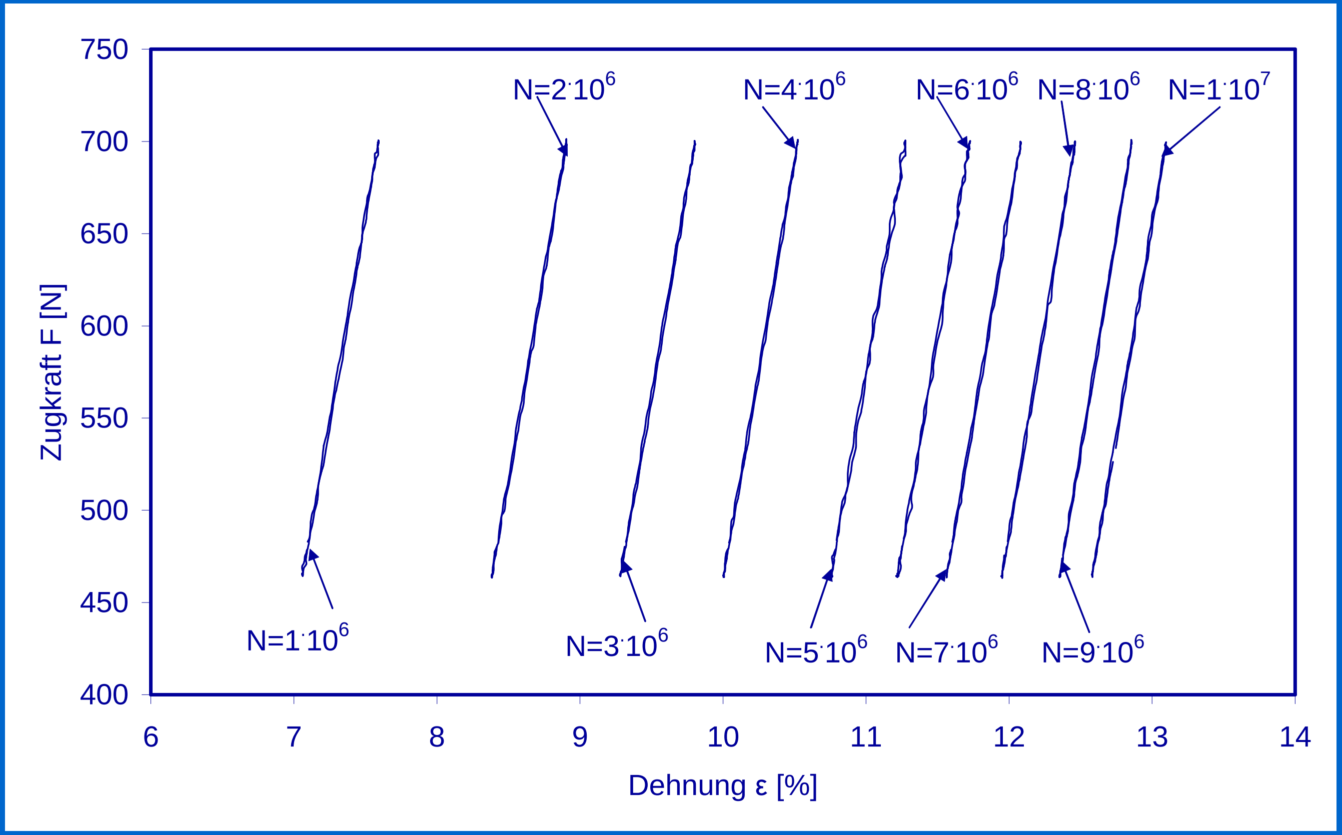


GG1-PET

Load strain hysteresis GG4-PP during 10E7 cycles

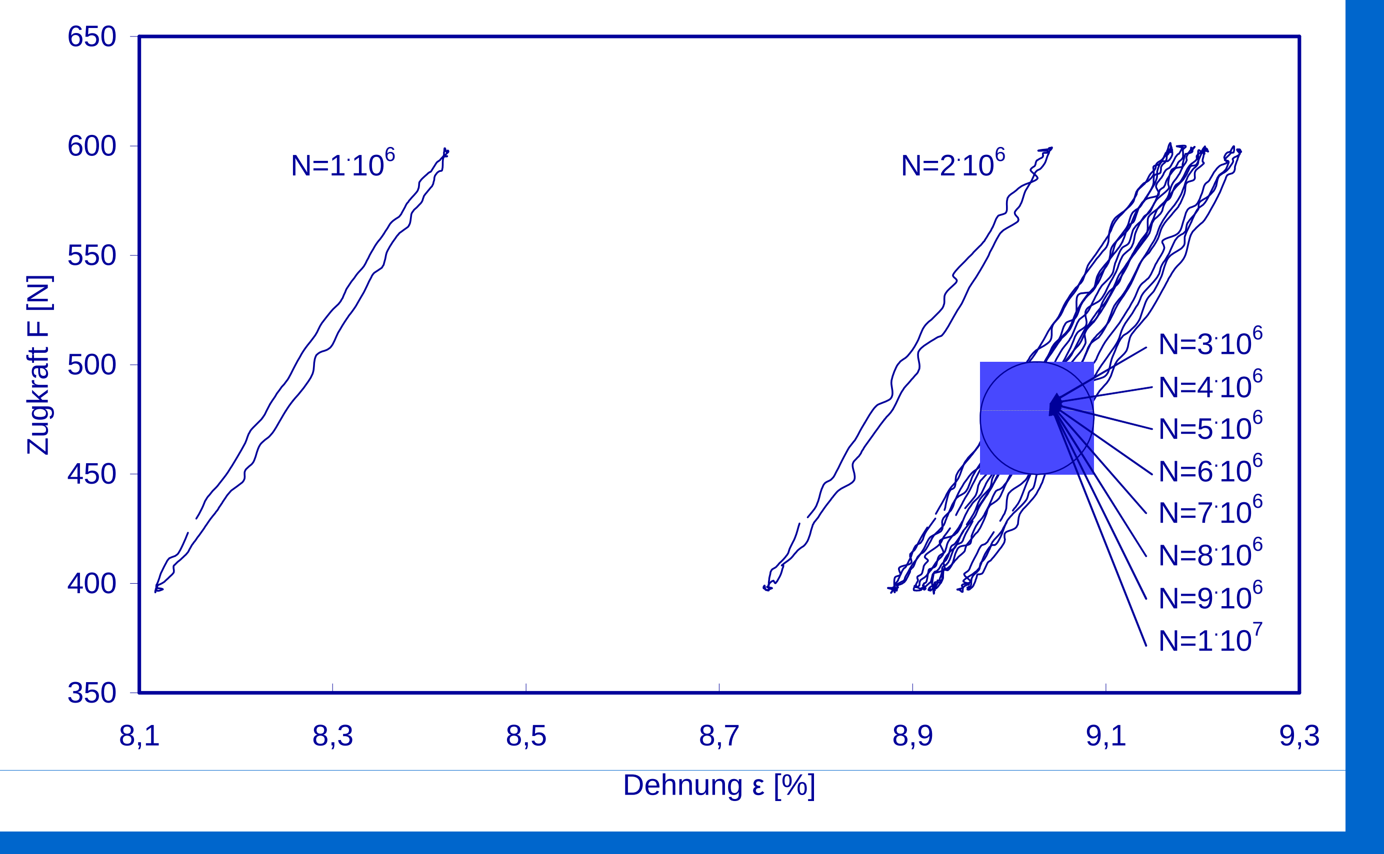
Remarkable creep

low change in stiffness

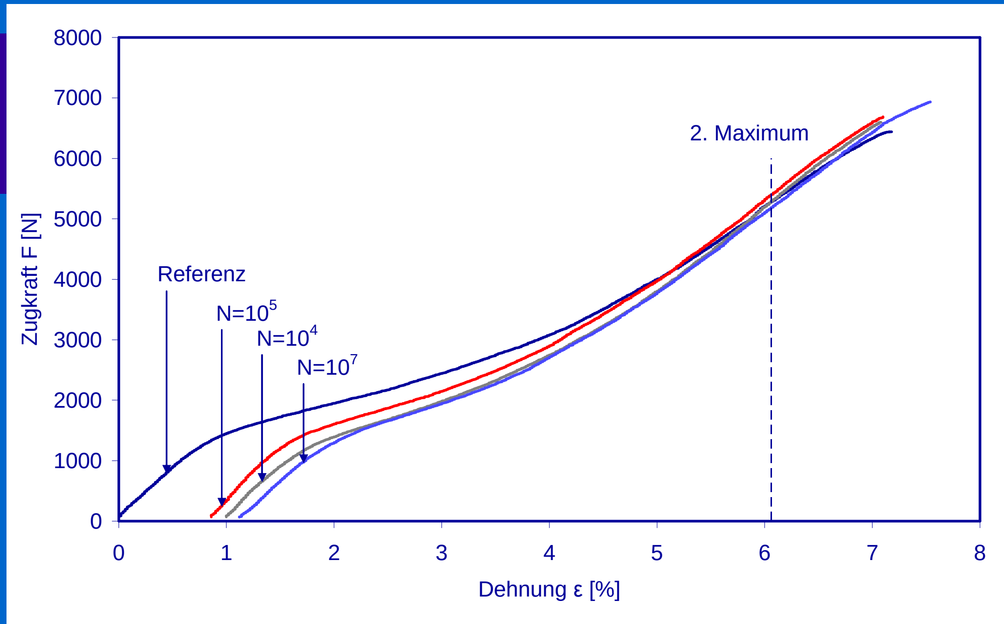


