DAMAGE ANALYSIS AND LOAD CAPACITY DETERMINATION OF A HEAVILY DAMAGED INDUSTRIAL CHIMNEY

BREDDERMANN+PARTNER

Gesellschaft Beratender Ingenieure mbB

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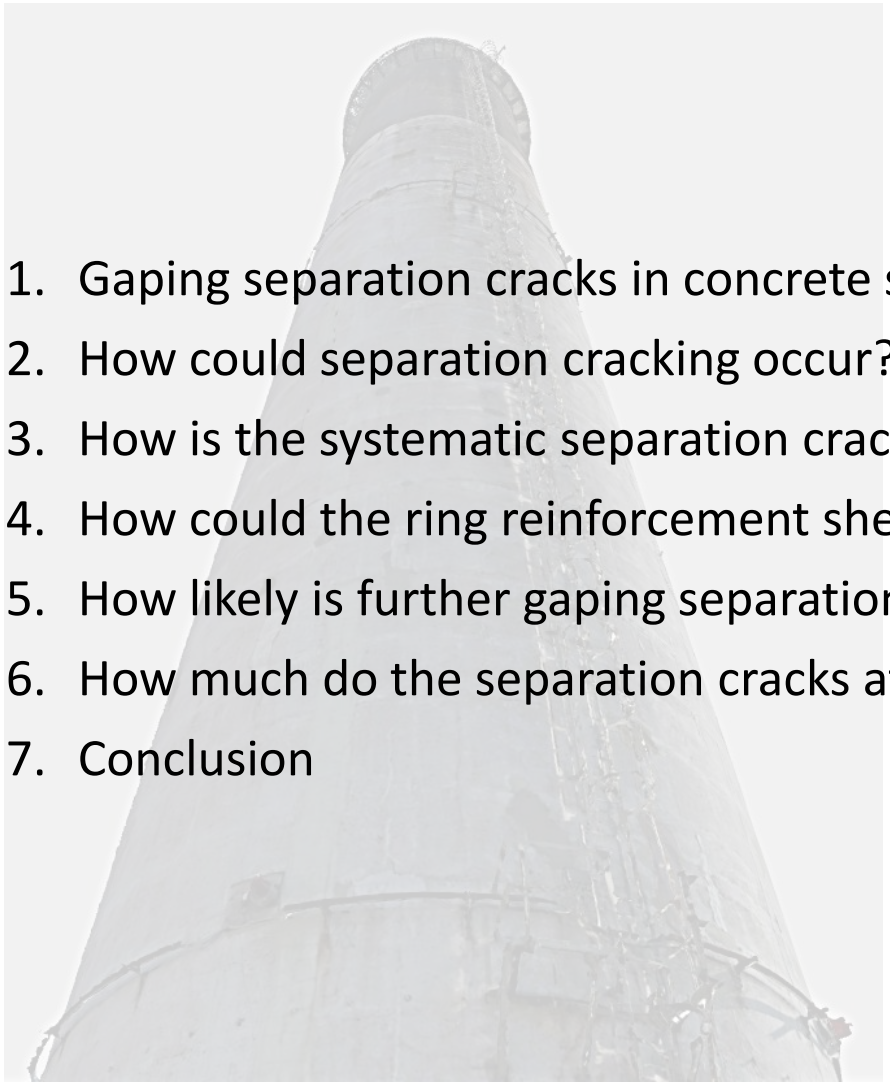
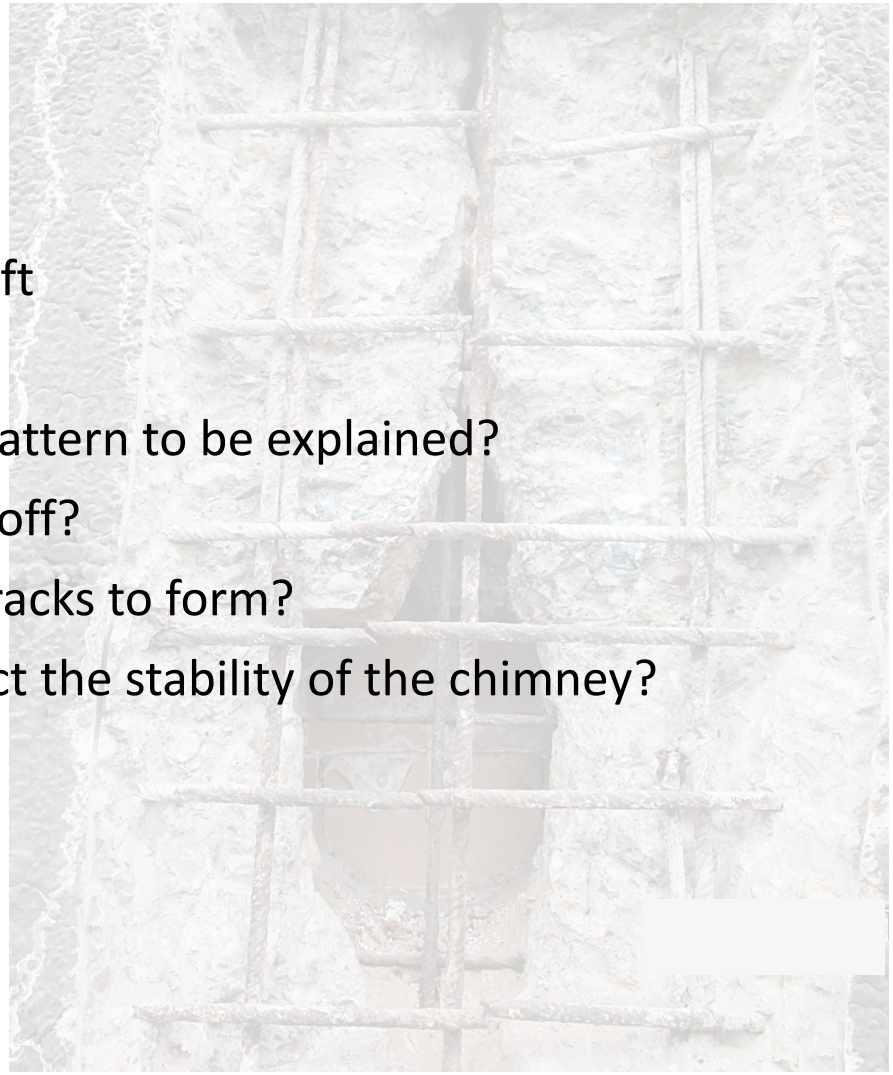
Damage Analysis and Load Capacity Determination of a Heavily Damaged Industrial Chimney





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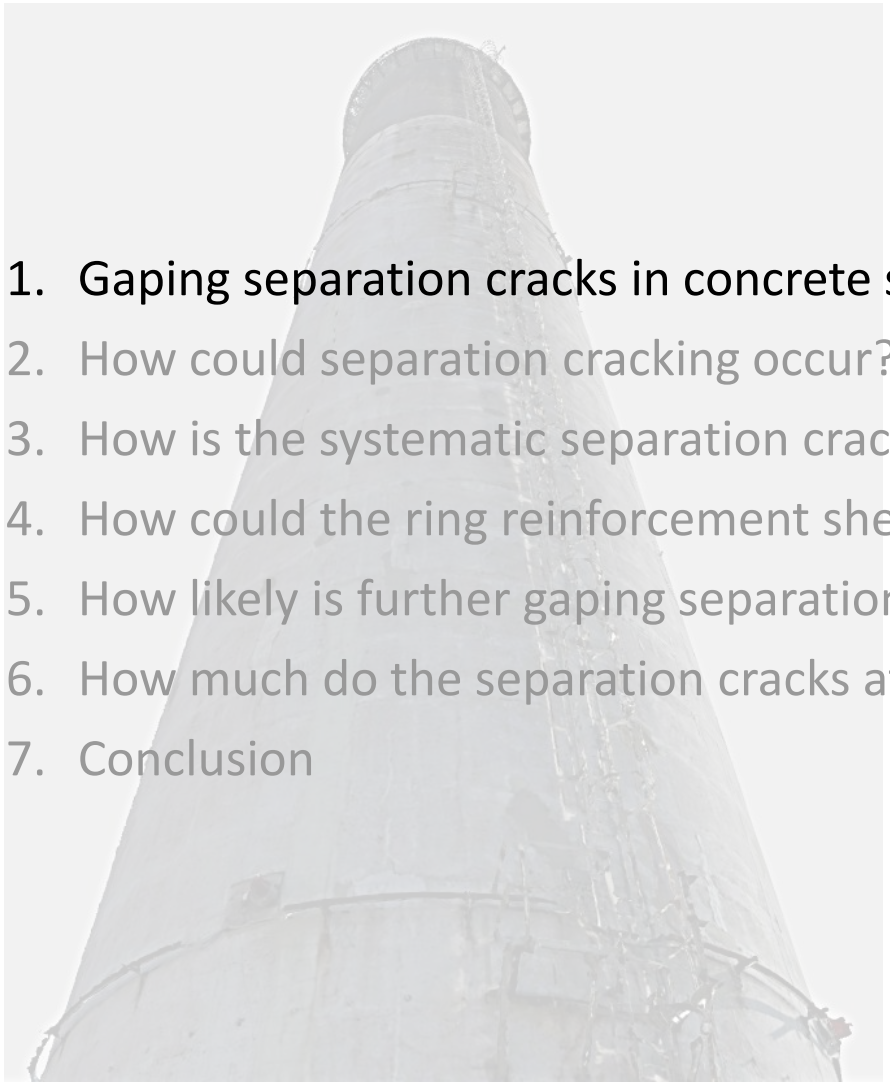

