SUPPORT STRATEGIES FOR TUNNELS IN WEAK GROUND AND HIGH OVERBURDEN

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INTRODUCTION

- Tunnelling in poor and faulted ground with high overburden frequently leads to damages in conventional supports
- This often is referred to as „squeezing“
- Definition of this term is difficult, as it is always related to type and quantity of support

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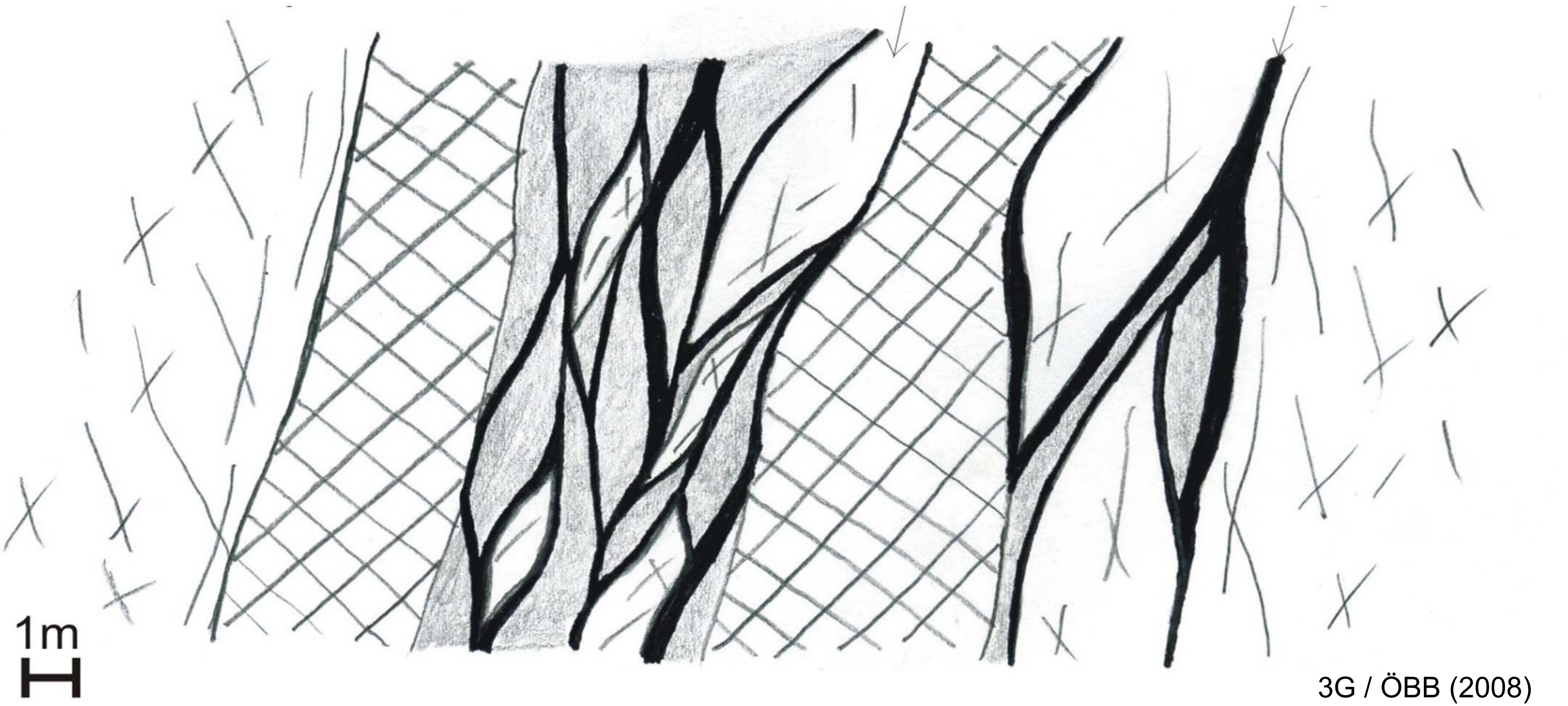
TYPICAL DAMAGES

TYPICAL STRUCTURE OF FAULT ZONES

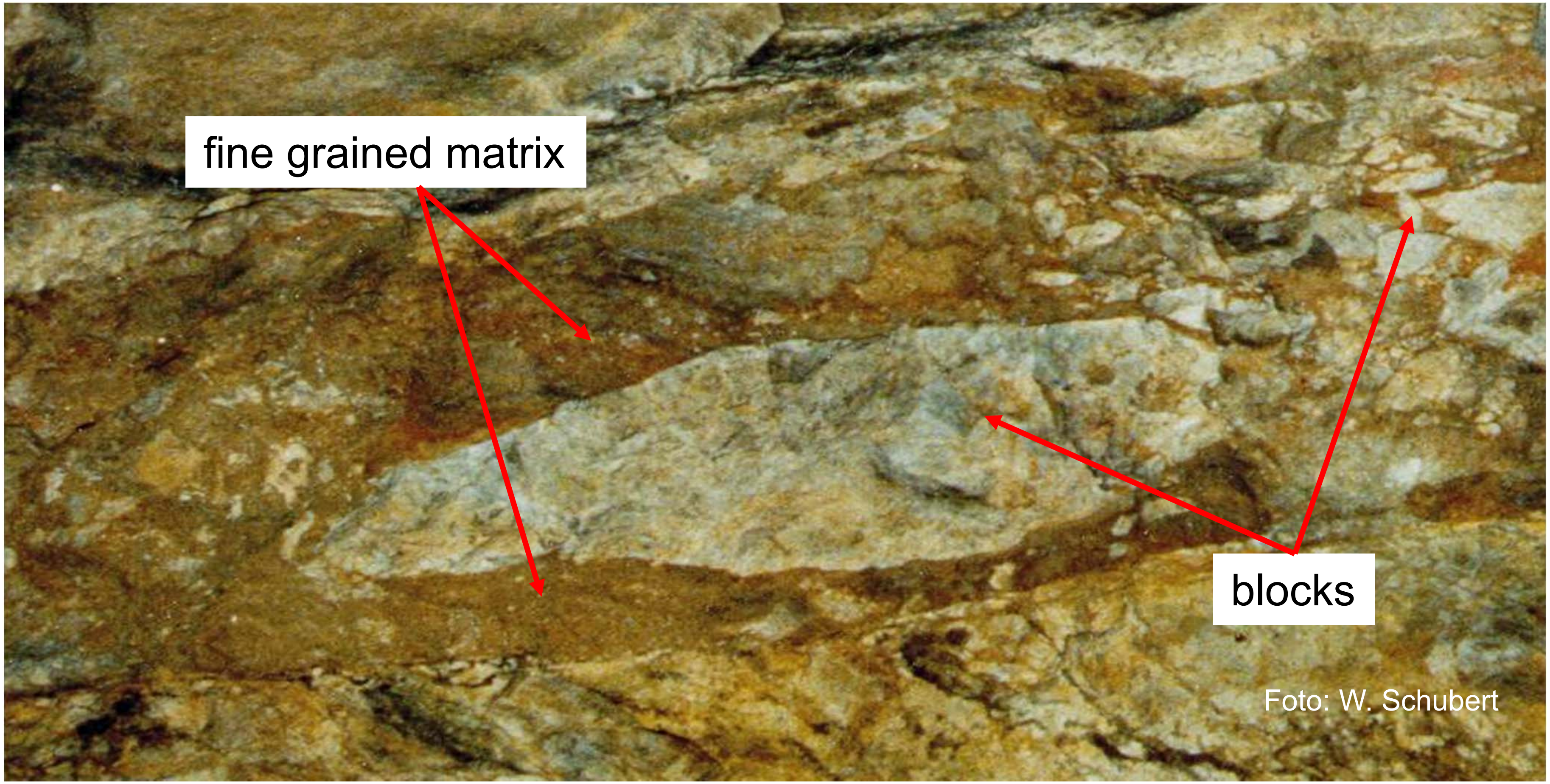
- Fault zones usually very heterogeneous, blocks and matrix, internal slickensides



3G / ÖBB (2008)