Load strain hysteresis of GG5-PE during 10E7 cycles

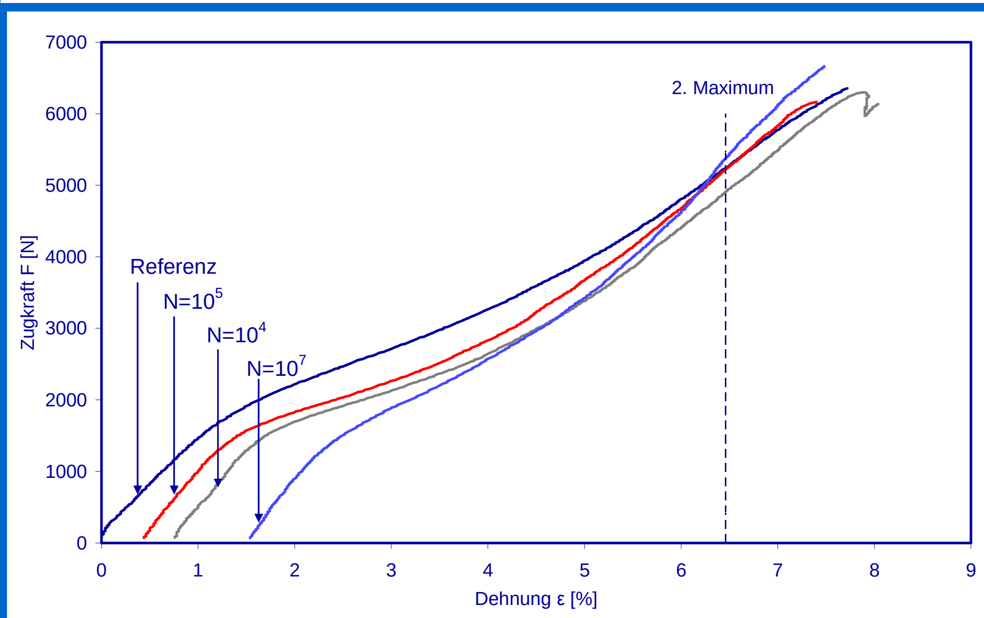
High initial creep, change in stiffness



Load strain curve before and after 10E7 cycles



GG1-PET



GG2-PET

F(ε) - Verhalten nach zyklischer Beanspruchung

Einleitung