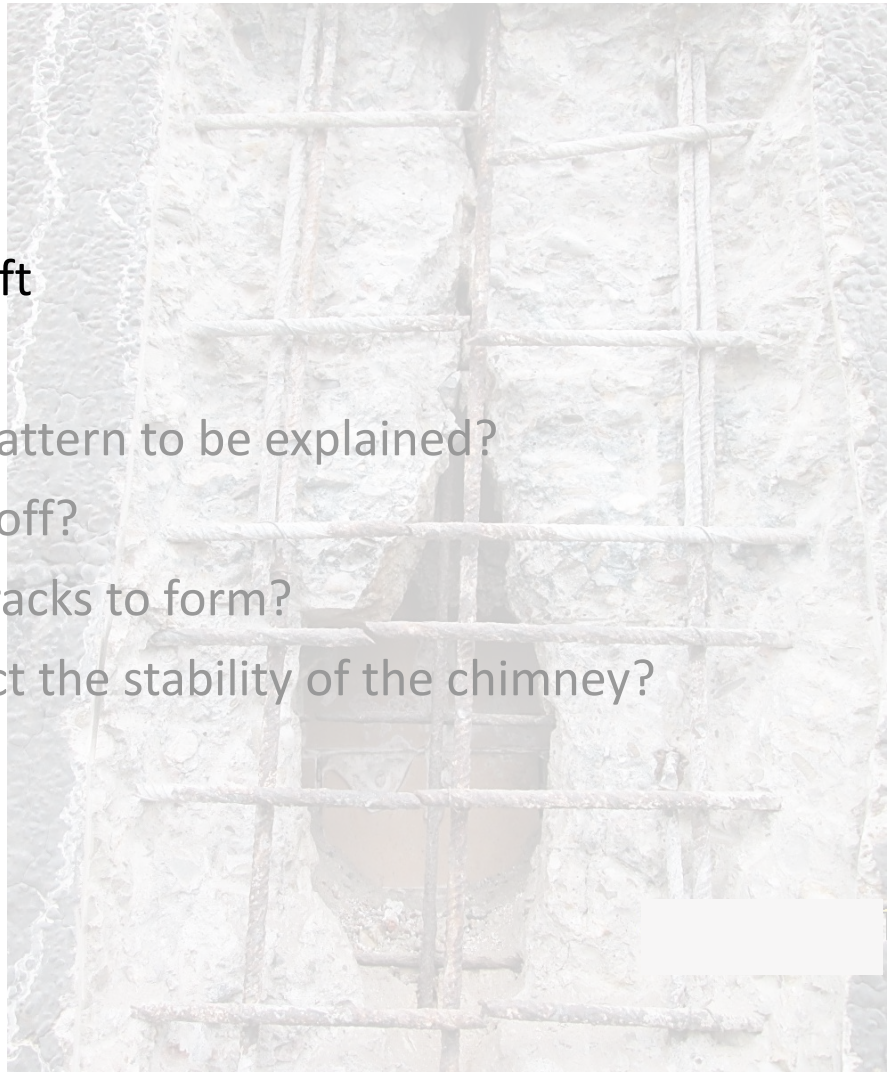

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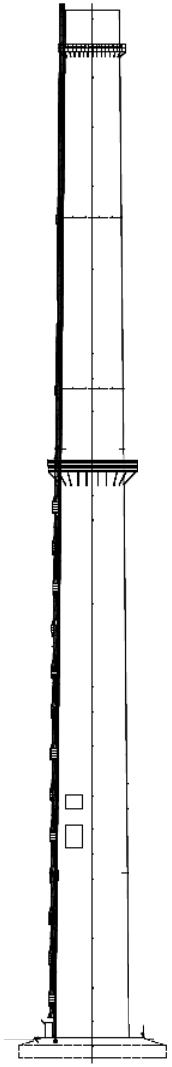

Views of the 150 m high reinforced concrete chimney

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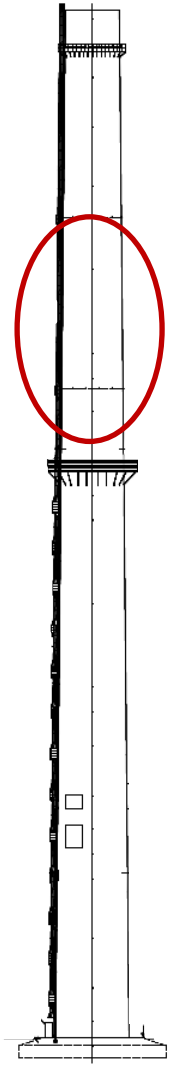