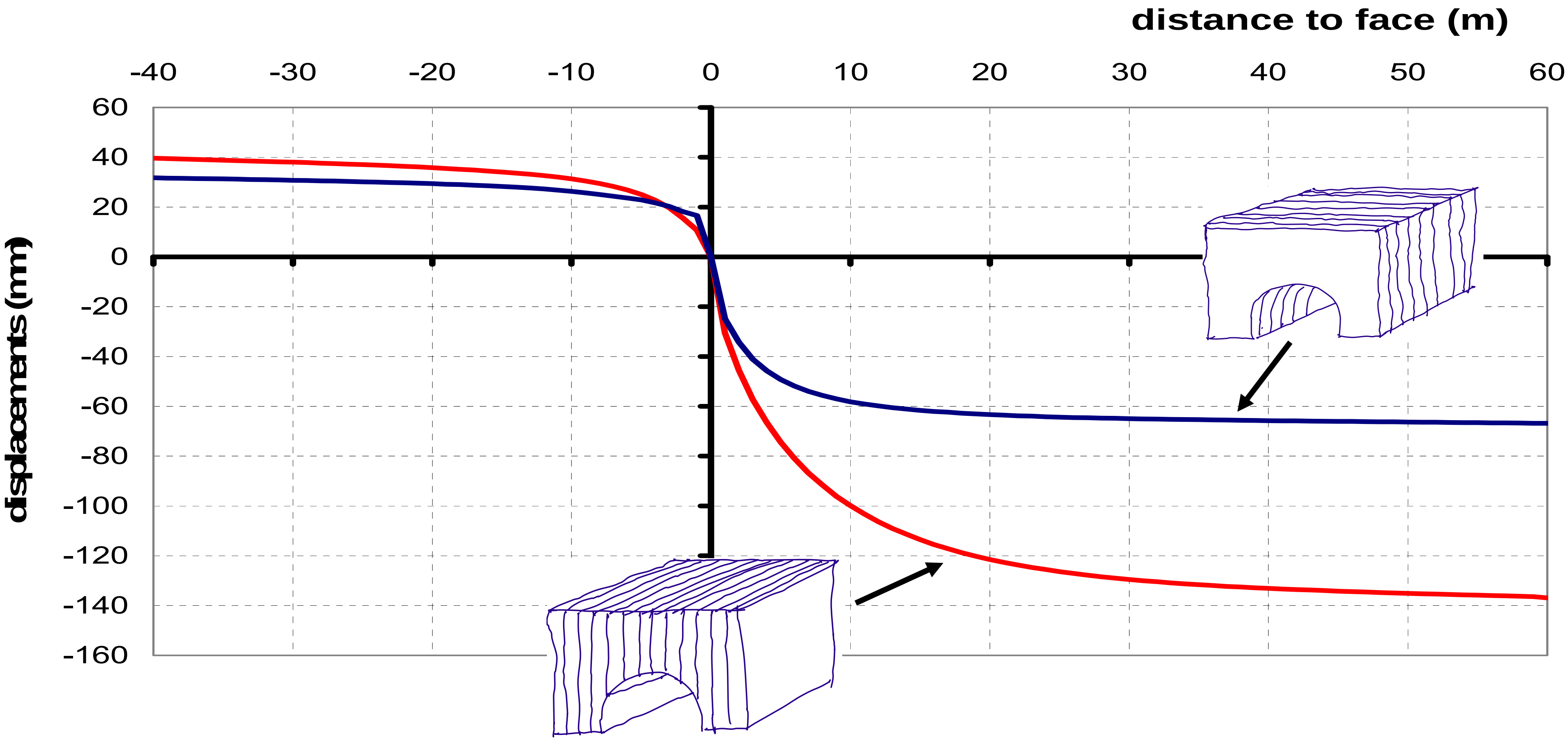
STRUCTURE OF FAULT ZONES

- Structure independent of size



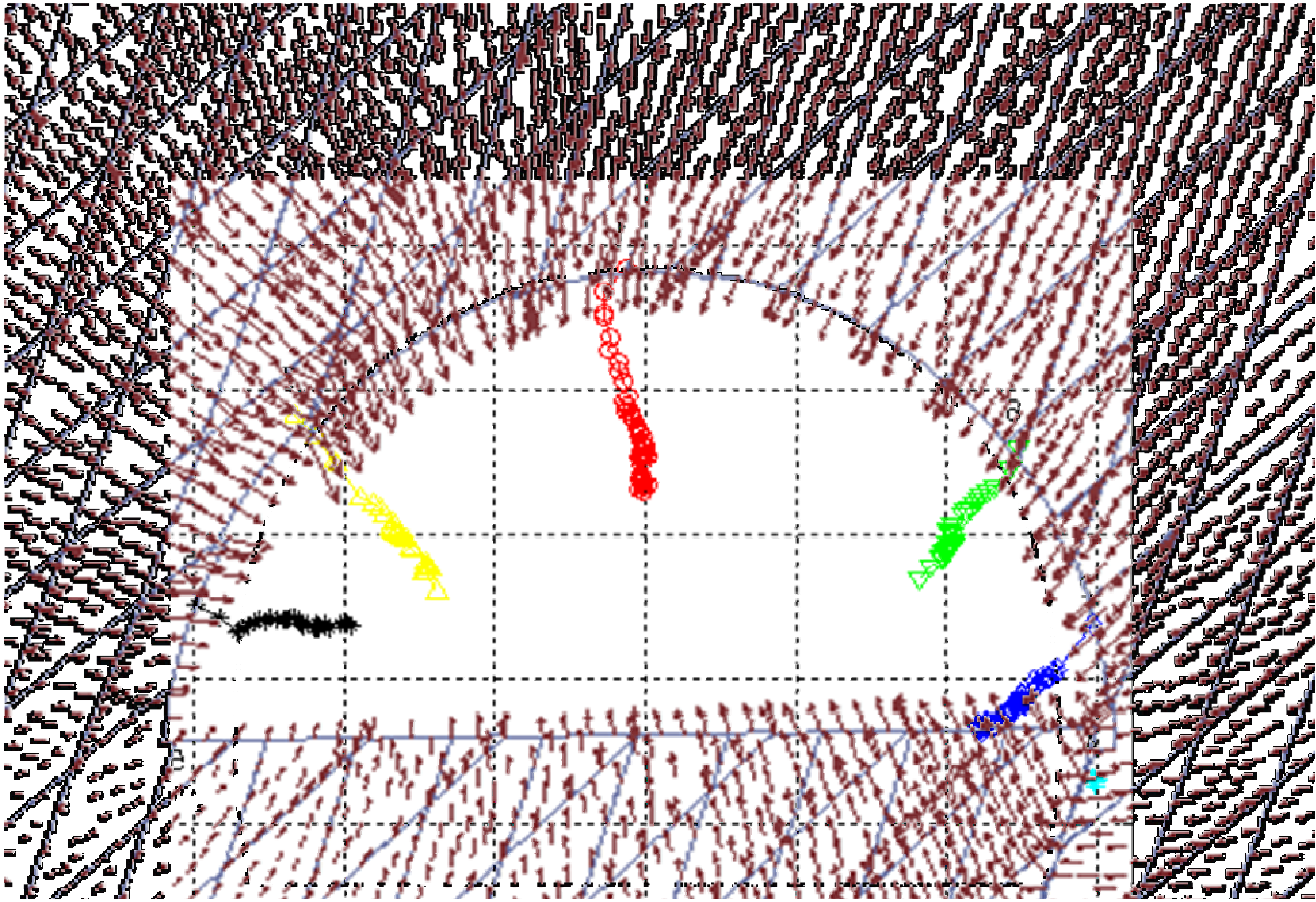
FOLIATED ROCK MASSES

- In foliated rock masses orientation between foliation and tunnel axis dominates mechanism and thus displacements



INFLUENCE OF DISCONTINUITIES

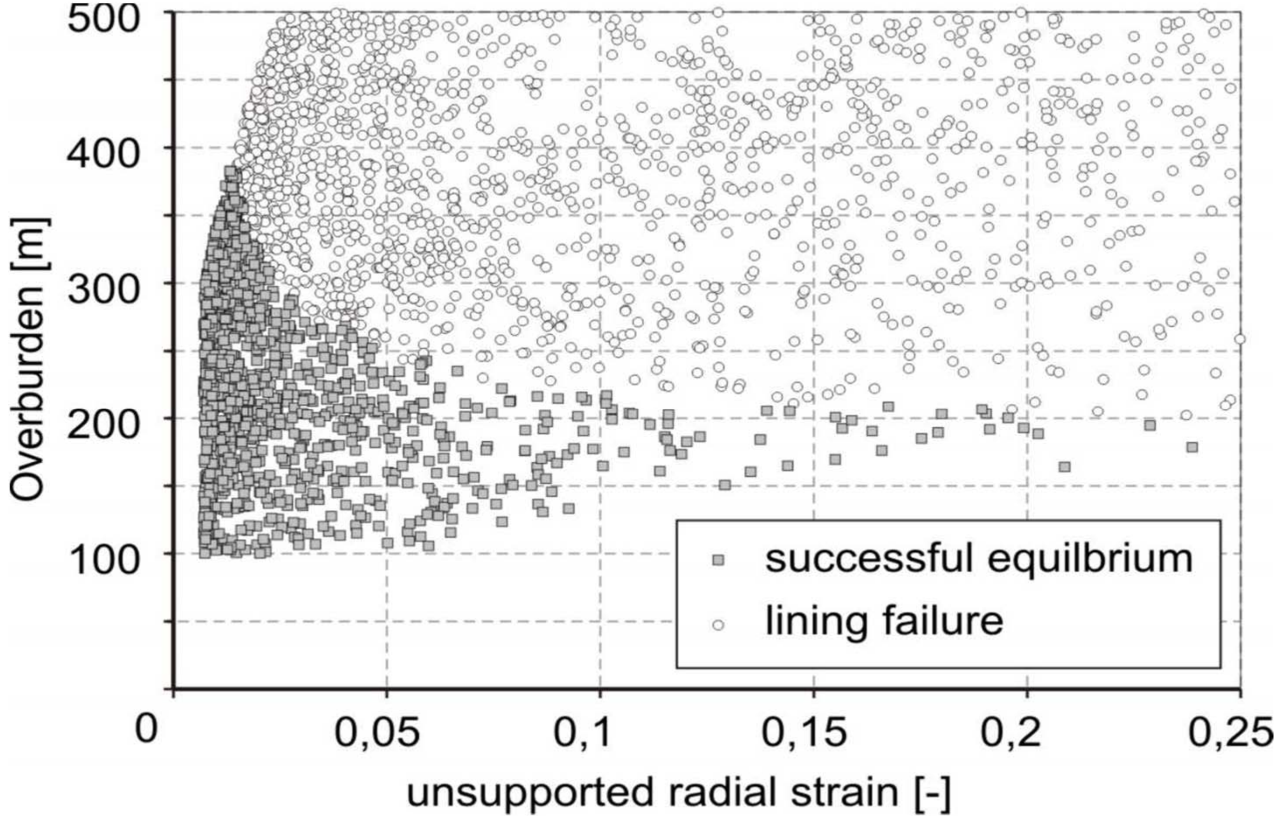
- Shearing along and opening perpendicular to discontinuities can cause stronly anisotropic displacements



DEFINITION OF „SQUEEZING“

- Using standard shotcrete support, reasonable range of ground parameters, and running a Monte Carlo simulation, Radocnic determined a critical oberburden for closed linings
- This relation can be used for a first assessment, if closed lining is feasible
- In case the critical overburden is exceeded, type of lining should be changed to ductile system

CRITICAL OVERBURDEN



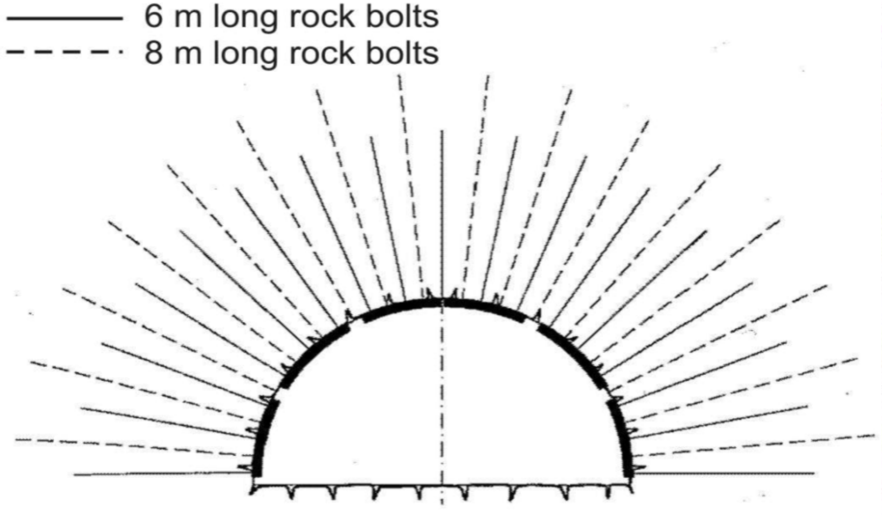
$$H_{crit} = (H_0 + H^* \tan\varphi) - 75 \cdot \left[1 - \left(\frac{X}{X + \varepsilon - \varepsilon_0}\right)^2\right]$$

ε …. total strain of unsupported tunnel

	X [-]	ε_0 [-]	H_0 [m]	H^* [m]
Full-face excavation	0.062	0.035	100	680
Top heading	0.062	0.045	100	680
Top heading w. Invert	0.030	0.030	75	375

PAST PRACTICE

- Open slots, dense bolting
- Disadvantage: support resistance low, stability relying on bolting