Kenntnisstand

Eigene Untersuchungen

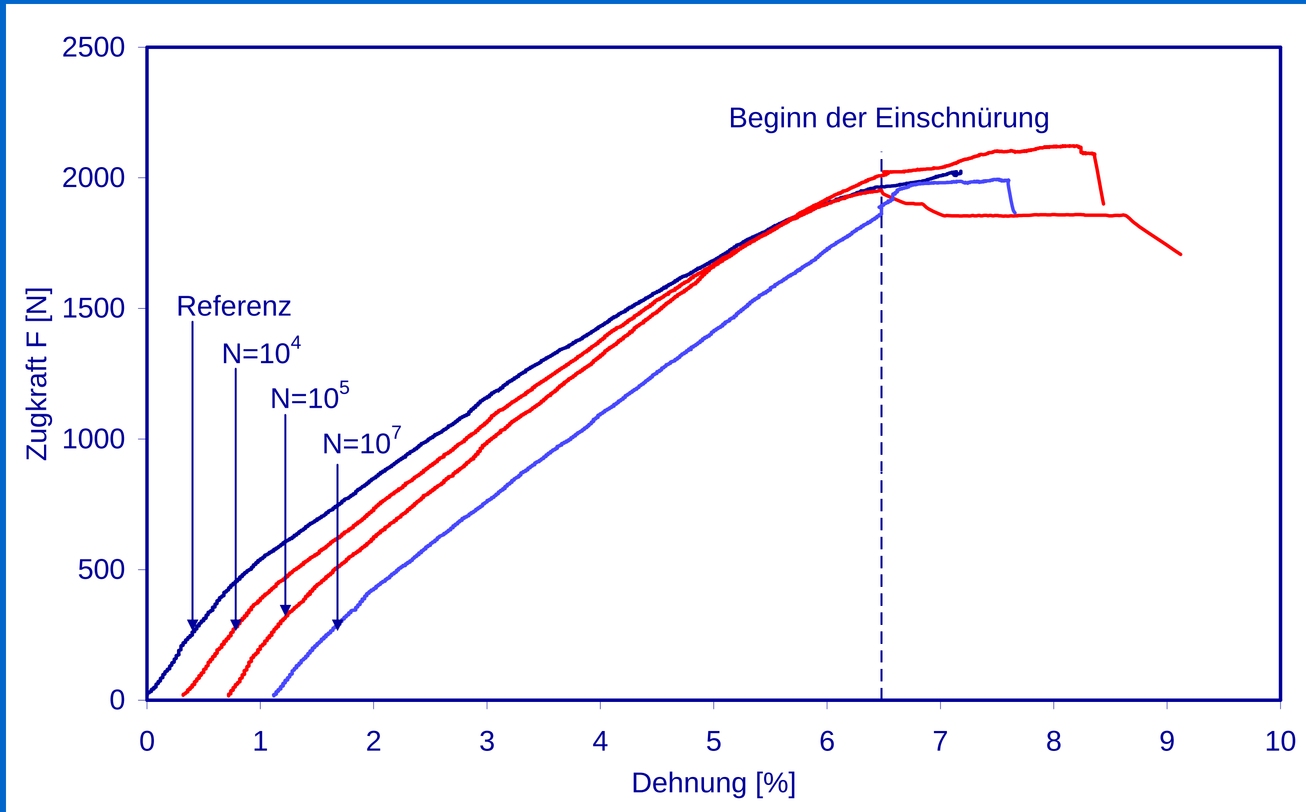
Auswertung

Ergebnisse

Zusammen-fassung

Ausblick

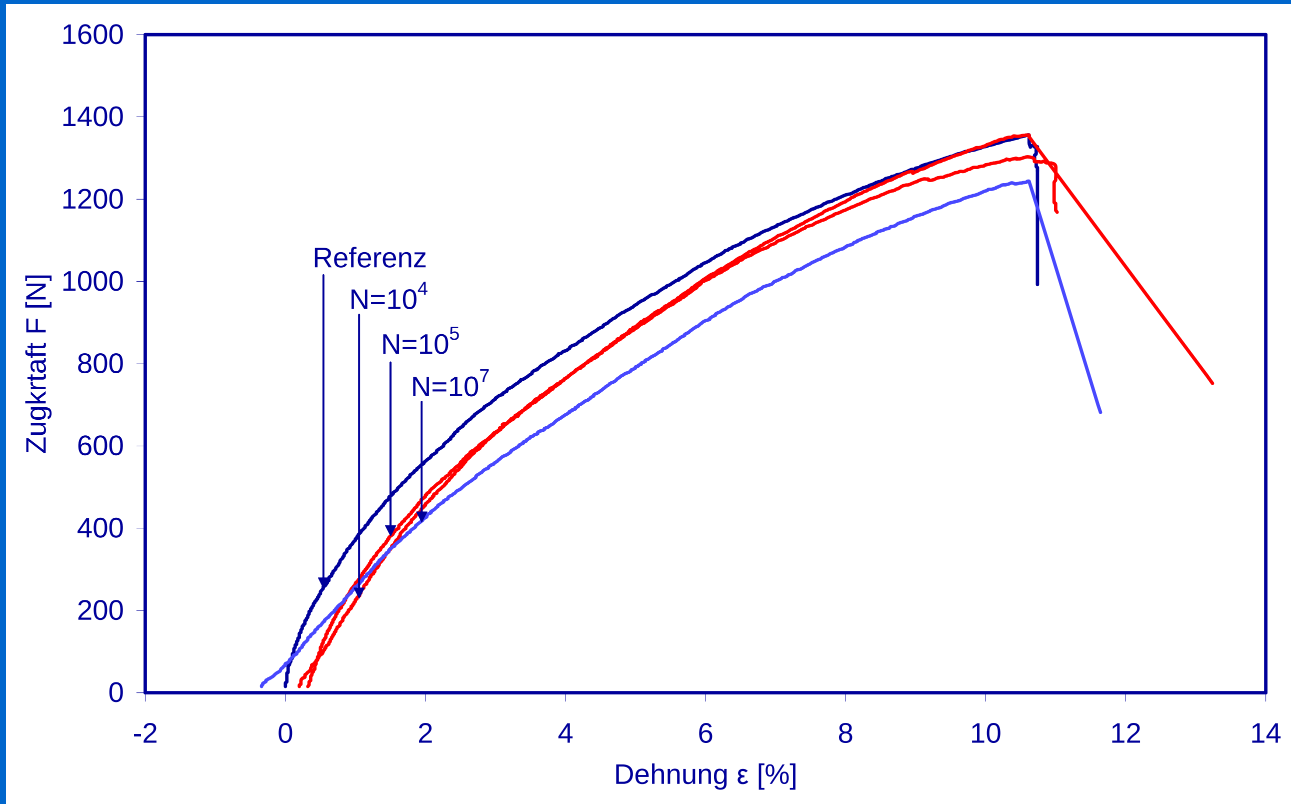
- Eindeutiger Einfluss von Lastwechselzahl auf die Gesamtdehnungen des Materials