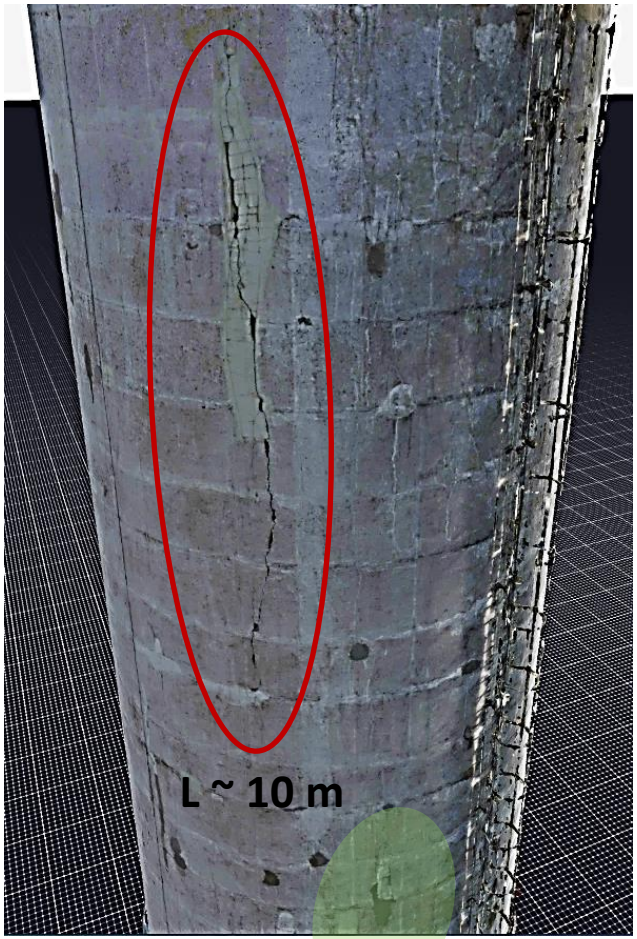

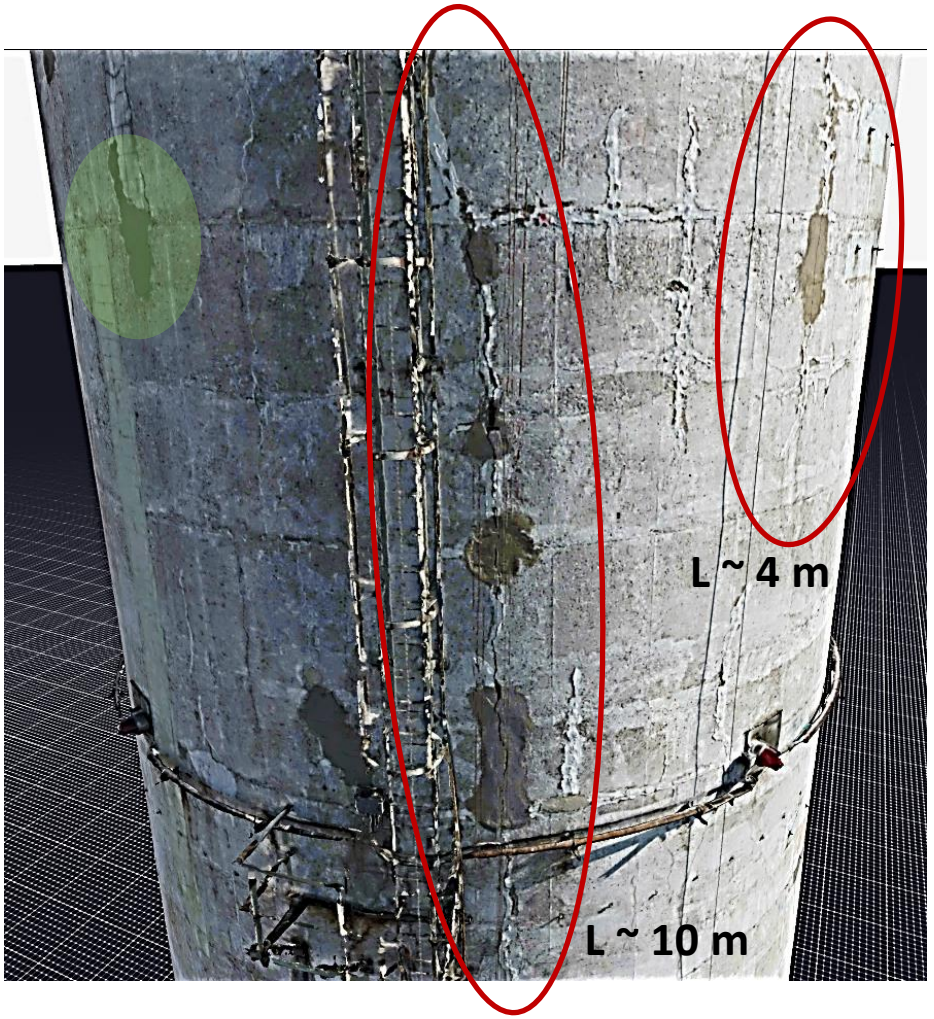

Long, up to 20 mm wide separation cracks

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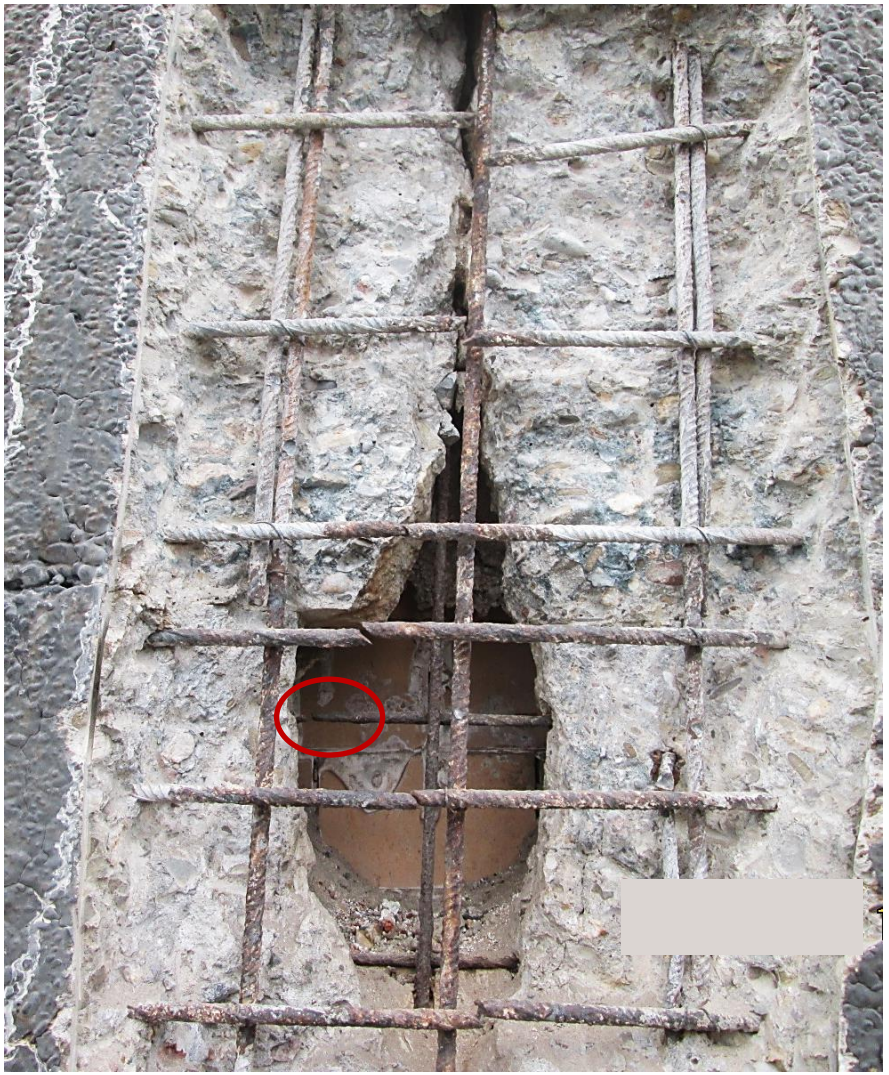

Broken ring reinforcement

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Necking and shearing of the ring irons

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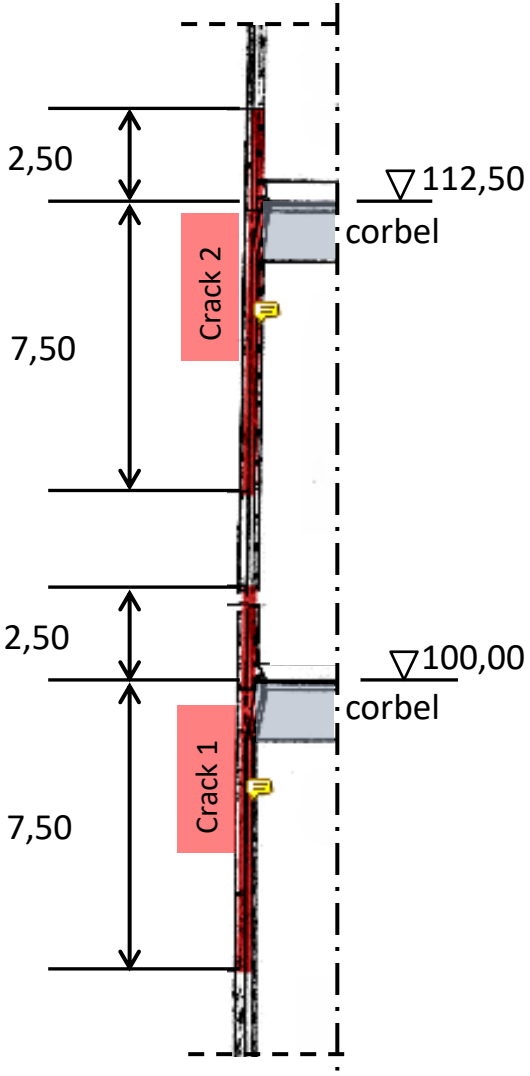

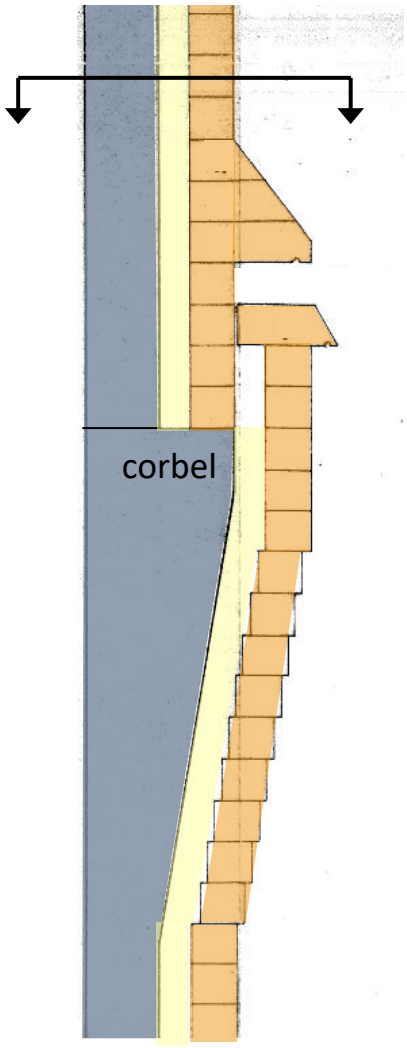

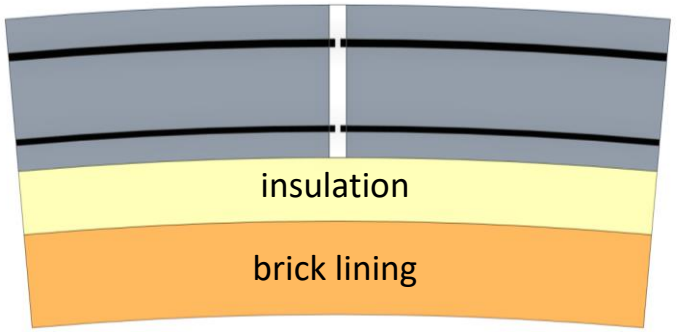

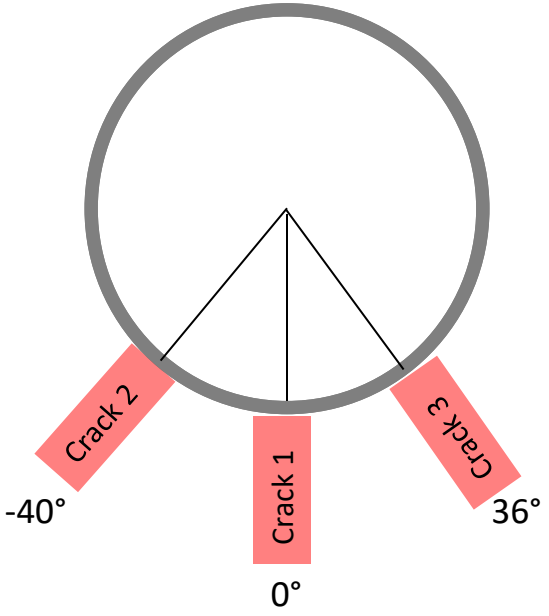

Crack location and some chimney design details

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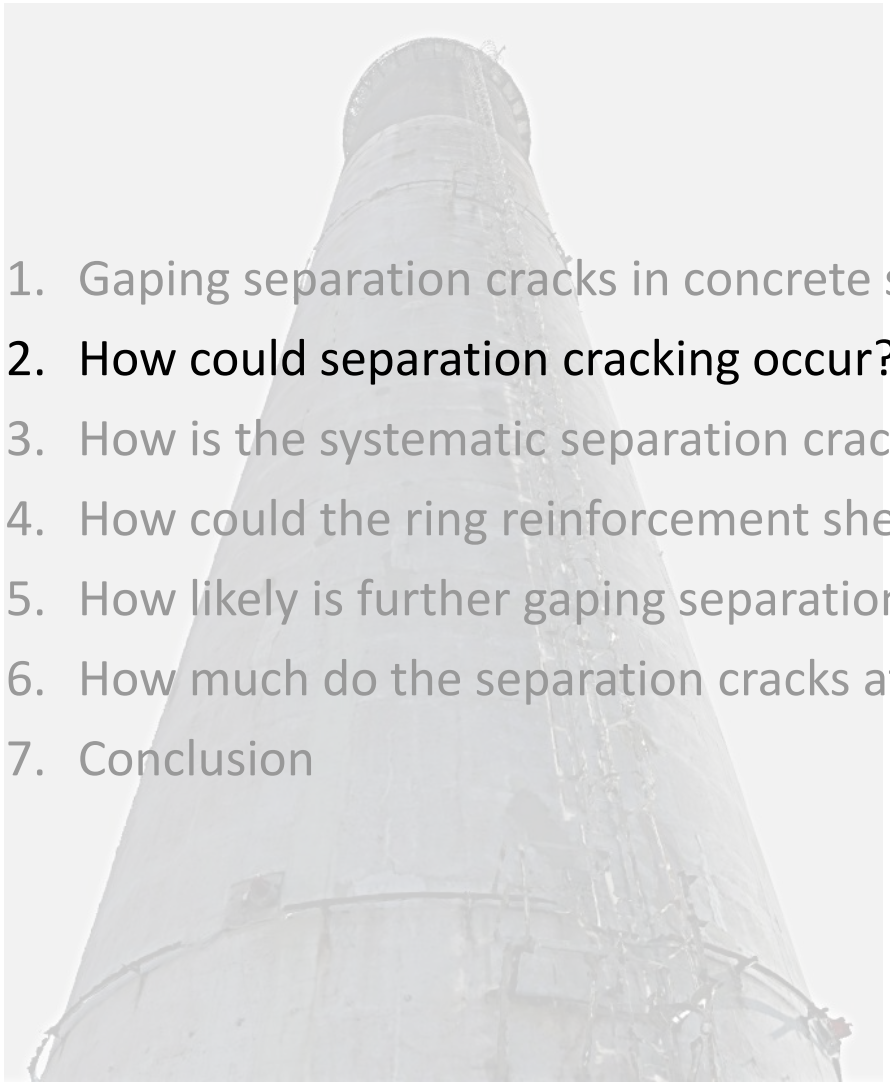