Inntaltunnel

TRADITIONAL SYSTEM

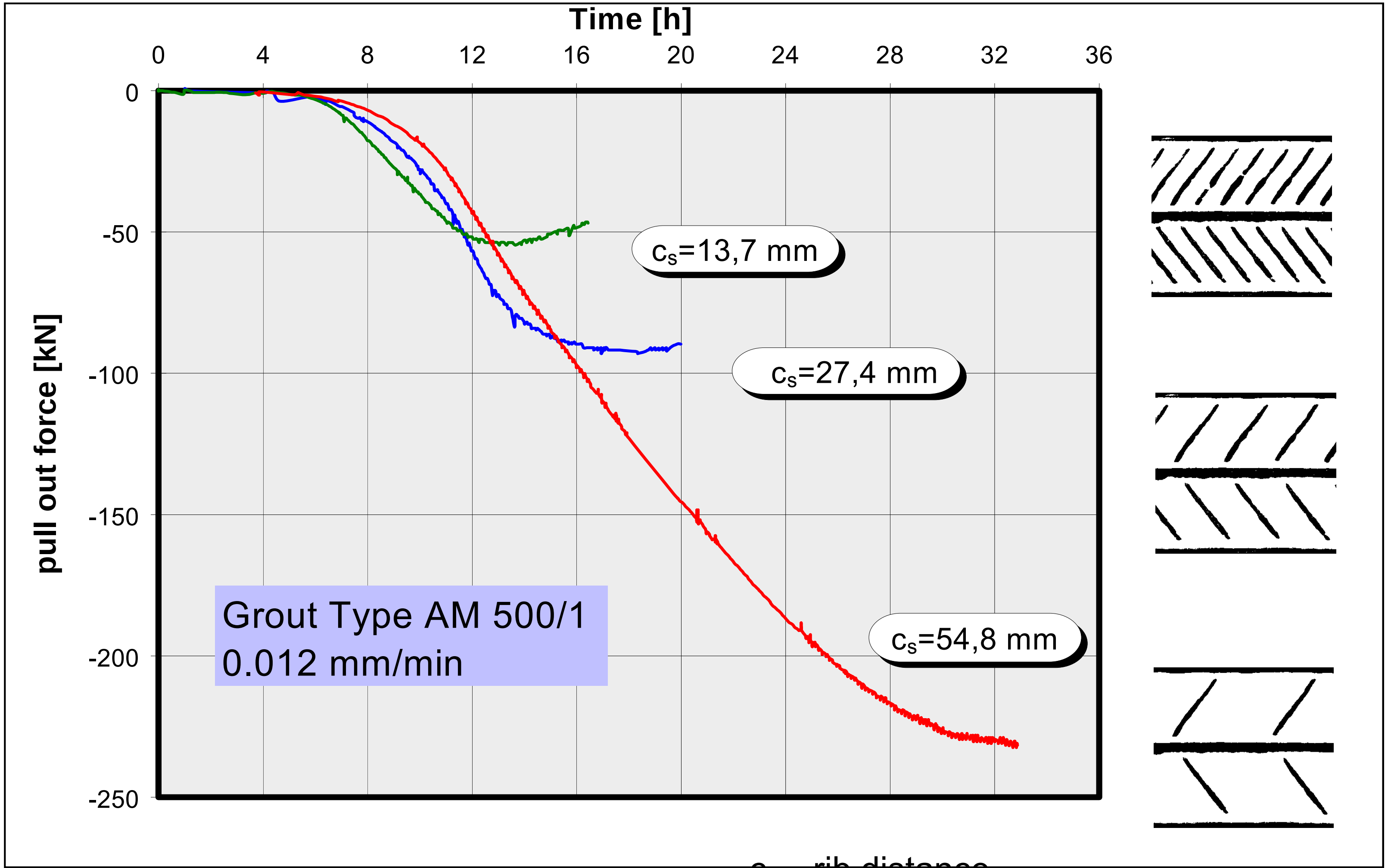
- Problem in strongly heterogeneous fault zones; brittle failure of blocks may occur

Galgenbergtunnel

BOLTS + OPEN SLOTS

- Due to large strains between bolt, grout and rock mass fresh grout can be sheared off
- Low capacity of bolts is the result
- Investigation showed that rib geometry has significant influence on bolt performance (Blümel, 1996)

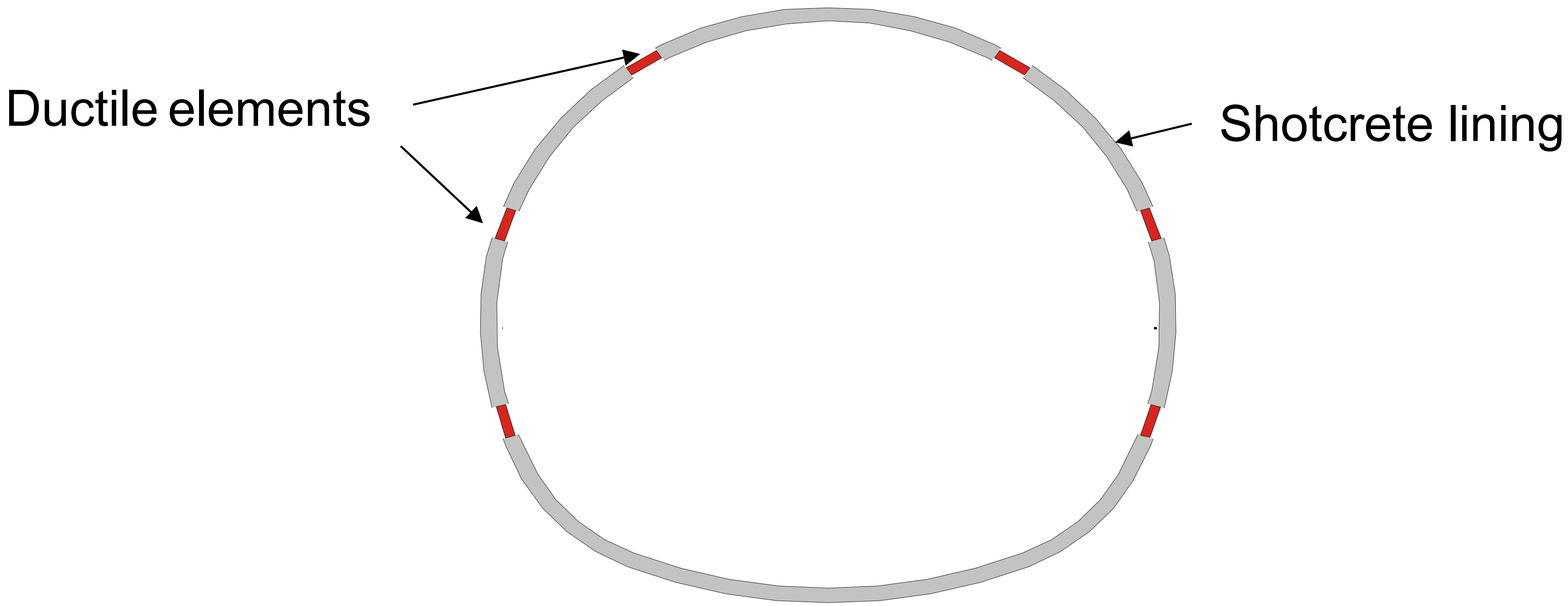
INFLUENCE OF RIB GEOMETRY



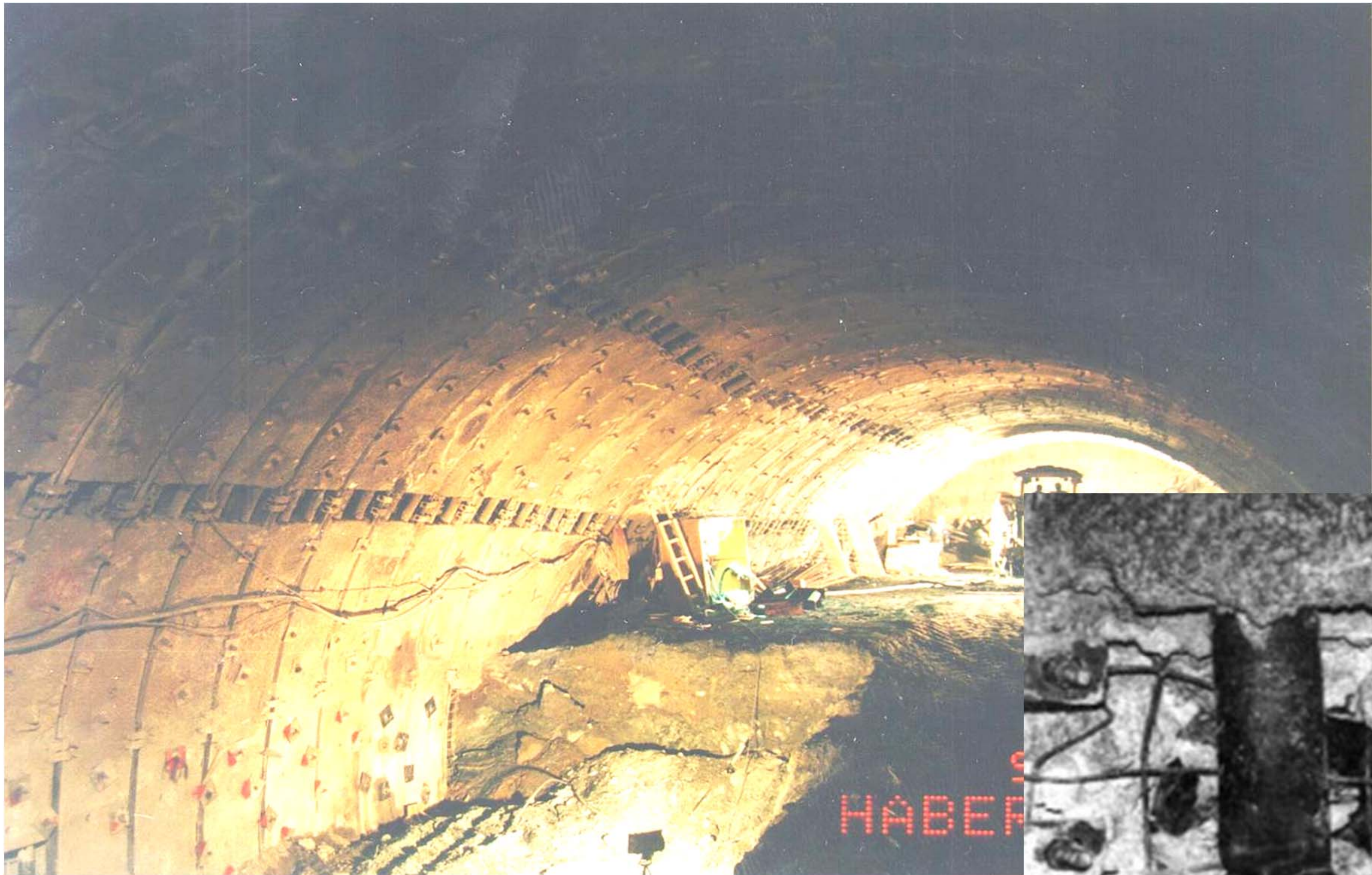
c_s…rib distance

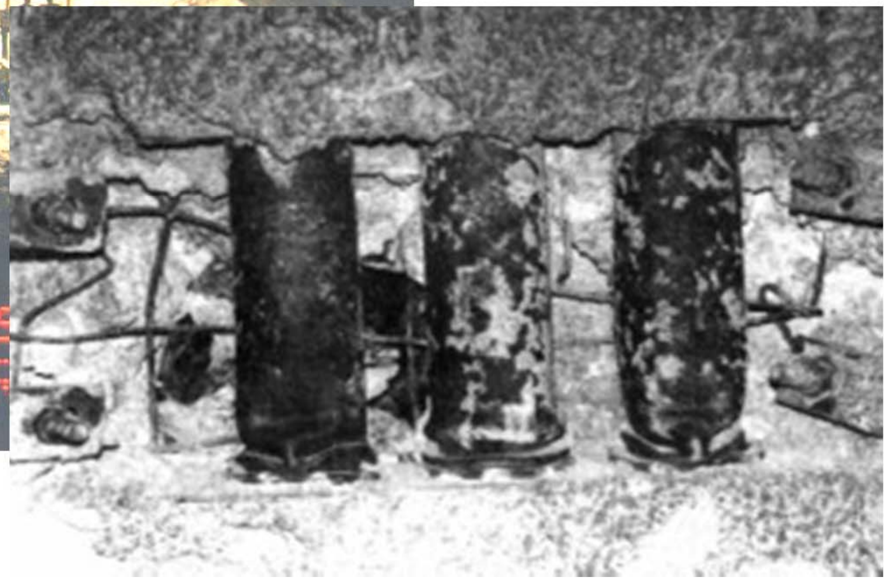
DUCTILE LINING

- Elements, which control the load in the lining
- Requirements:
  - In combination with shotcrete linings low initial resistance
  - Controlled increase of resistance with further deformation
  - Adjustable to a wide range of conditions