GG3-PP

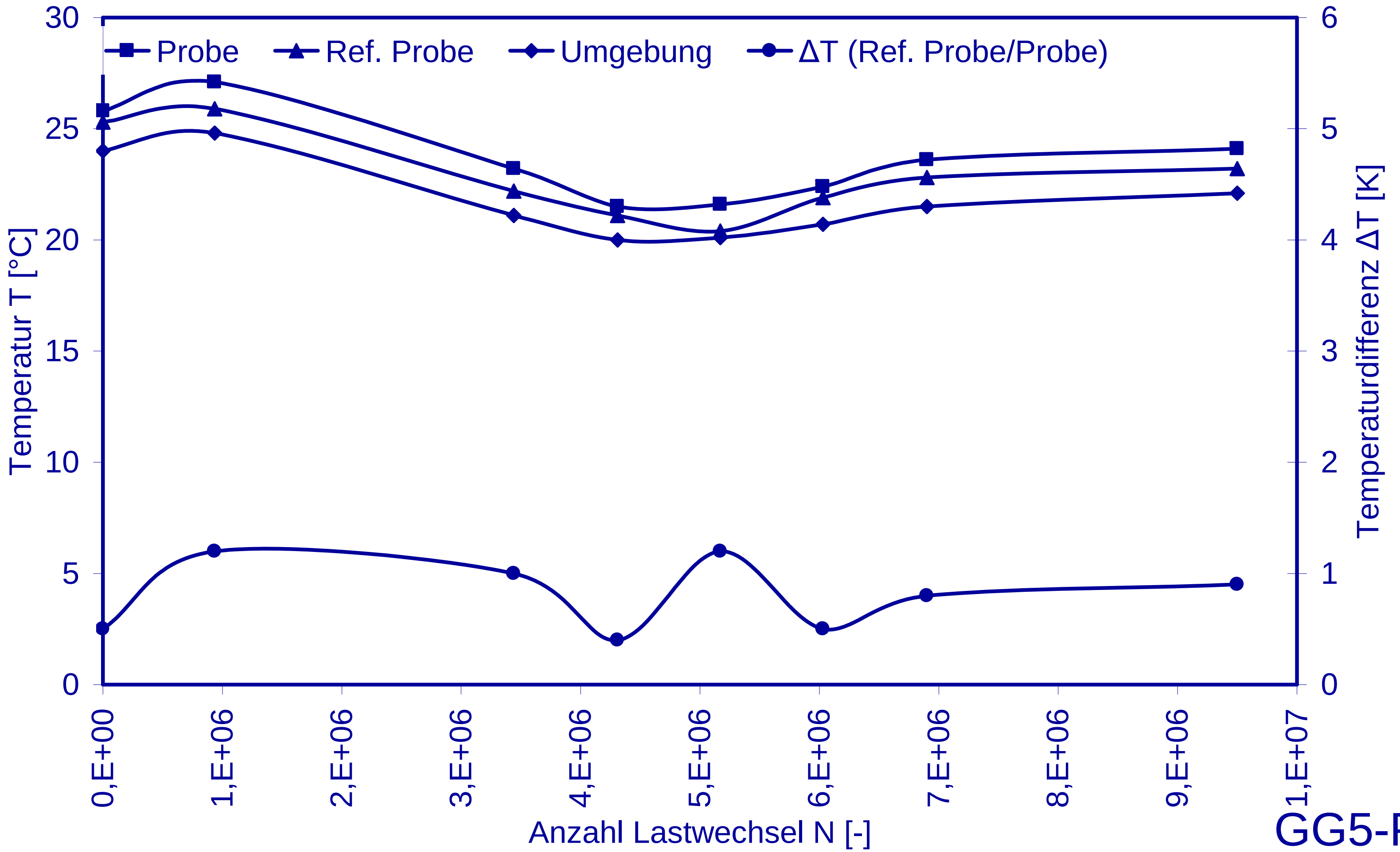
Load strain curve of GG5-PE before and after cyclic loads