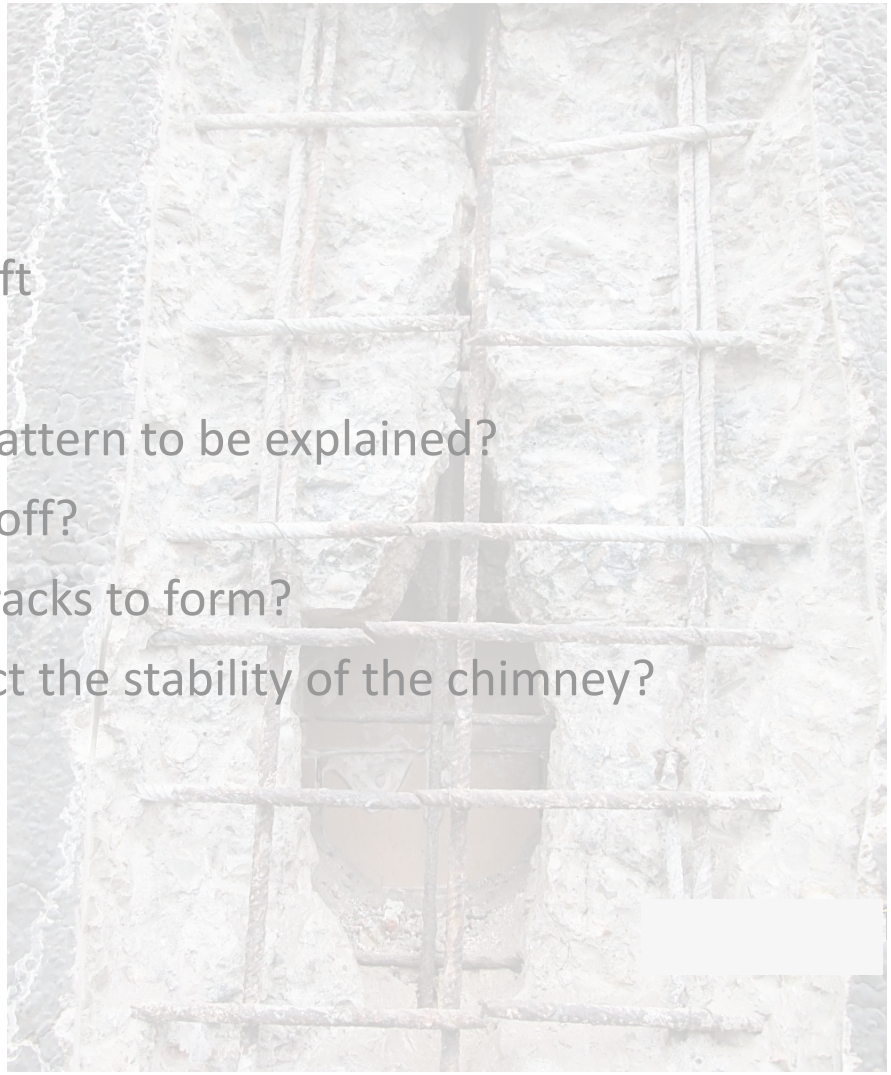

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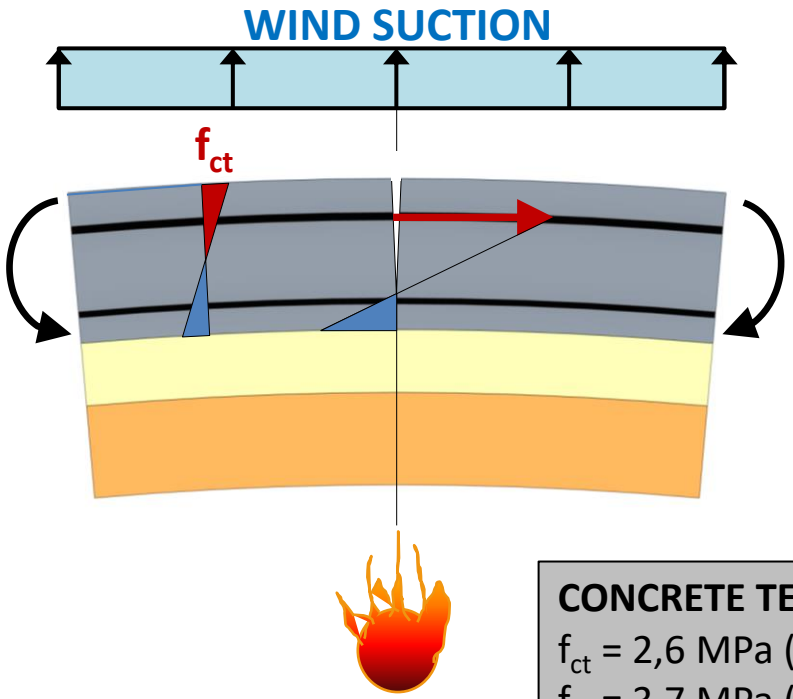

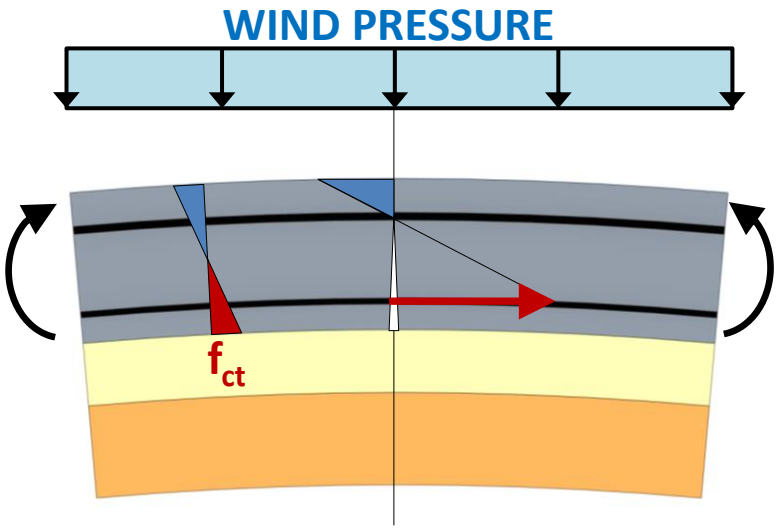

CONCRETE TENSION STRENGTH
f_{ct} = 2,6 MPa (under pure tension)
f_{ct} = 3,7 MPa (under pure bending)