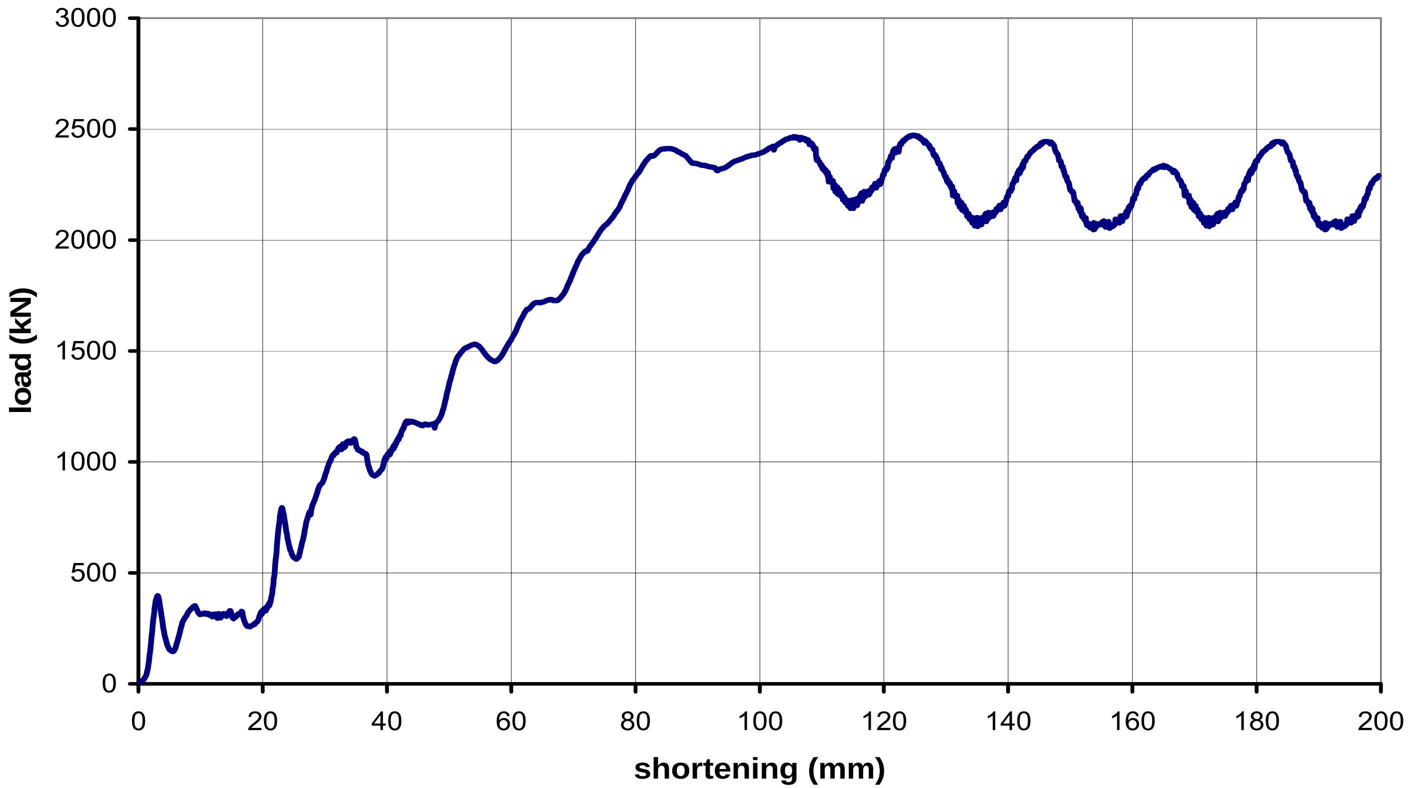
LSC YIELDING ELEMENTS, 1st generation





Galgenbergtunnel

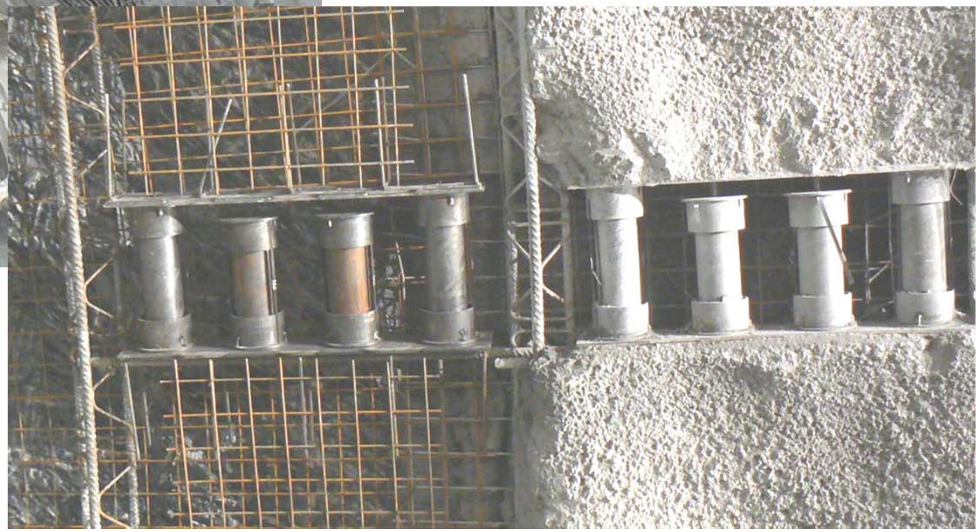
LSC YIELDING ELEMENTS, 2nd generation



Load line for group of 4 elements

APPLICATION OF DUCTILE LINING

Tauerntunnel

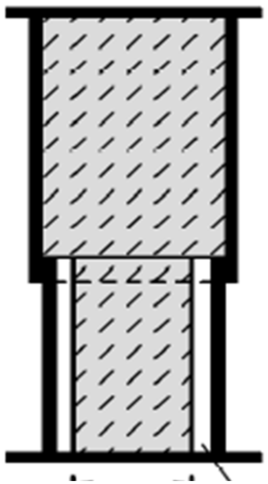


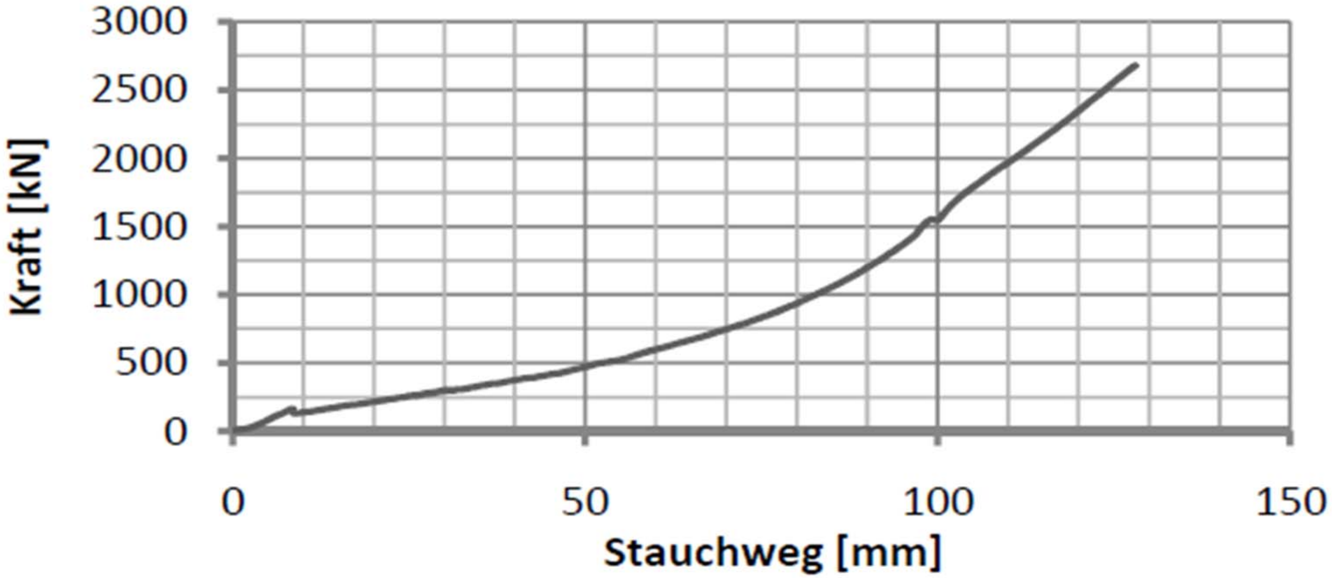
BENEFITS

- Compared to open linings, displacement reduced by at least 50%
- Increased safety
- Less disturbance of rock mass

LSC YIELDING ELEMENTS, 3rd generation

- Combination of steel cylinders and porous filling allows:
  - Cheaper production
  - Higher energy absorption
  - More flexibility by variation of steel pipe dimensions and filler properties