Low creep, very low change in stiffness



GG5-PE

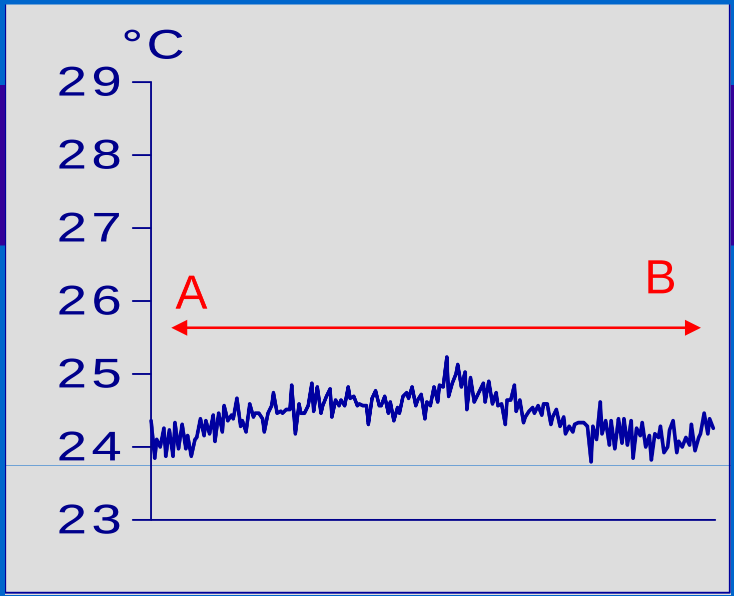
Temperature during test

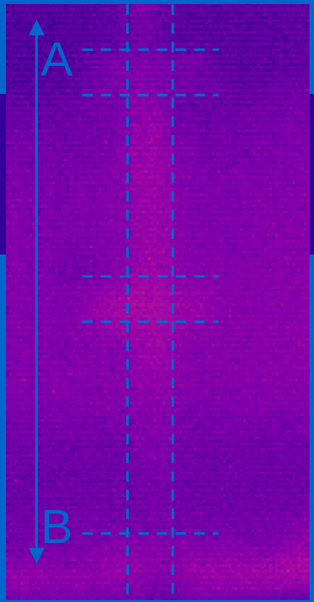


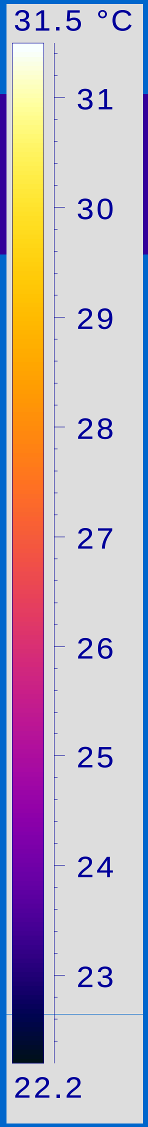
GG5-PE

- Temperature distribution

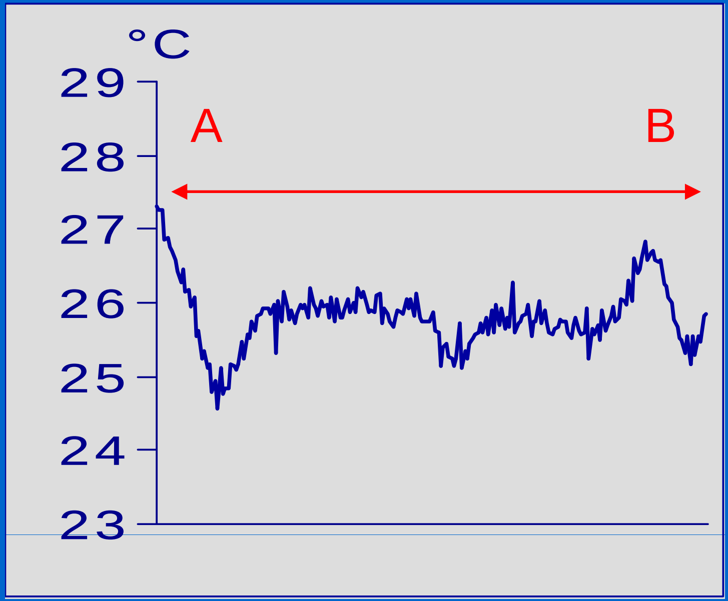
Reference

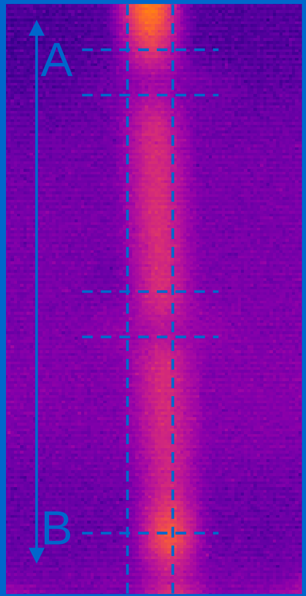






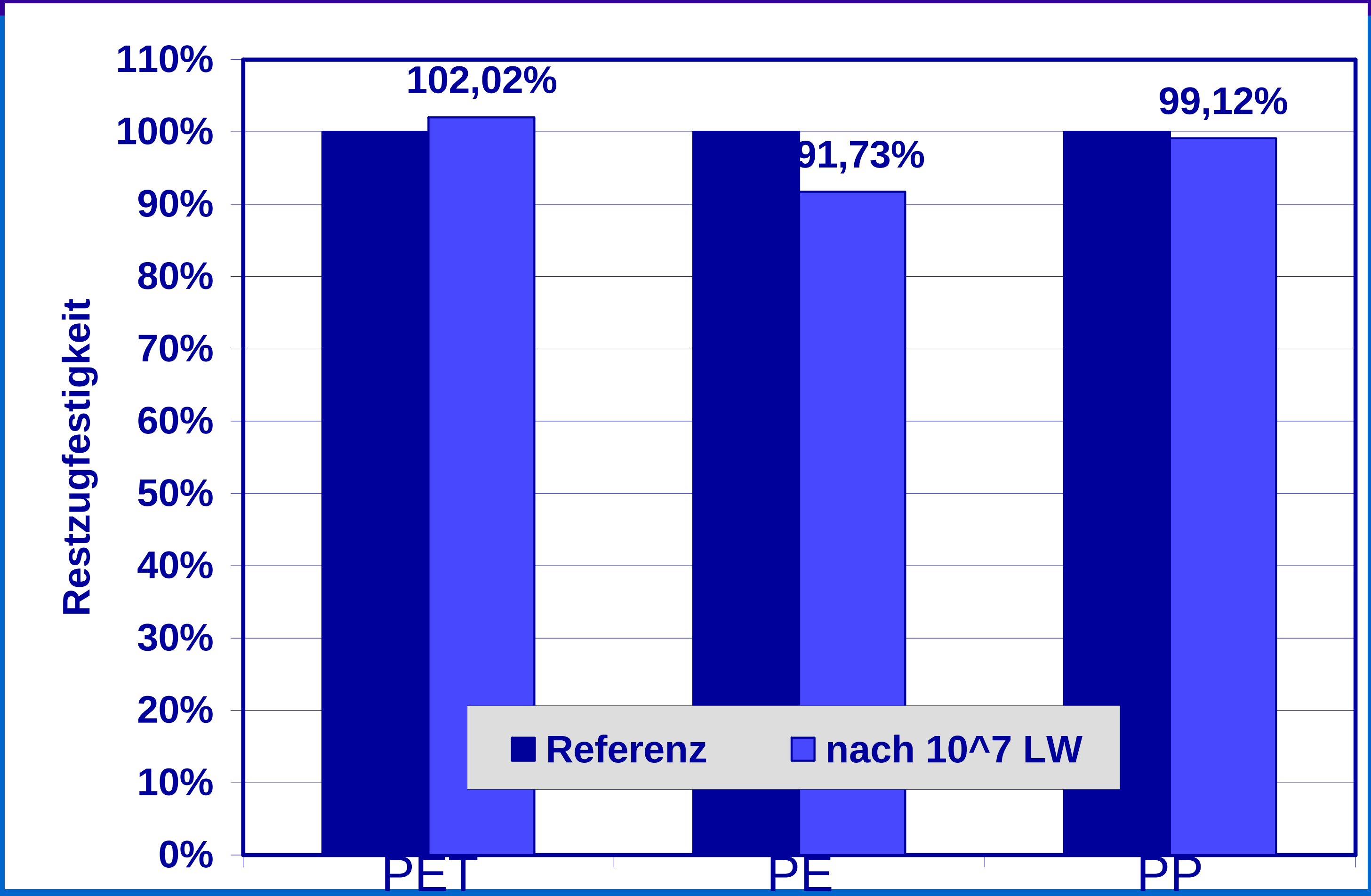
loaded specimen





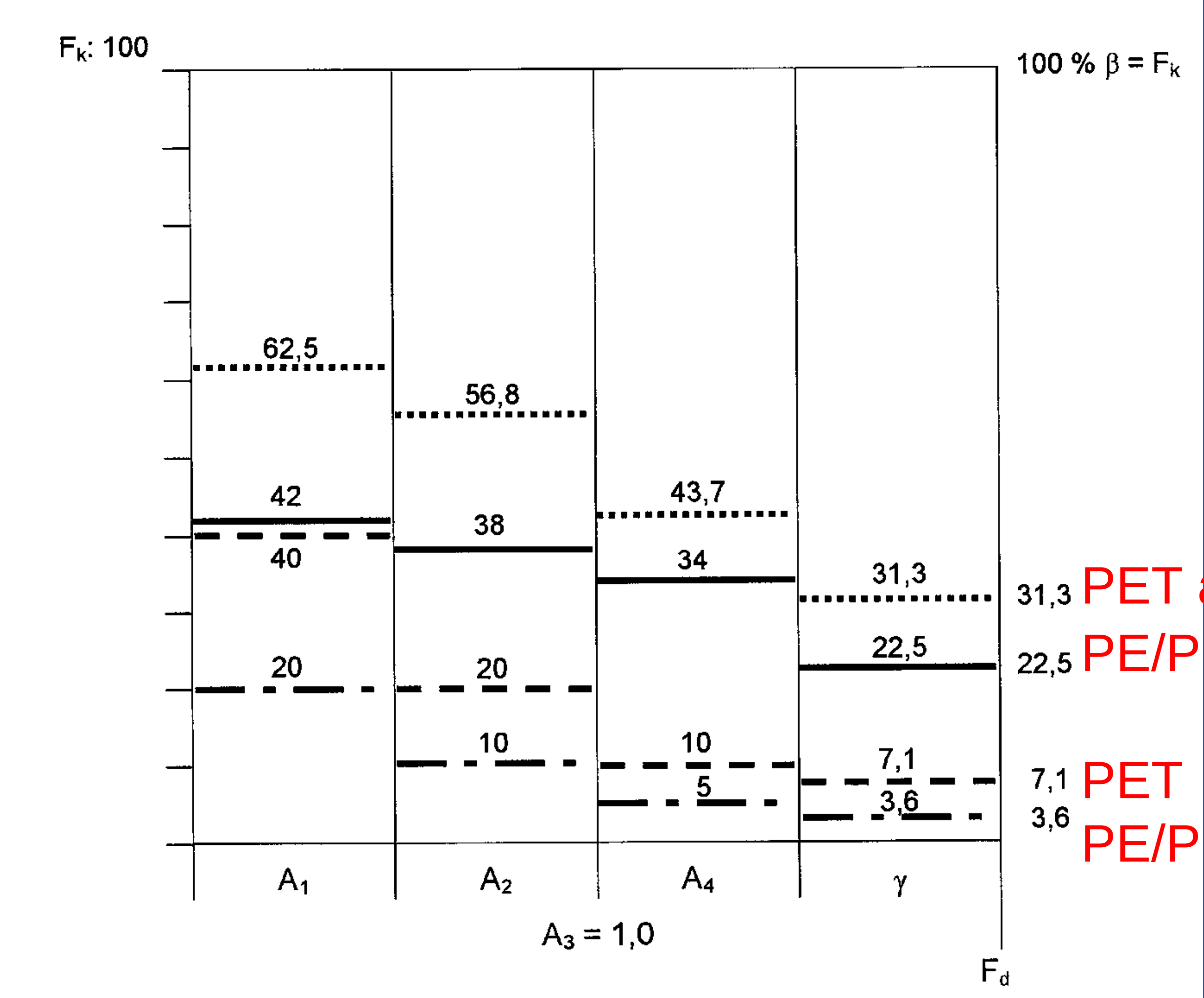