STEEL YIELDING LIMIT
f_y = 400 MPa

Commonly considered load conditions in the design of ring reinforcement

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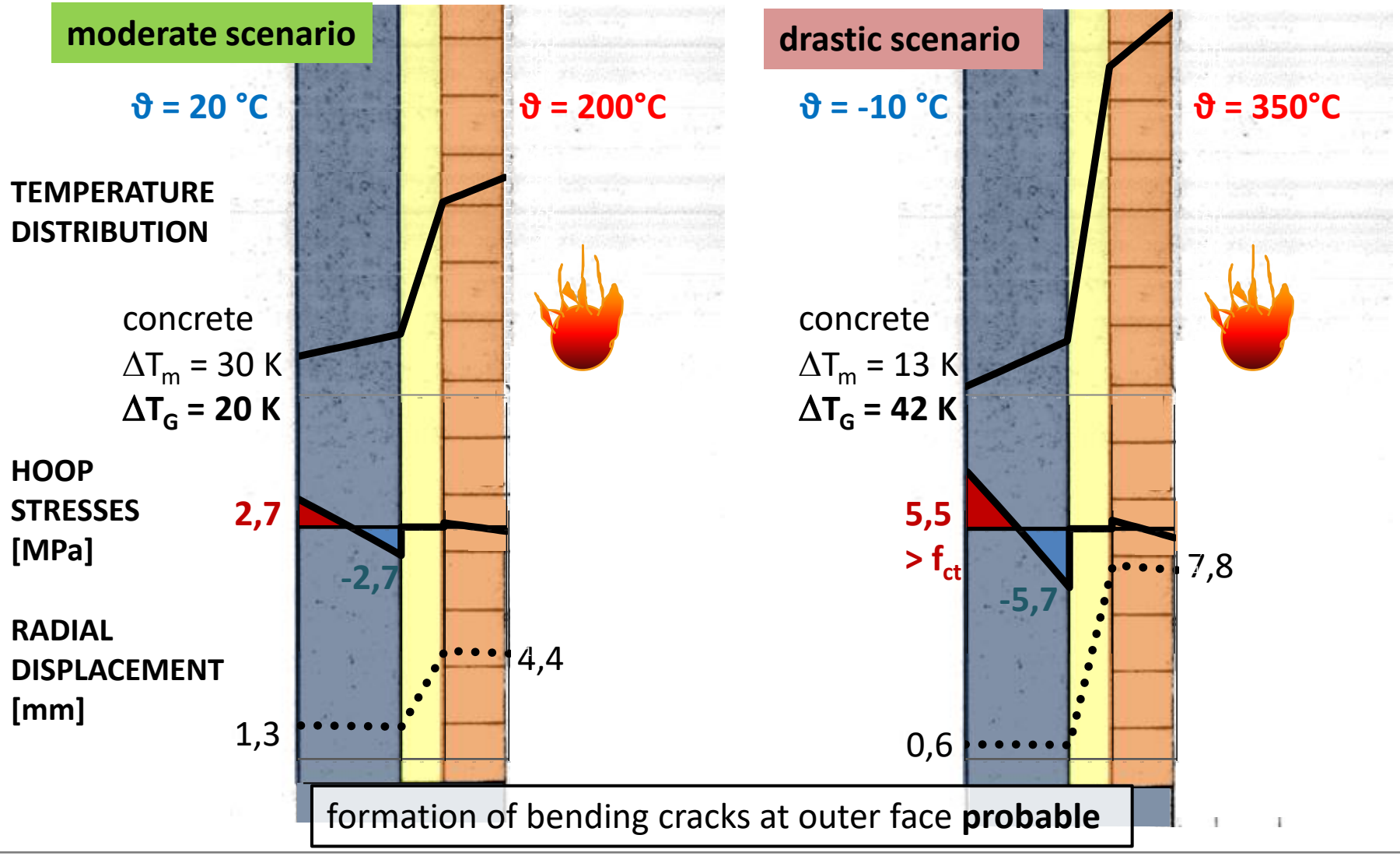

Can bending cracks occur on the outside? ✓

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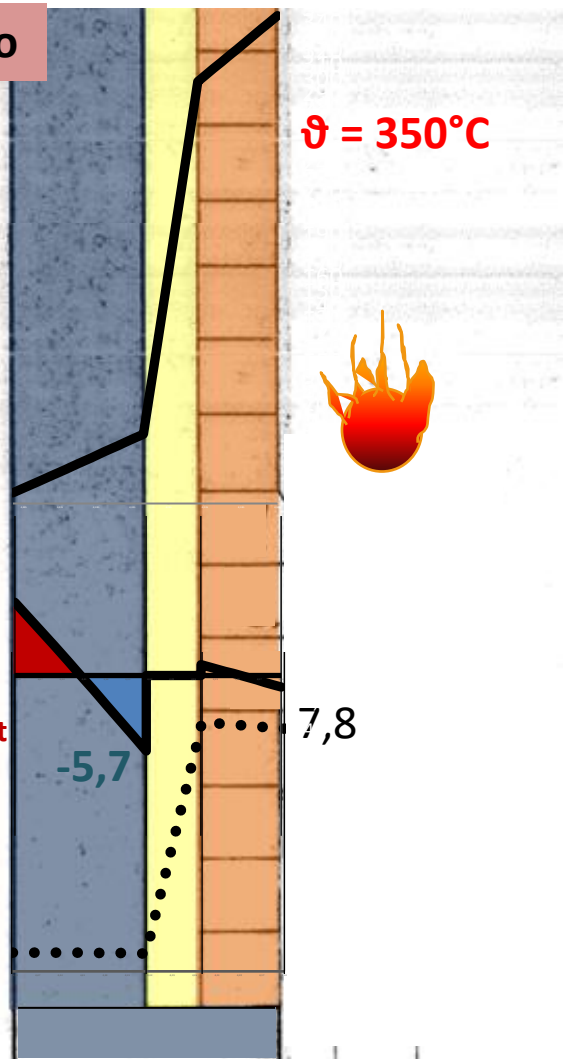
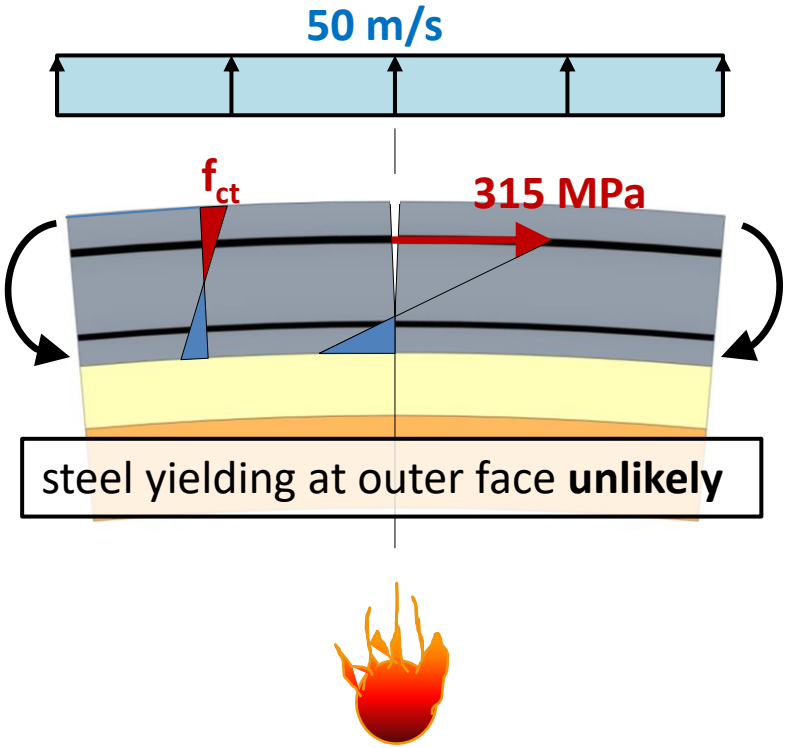
drastic scenario





Does the steel tend to yield at the bending crack? ✗

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drastic scenario A
heating of the outer surface by 5 K/h

drastic scenario B
hurricane

TEMPERATURE DISTRIBUTION

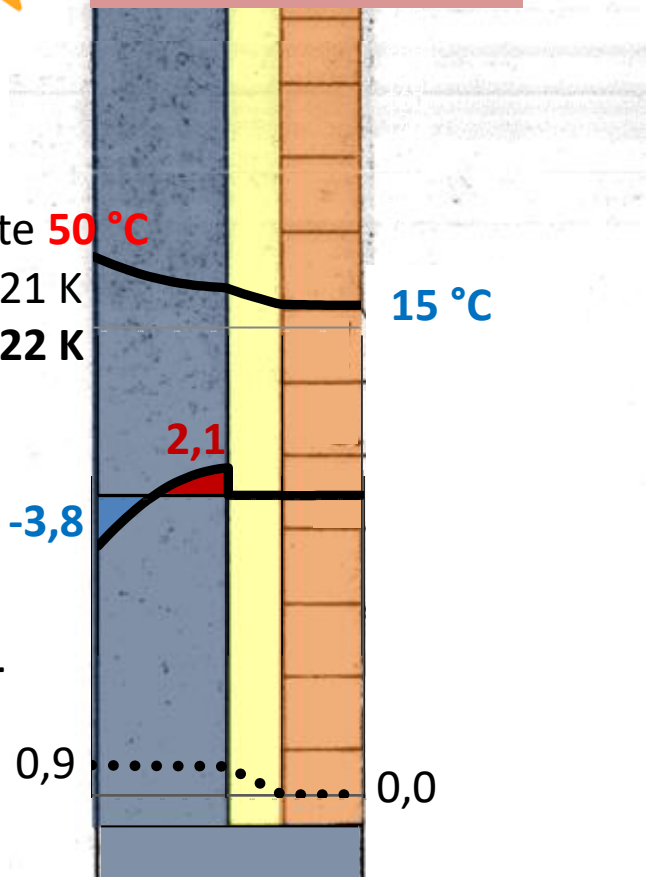
concrete **50 °C**

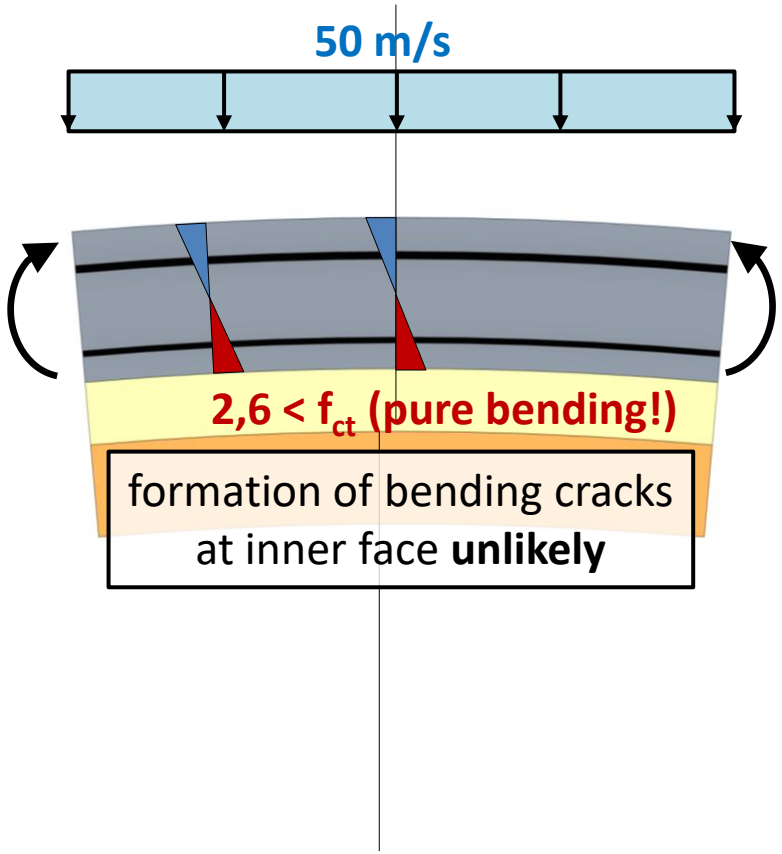
ΔT_m = 21 K

ΔT_G = -22 K

HOOP STRESSES [MPa]