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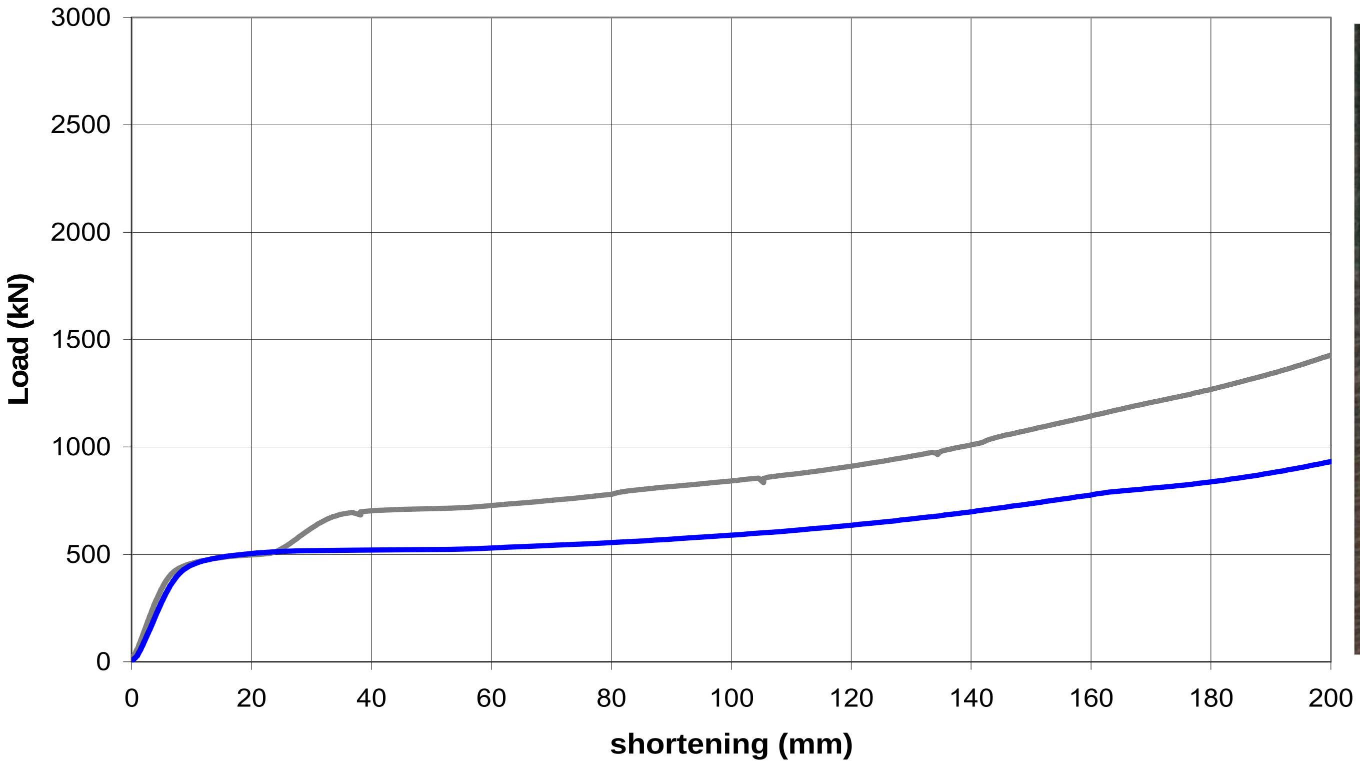
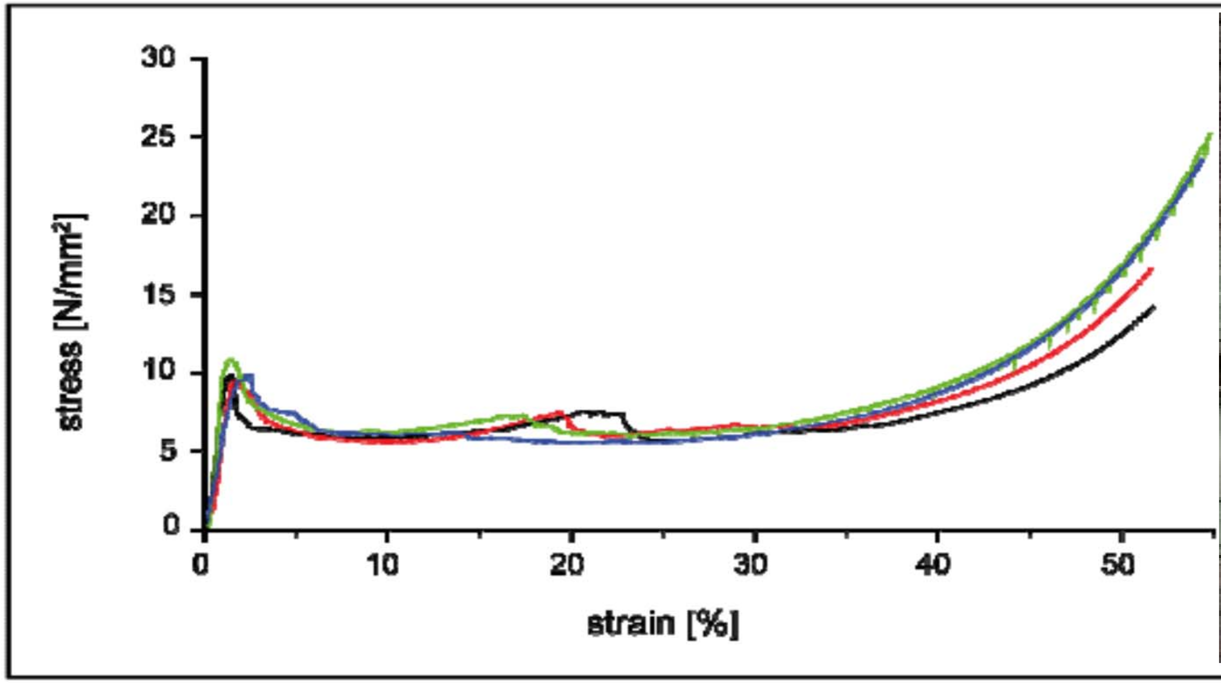
System WABE

- Poor performance, low energy consumption



hiDCon

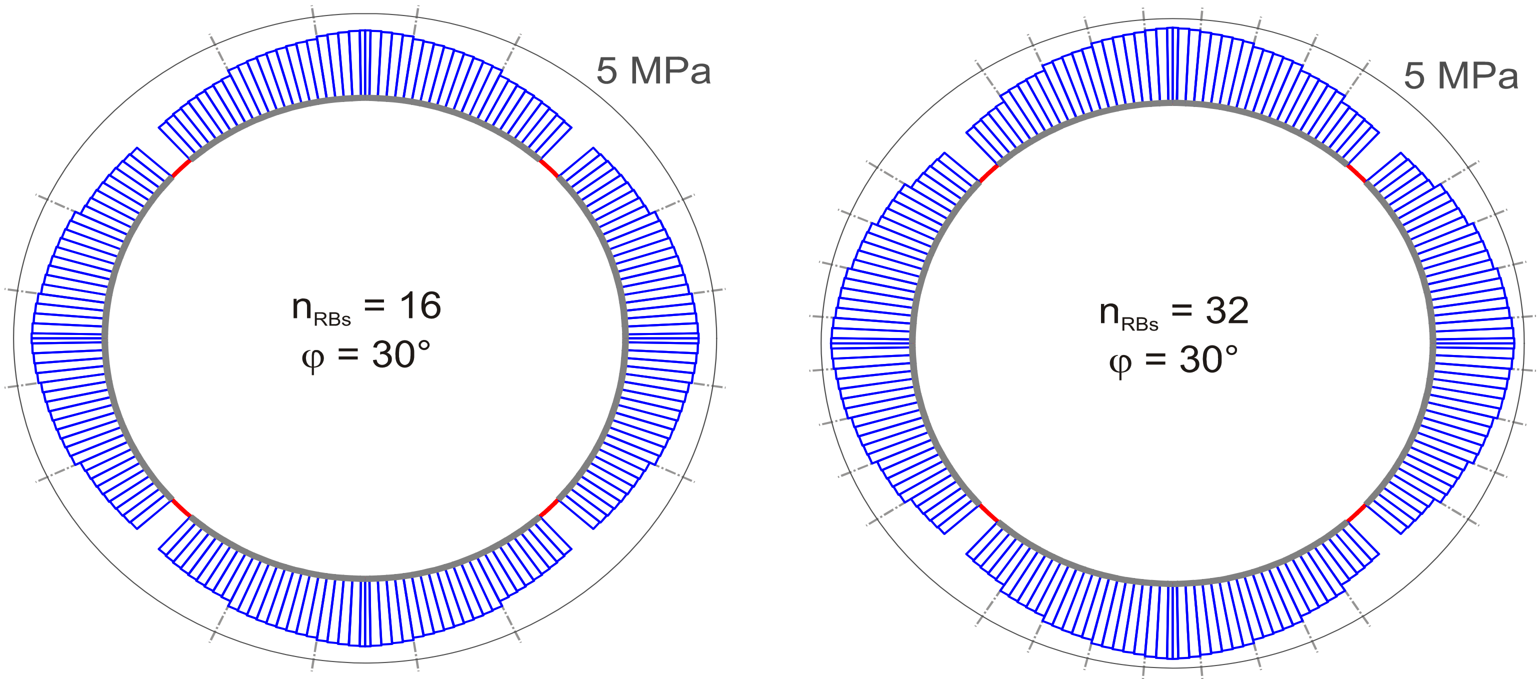
- Cement based system
- High initial stiffness likely to cause damage to lining



hiDCon element
(cement with porous additives)

DISTRIBUTION OF AXIAL FORCES IN THE LINING

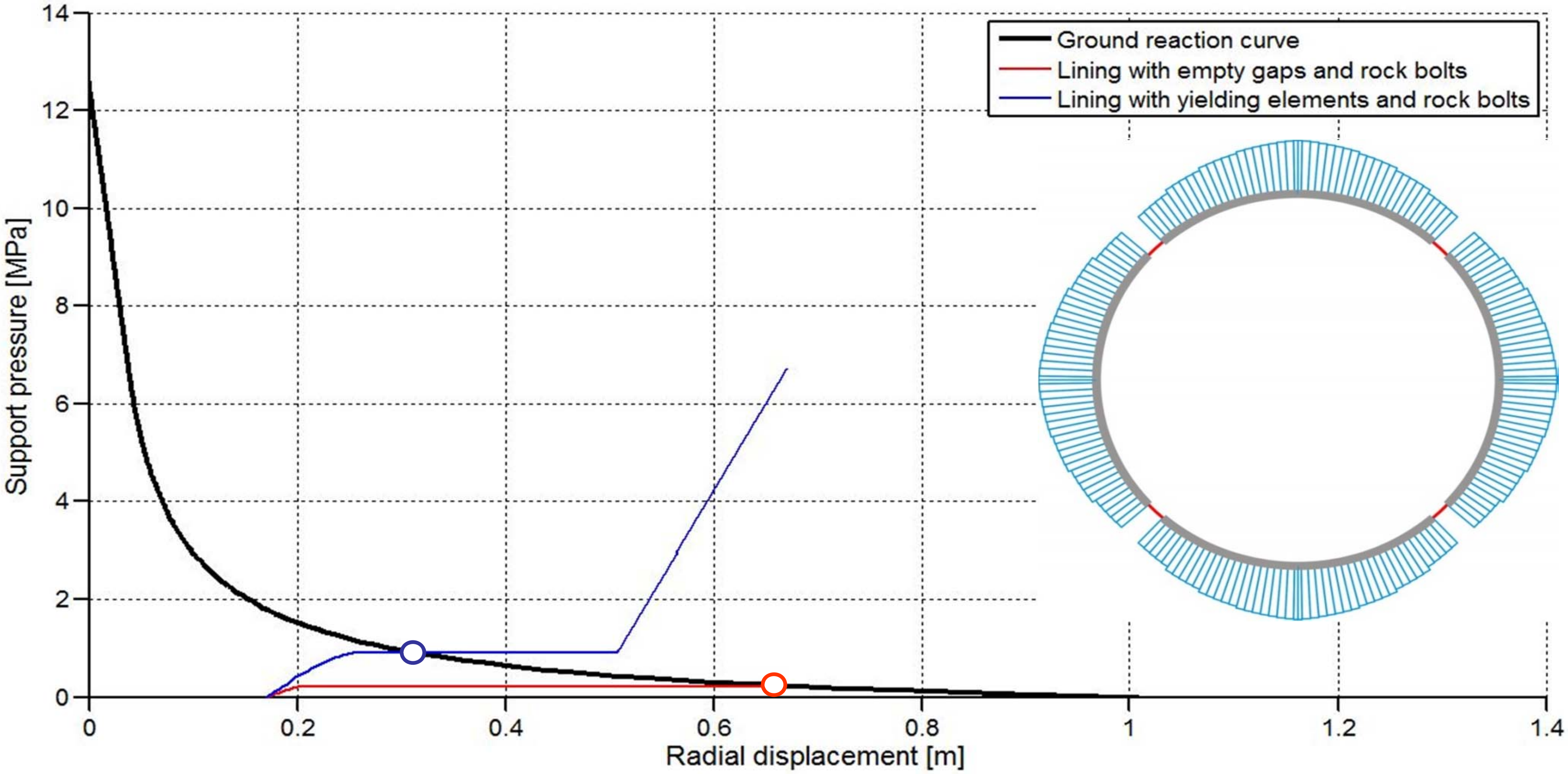
- Yielding elements limit the loads at the gaps; additional loads in the lining develop due to dowel effect of bolts and shear forces at contact linig-ground