GG1-PET

Tensile tests after 10E7 cycles to determine A_5



Admissible load in % F_k

EBGEO



31,3 PET all A_i proven
22,5 PE/PP all A_i proven
7,1 PET default values
3,6 PE/PP default values

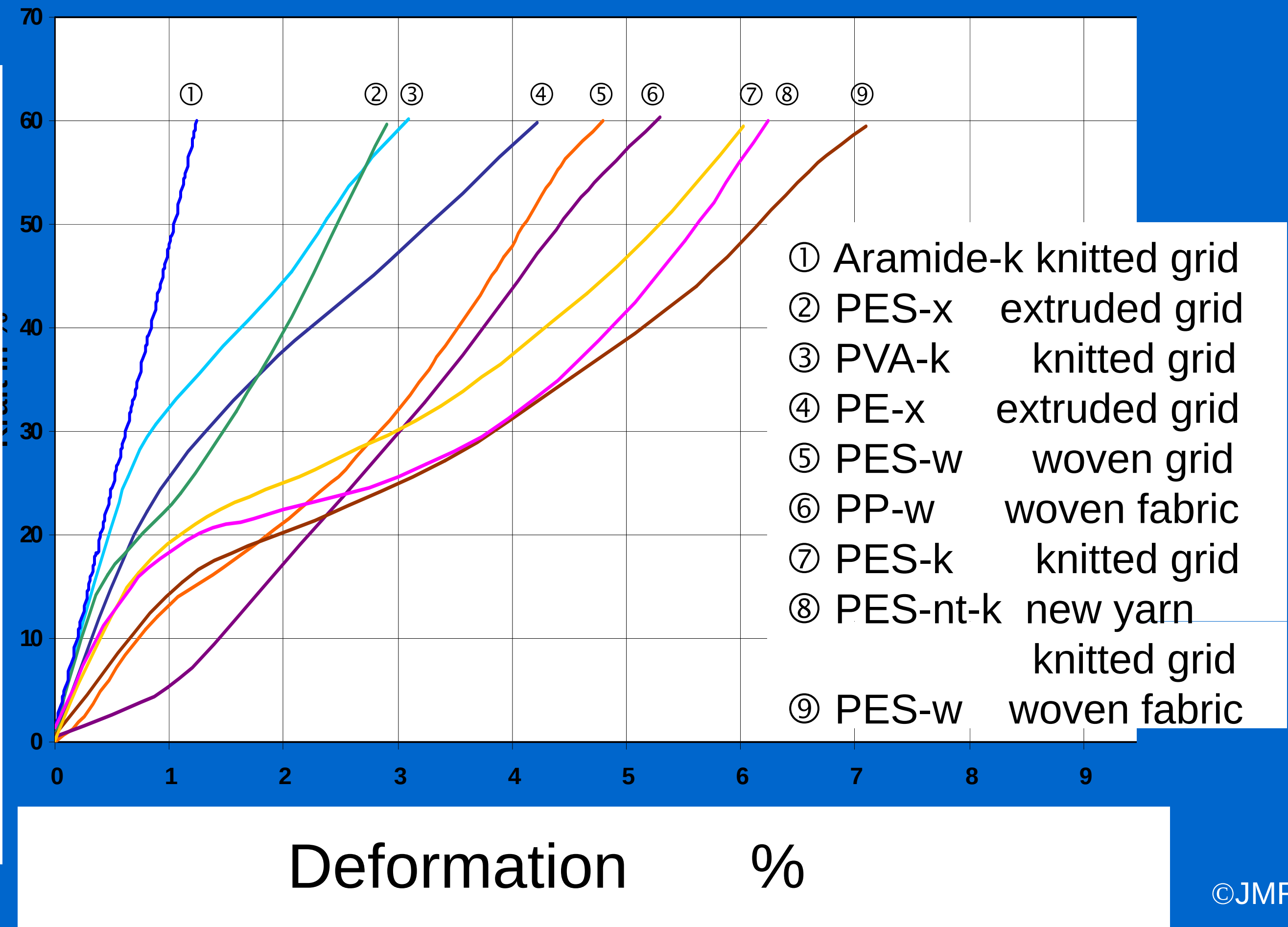
©JMR

Look to strain at admissible Force

normalised by

100 Fi
Fm

deformation measurement by clip on gages with very high accuracy (normally used for elastic deformation of steel