RADIAL DISPLACEMENT [mm]





Can bending cracks occur on the inside? ✗

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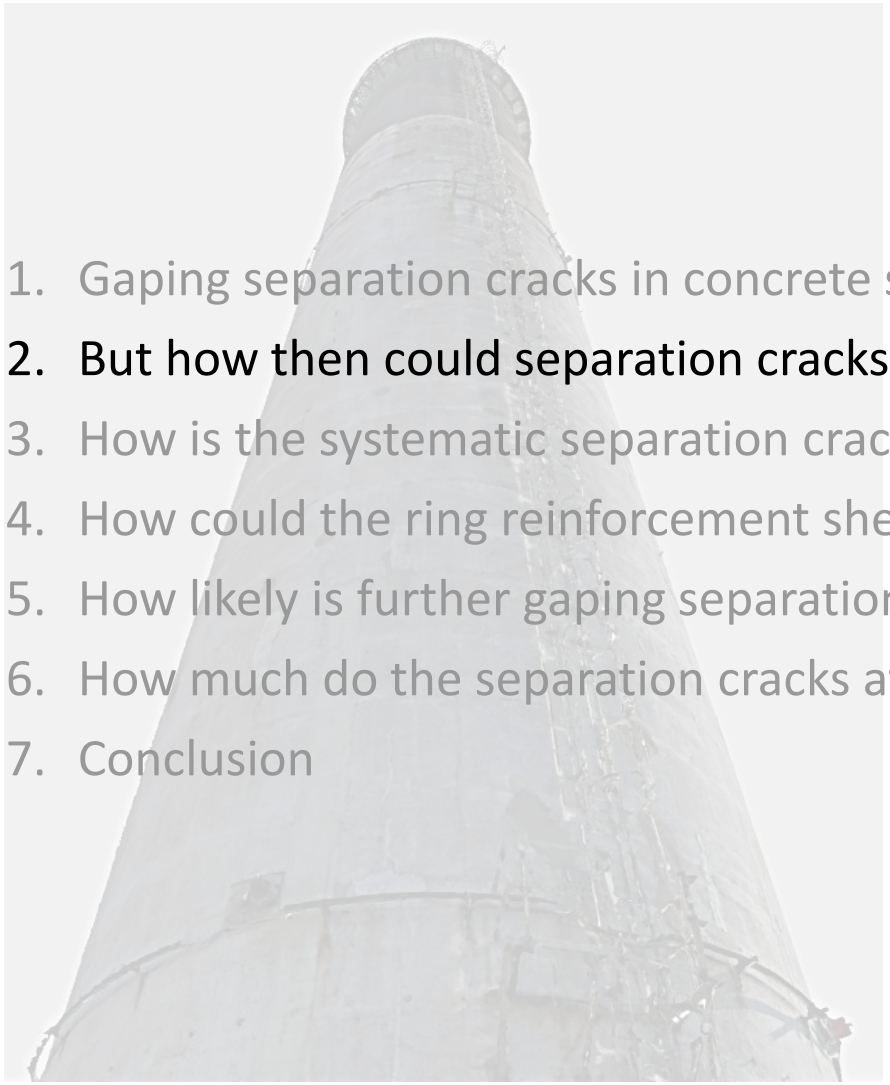

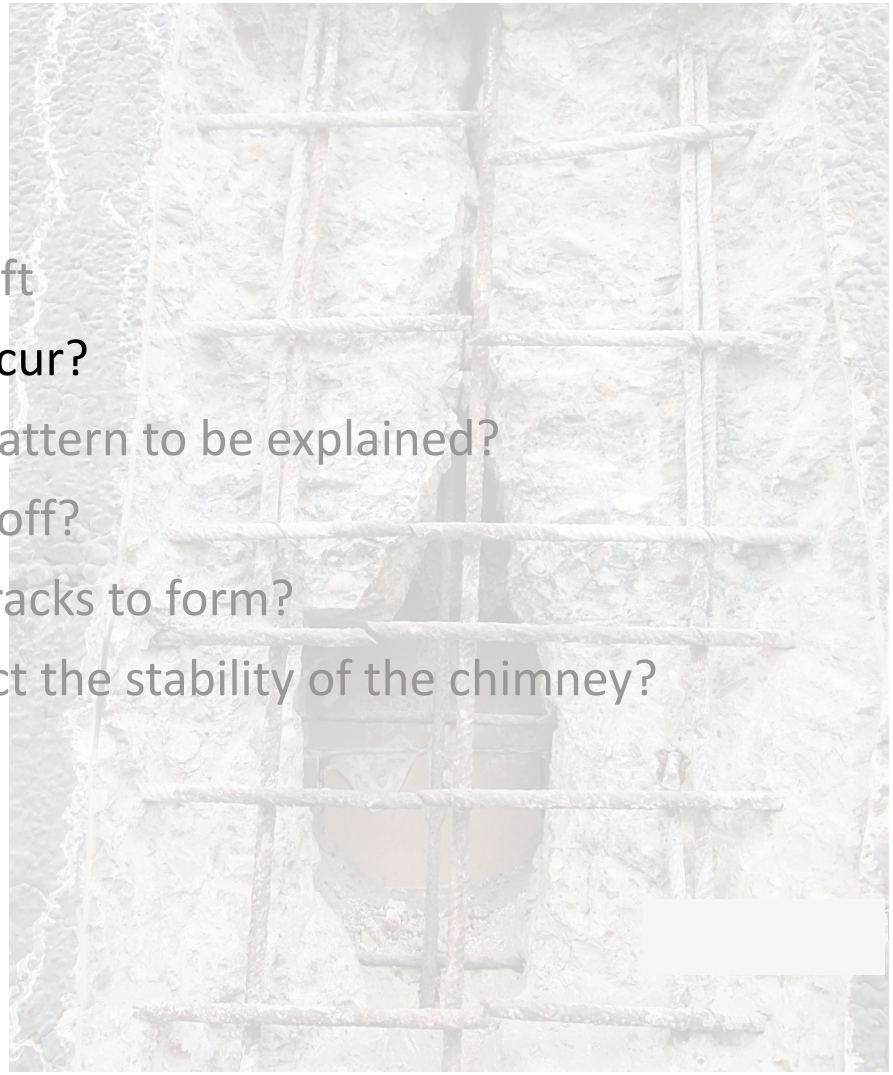

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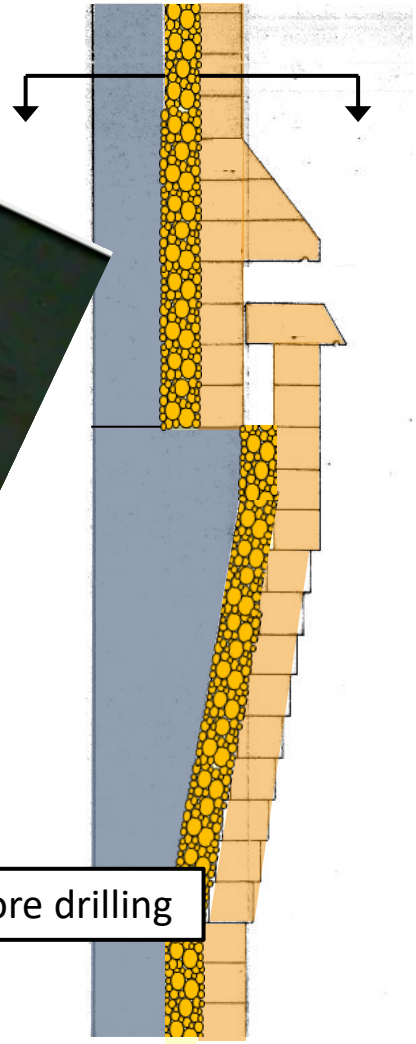
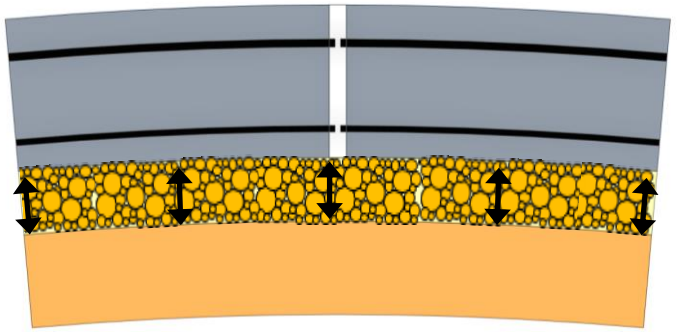
pouring out of the insulation fill after core drilling





Insulation filling compacted and under radial compression?