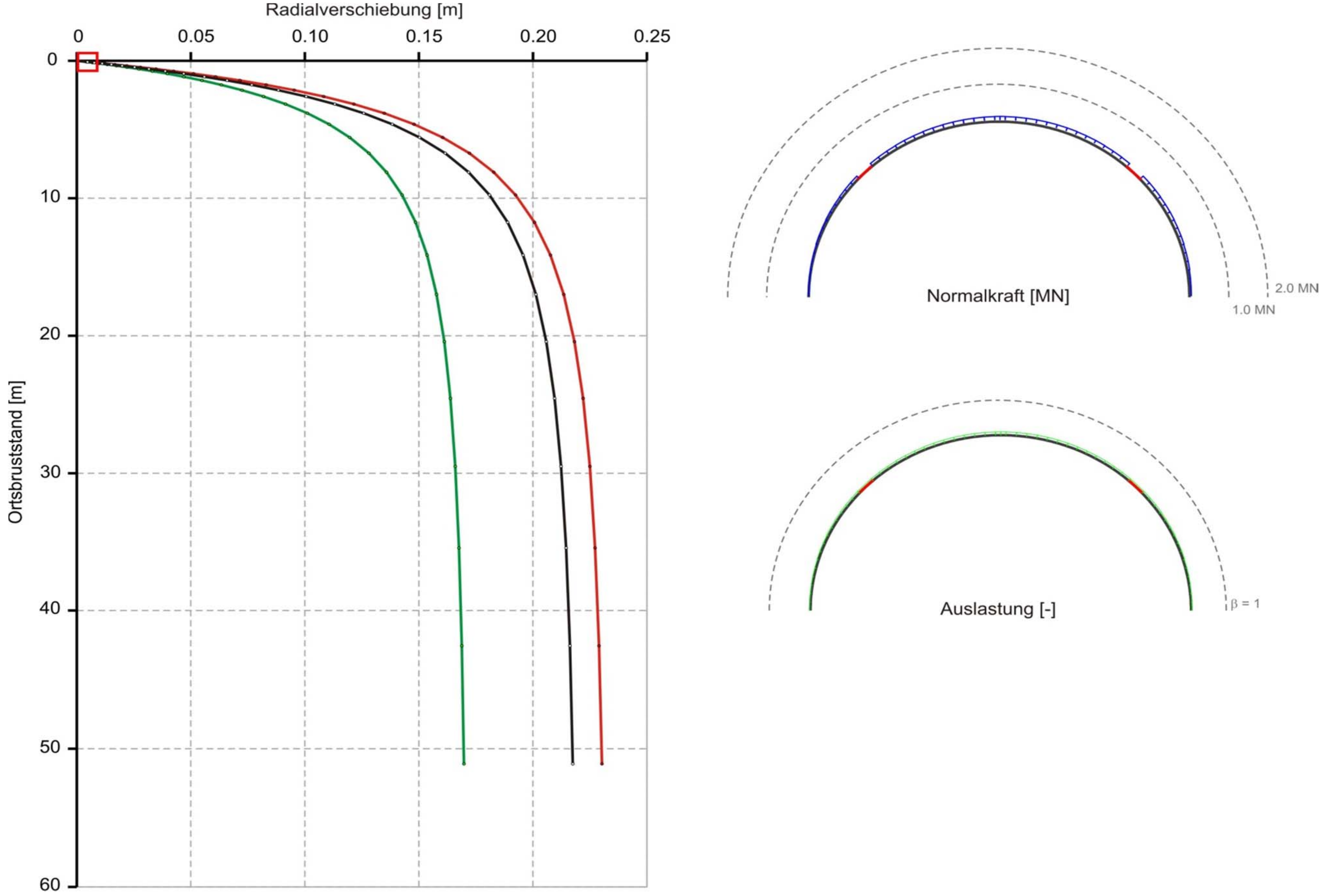
Radoncic, 2011

EFFECT OF COMBINED BOLT-LINING SYSTEM

- A relatively small increase in support pressure strongly decreases the final displacements and ground disintegration!



AXIAL LOAD AND LINING UTILIZATION



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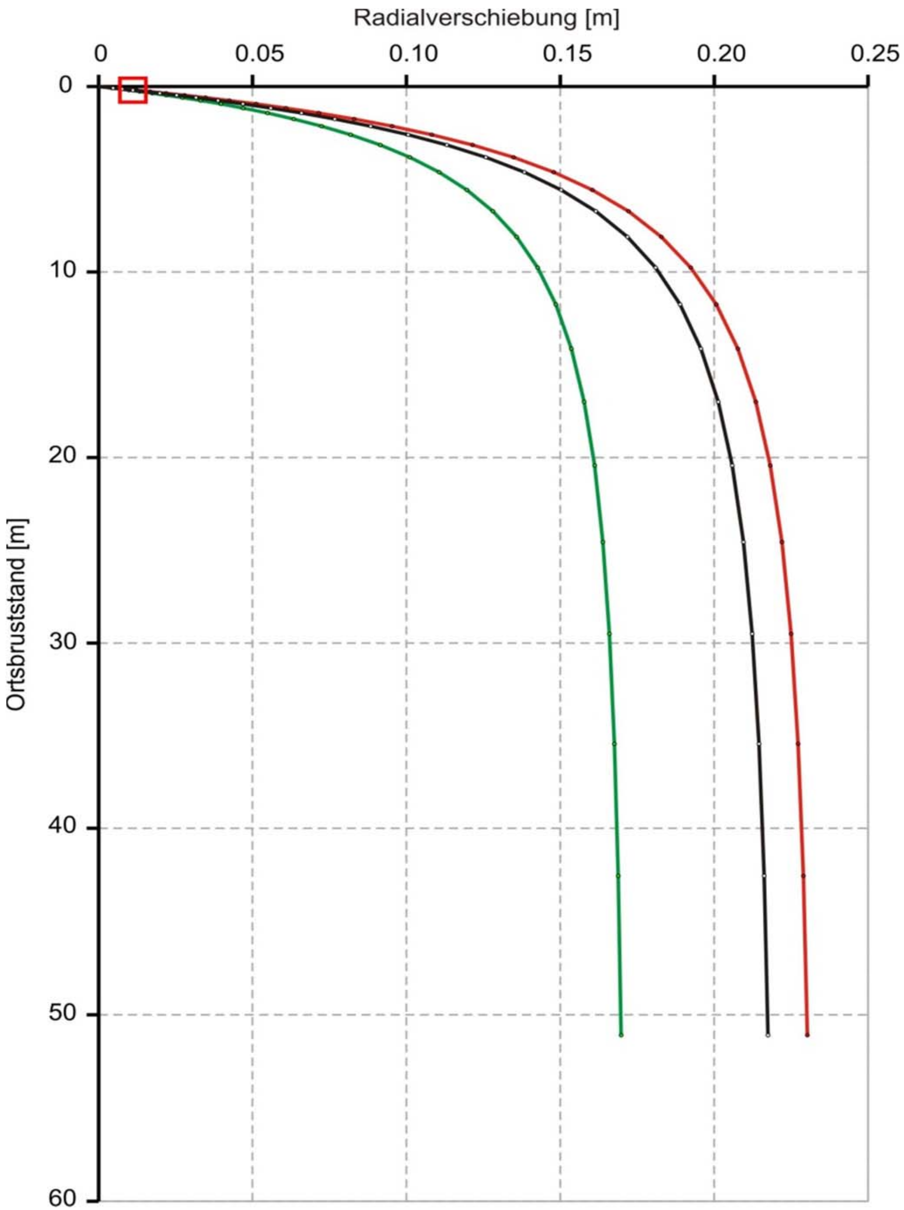