Design of Reinforcement

$F_d = F_k / A_1 \cdot A_2 \cdot A_3 \cdot A_4 \cdot A_5 \cdot \gamma$

If you have tested all values properly, you can exclude material failure and you are able to design properly

Repair of Mudslide in Gondo Simplon Pass – Switzerland

Desaster 10. Oct. 2000:

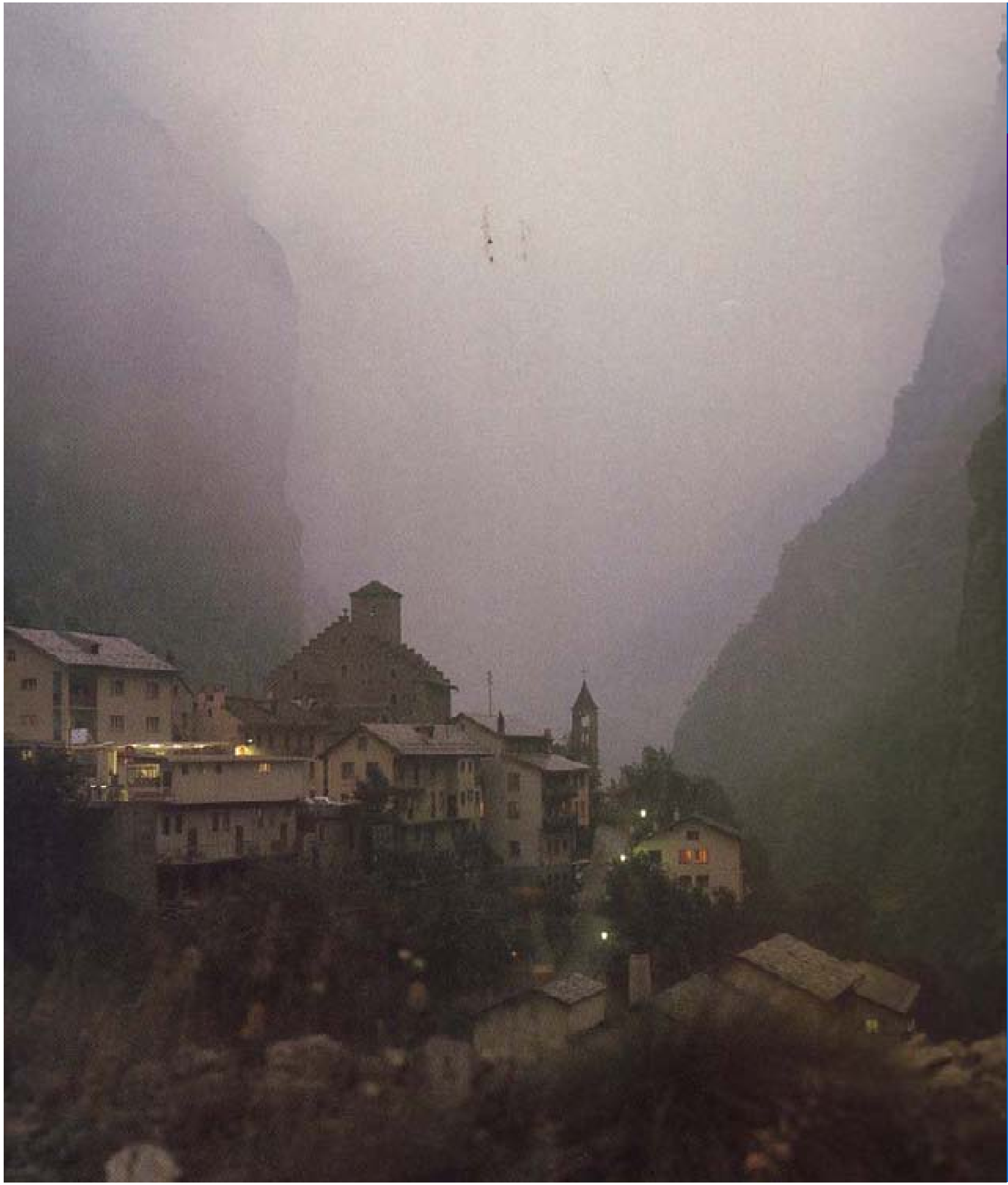
10 houses washed out

13 casualties

Felix P. Jaecklin

Dr. Sc. Tech. ETH,

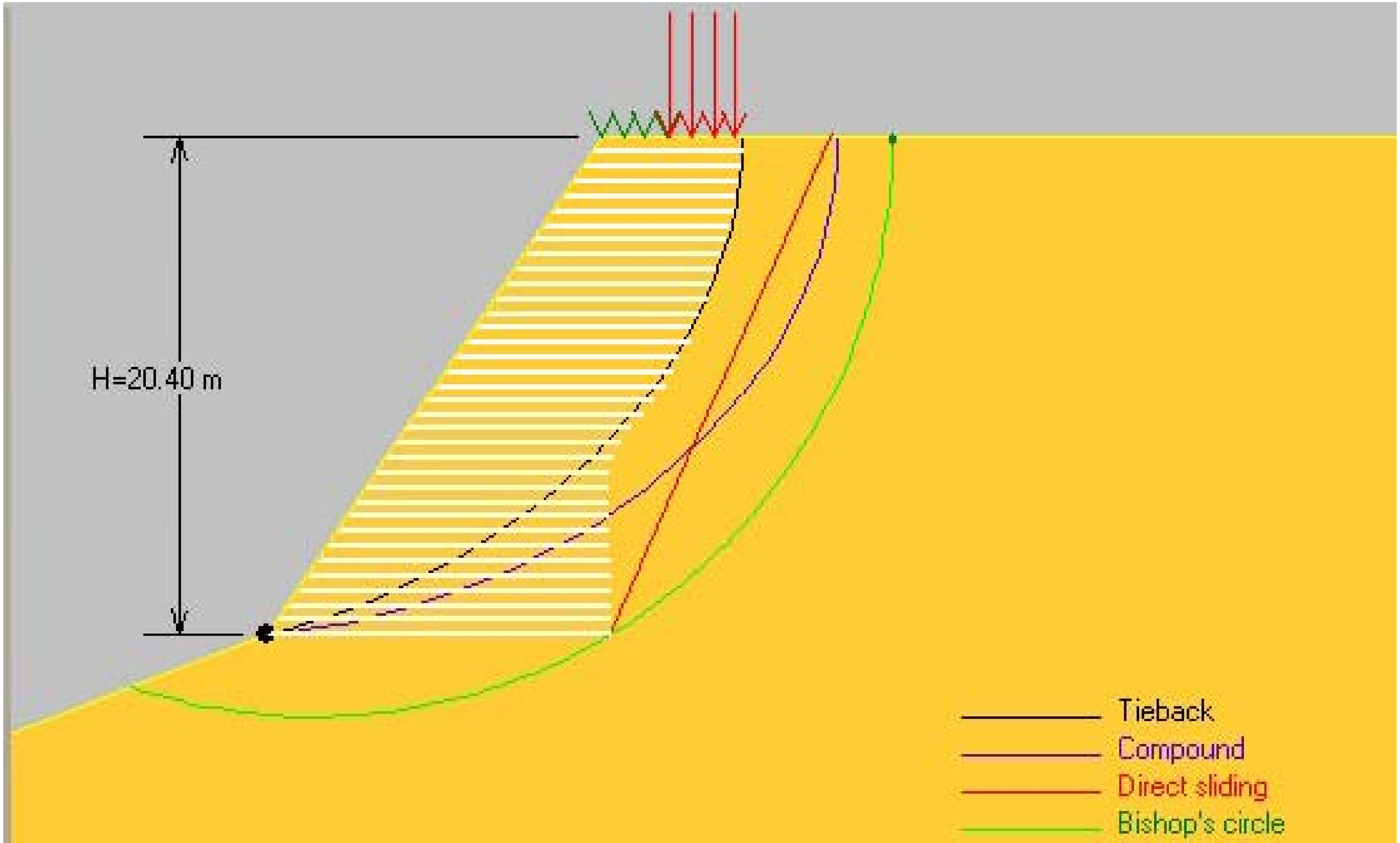
Dipl. Ing. ETH



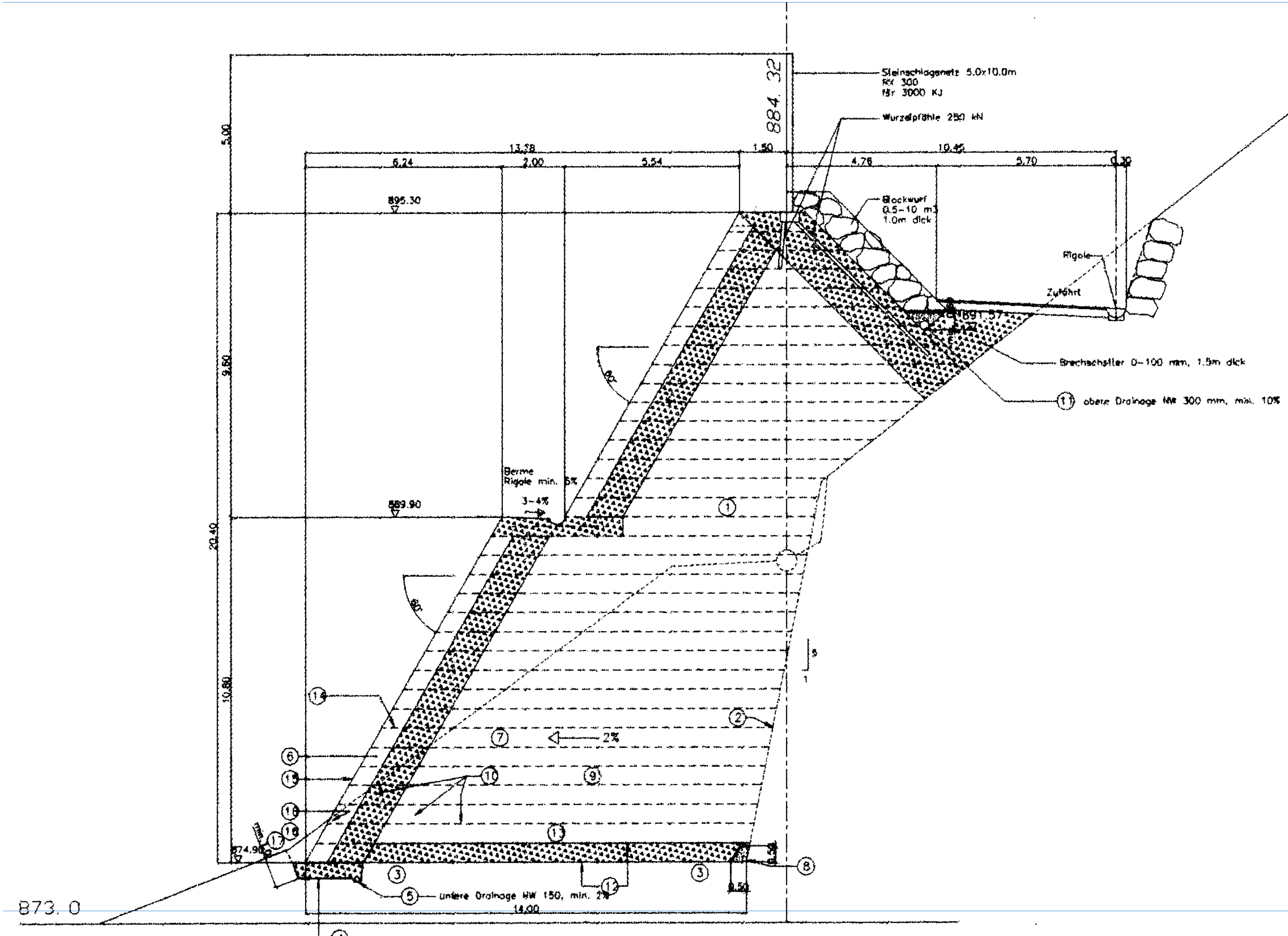
before

after

High Risks for Rockfall



Q2 = 1466.00 kPa.



Steinschlagnetz 5.0x10.0m
RX 300
für 3000 KJ
Wurzelpfähle 250 kN
884.32
13.78
6.24
2.00
5.54
1.50
10.45
4.76
5.70
0.30
5.00
895.30
Blockwurf
0.5–10 m3
1.0m dick
Rigole
Zufahrt
891.57
Brechschotter 0–100 mm, 1.5m dick
obere Drainage NW 300 mm, min. 10%
9.60
Berme
Rigole min. 5%
3–4%
889.90
20.40
10.80
2%
874.90
unlere Drainage NW 150, min. 2%
14.00
0.50
873.0

Properly tested values,

Good engineered design

=

safe structures
with geosynthetics