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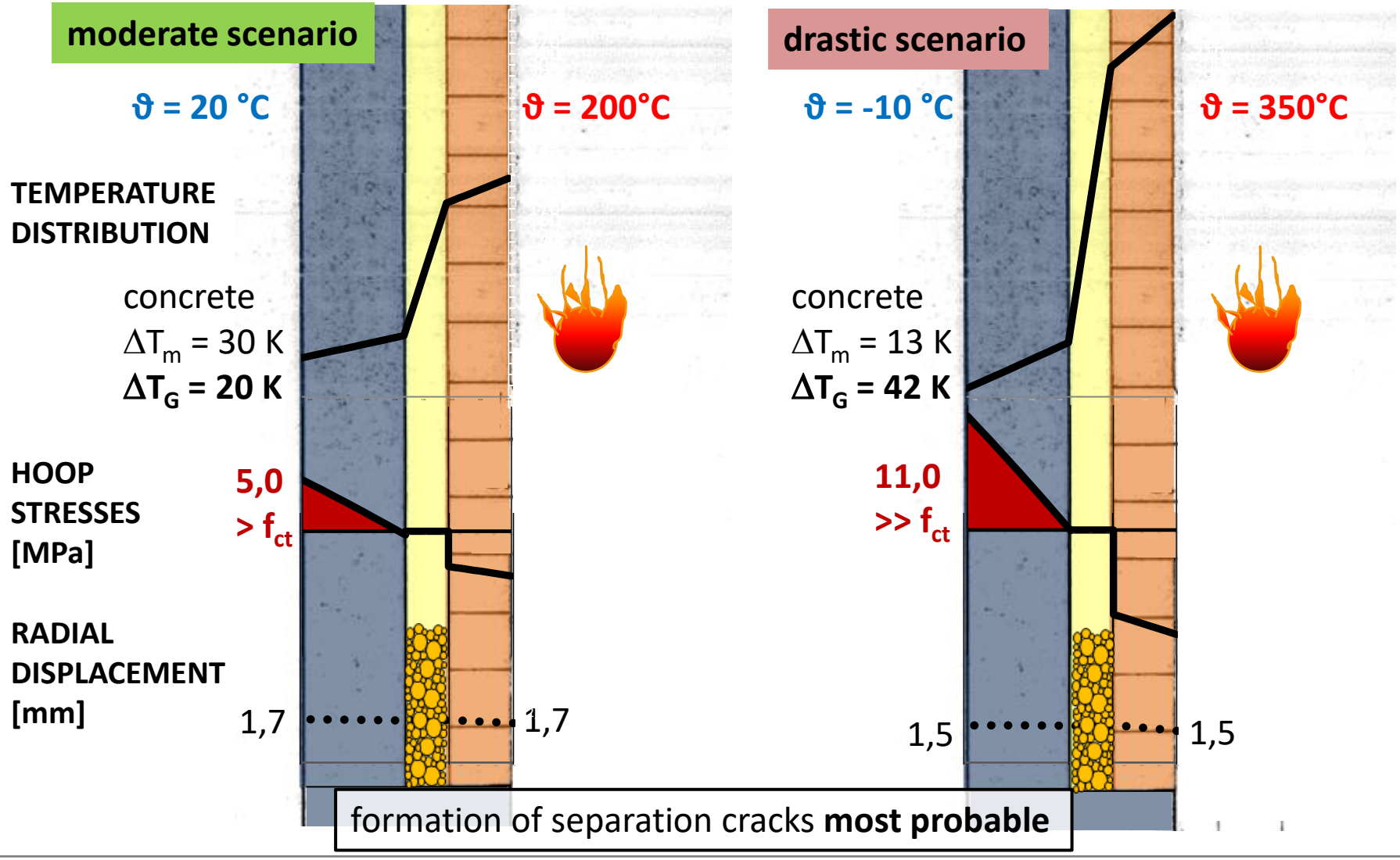

Can separation cracks occur due to radial compression? ✓

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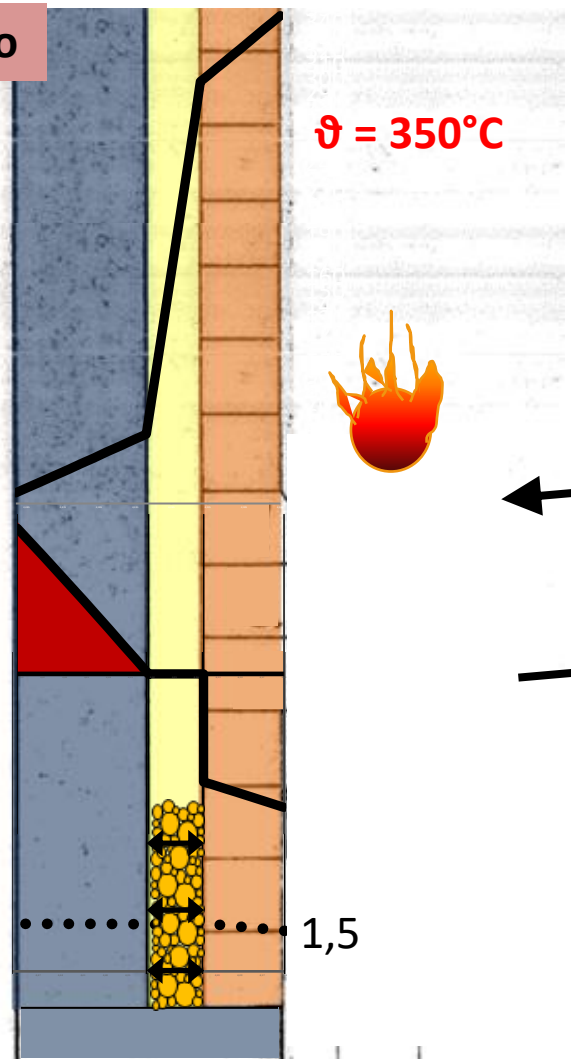

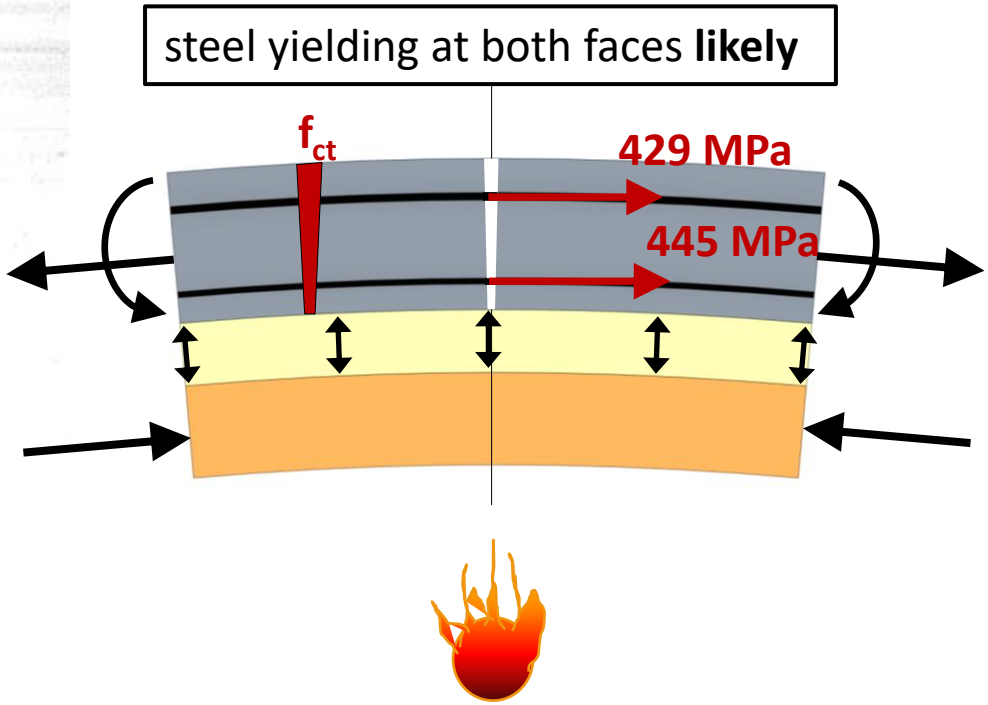

Does the steel tend to yield at the separation crack? ✓

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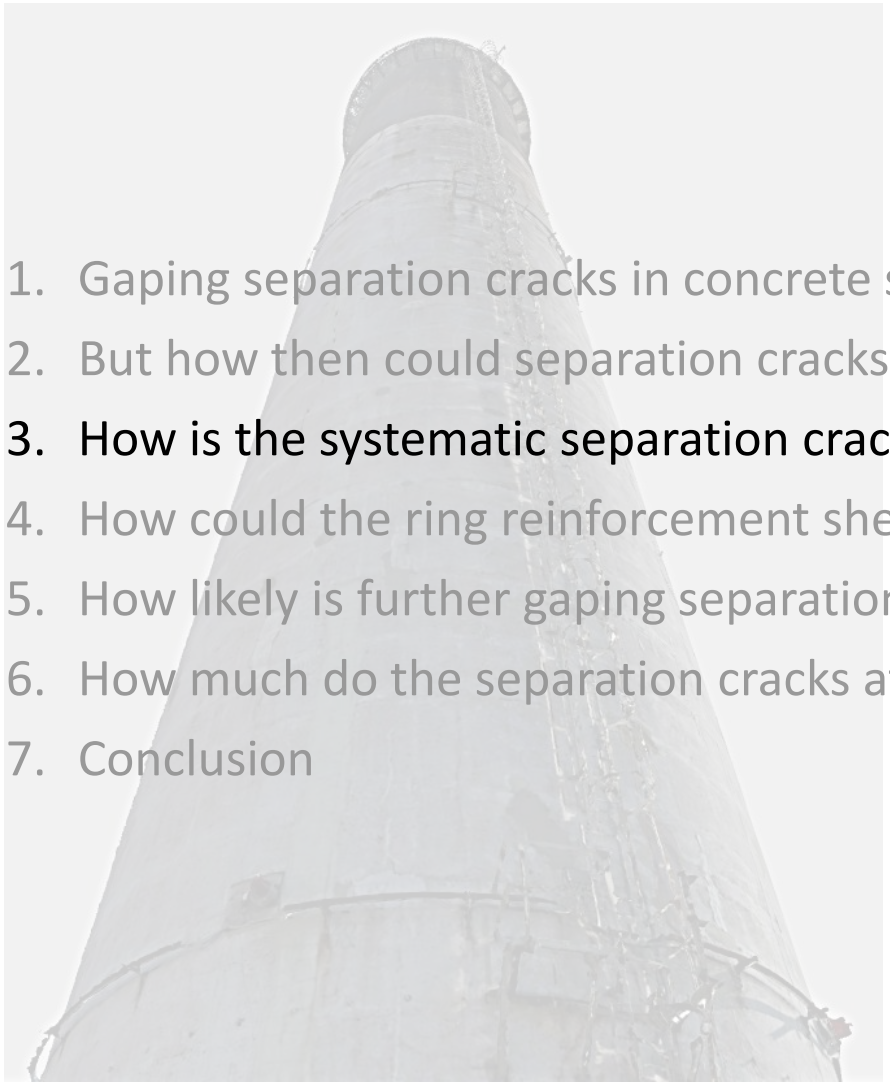