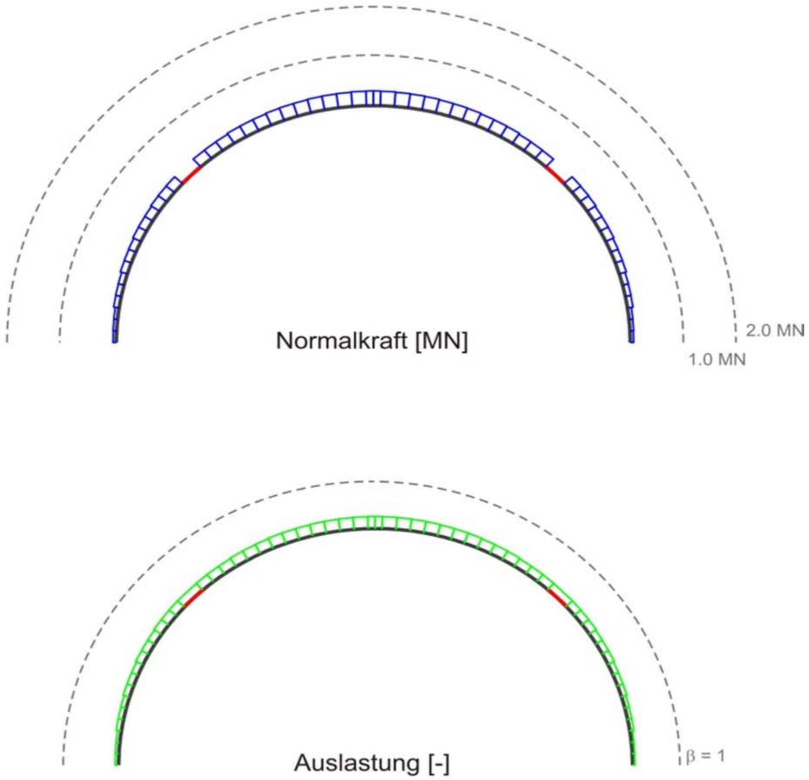

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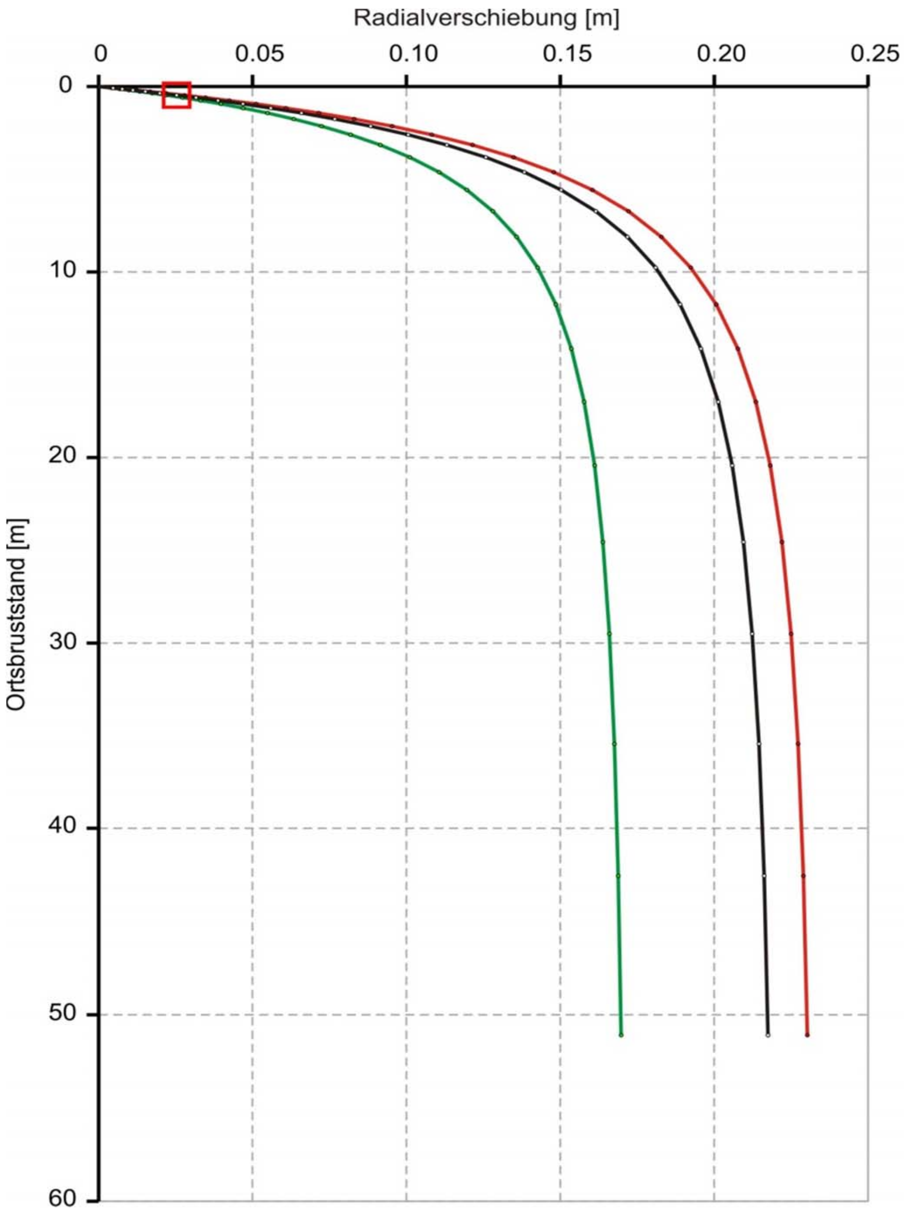

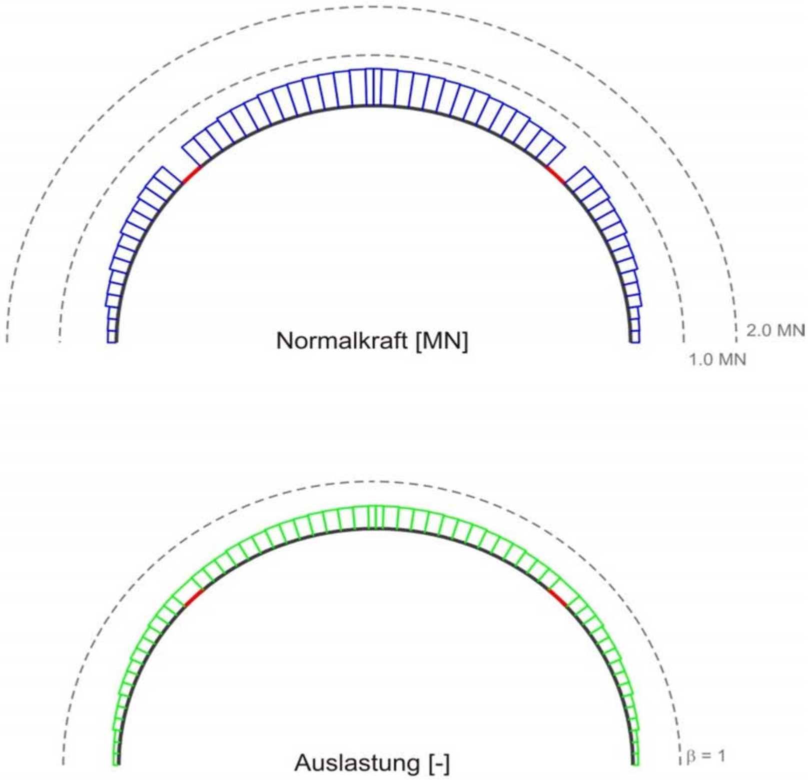

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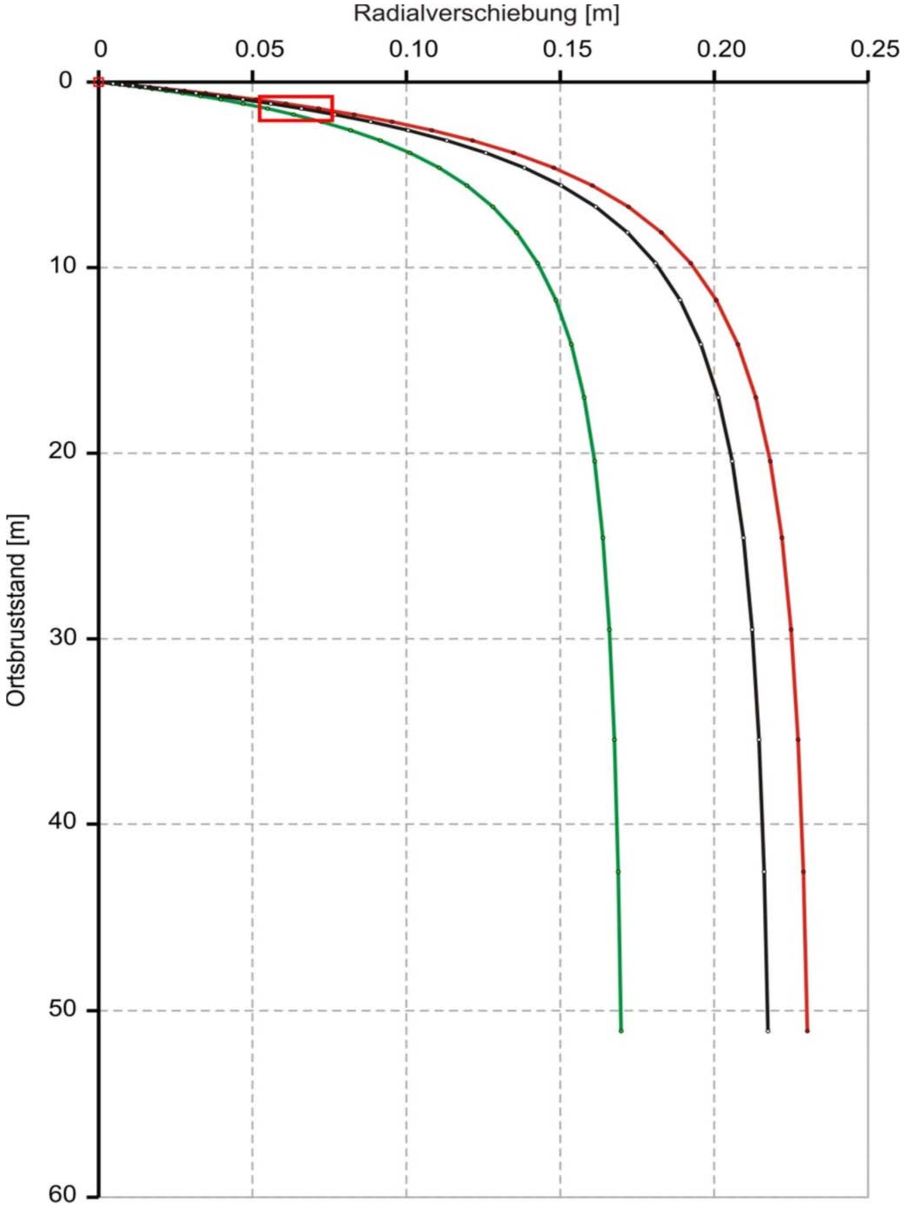

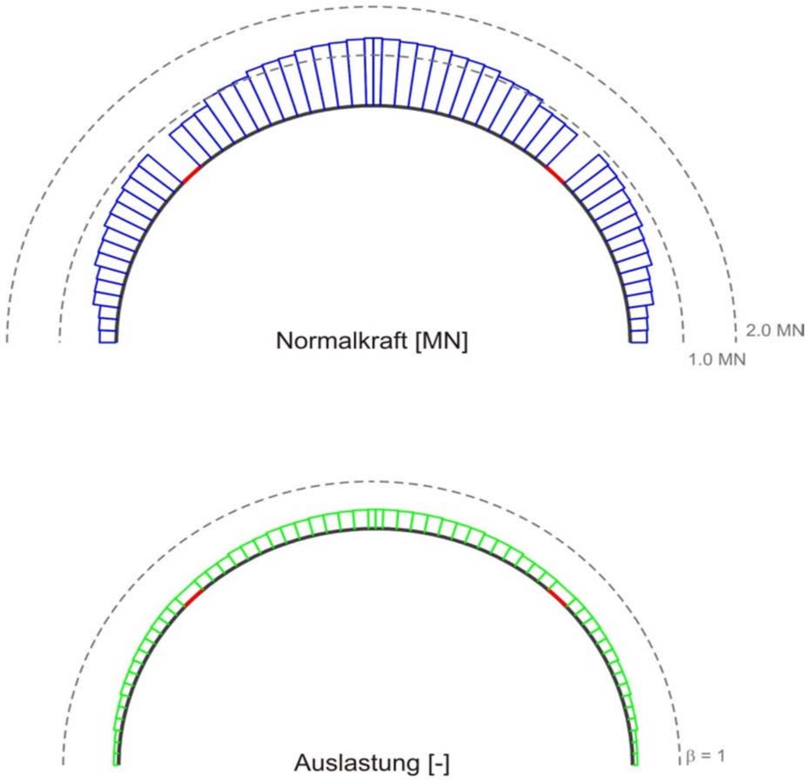

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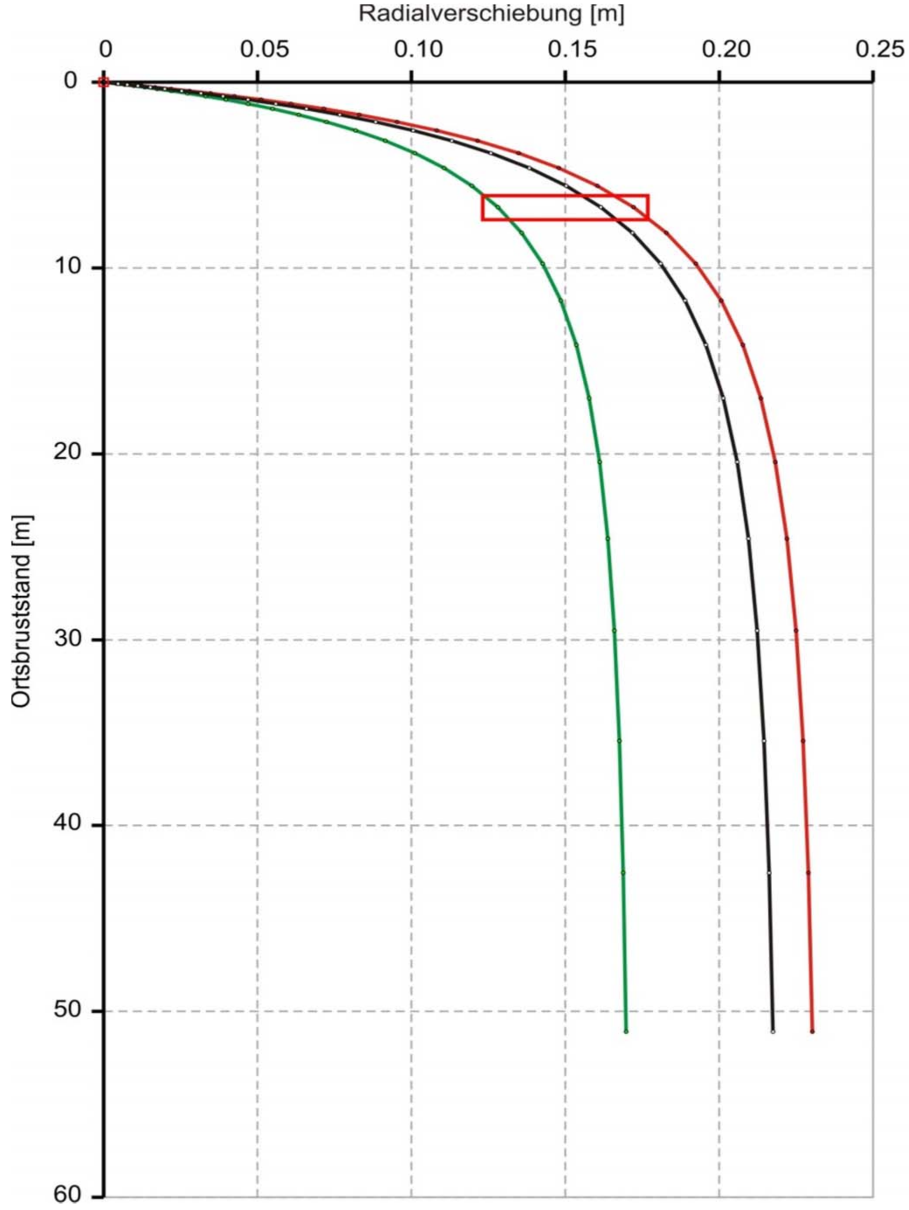

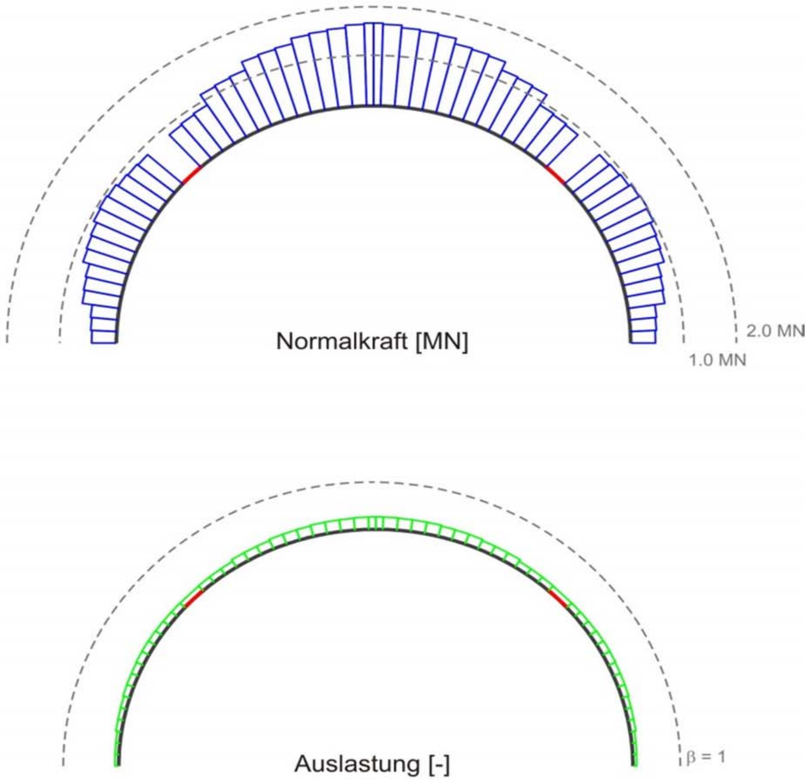

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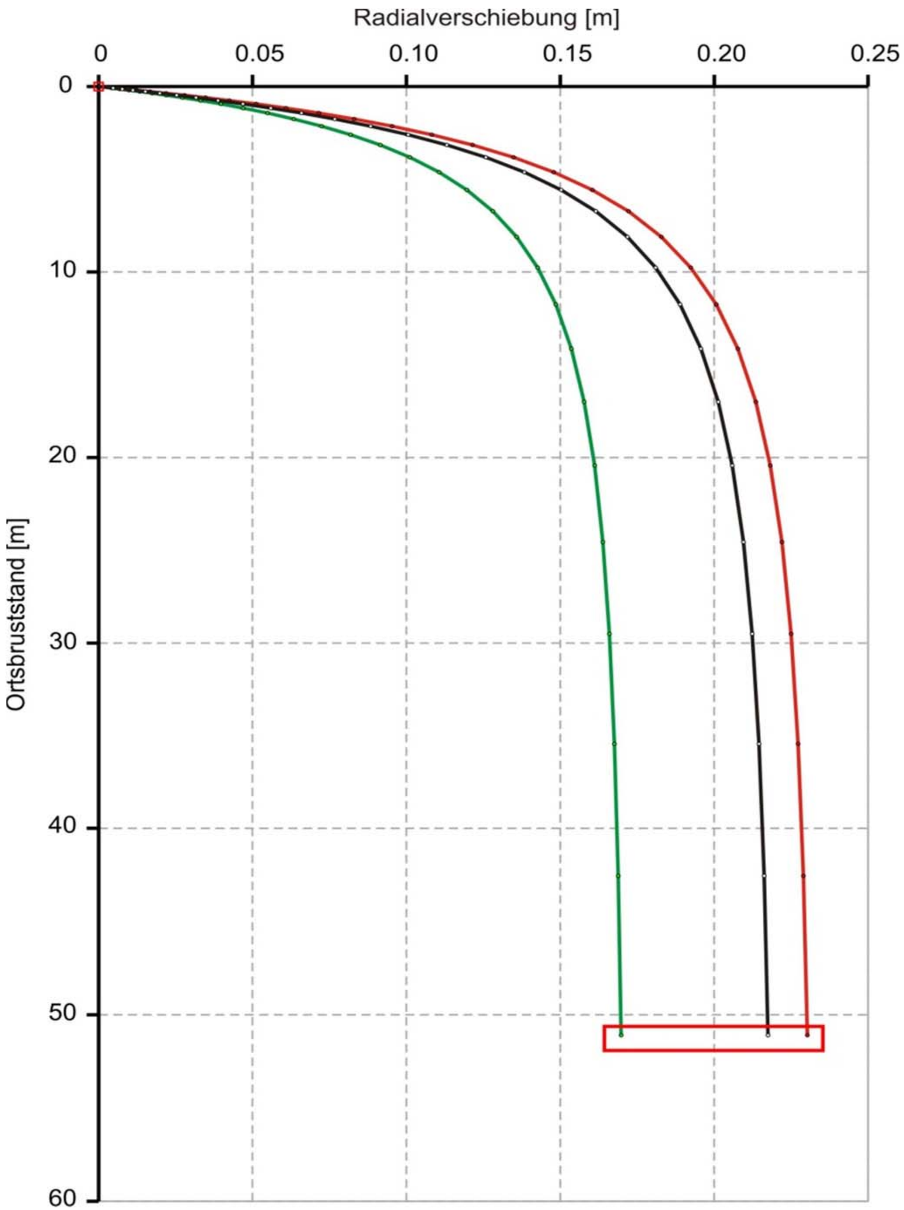

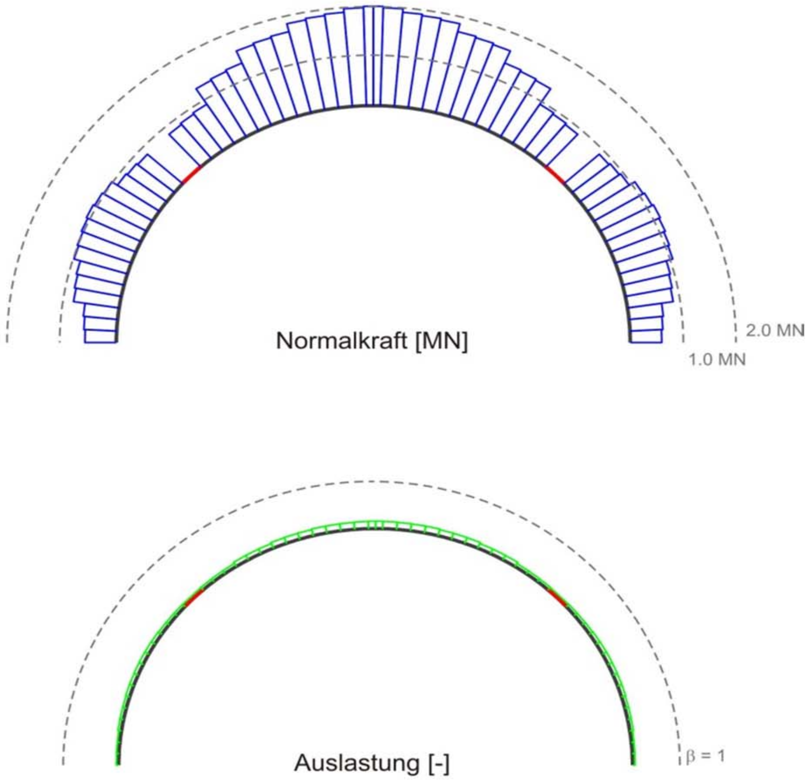

CONCLUSION

- When dealing with large displacements, linings have to be designed with great care
- It is important that lining provides controlled build up of resistance during deformation to prevent lining failure
- At the same time, lining capacity should be utilized optimally throughout the whole deformation process
- All support elements have to be compatible with developing strains