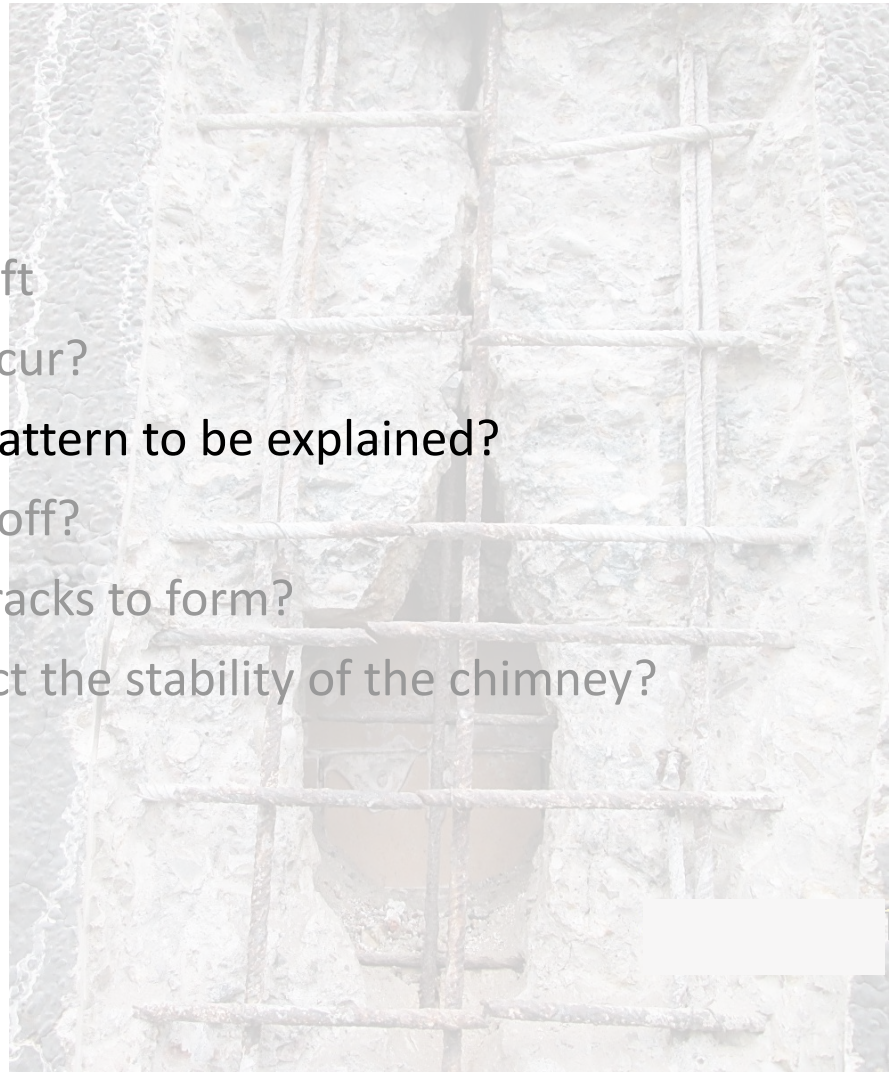

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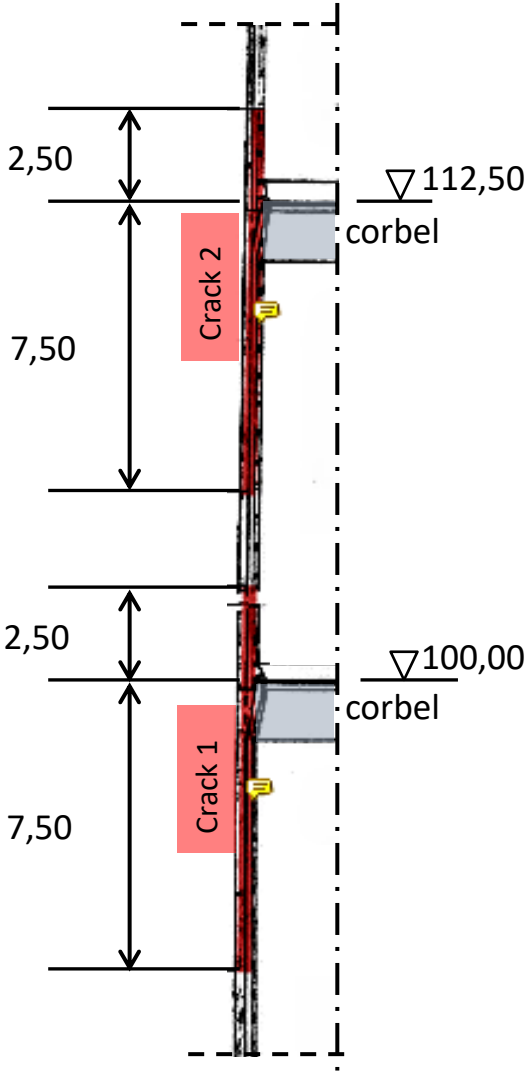

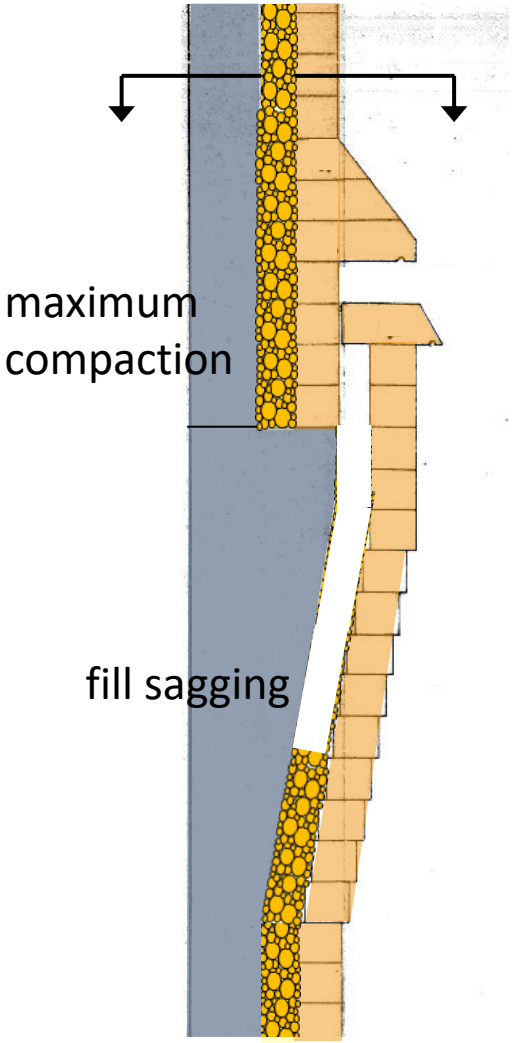

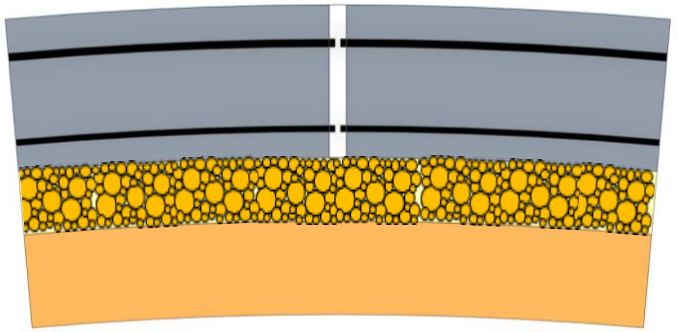

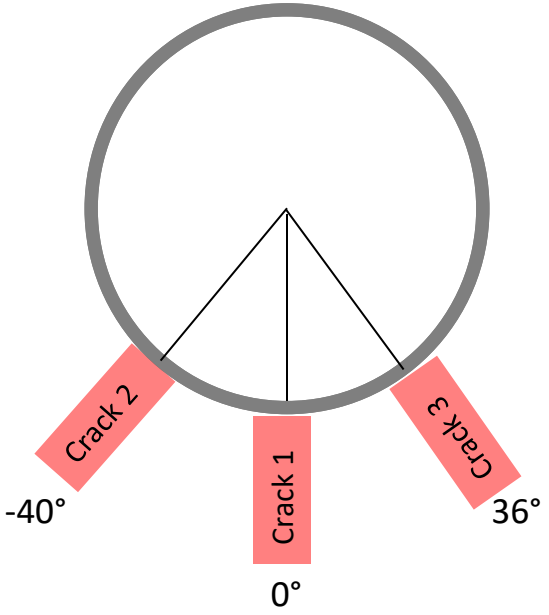

Due to fill setting, radial compression below the corbel should not be that high...

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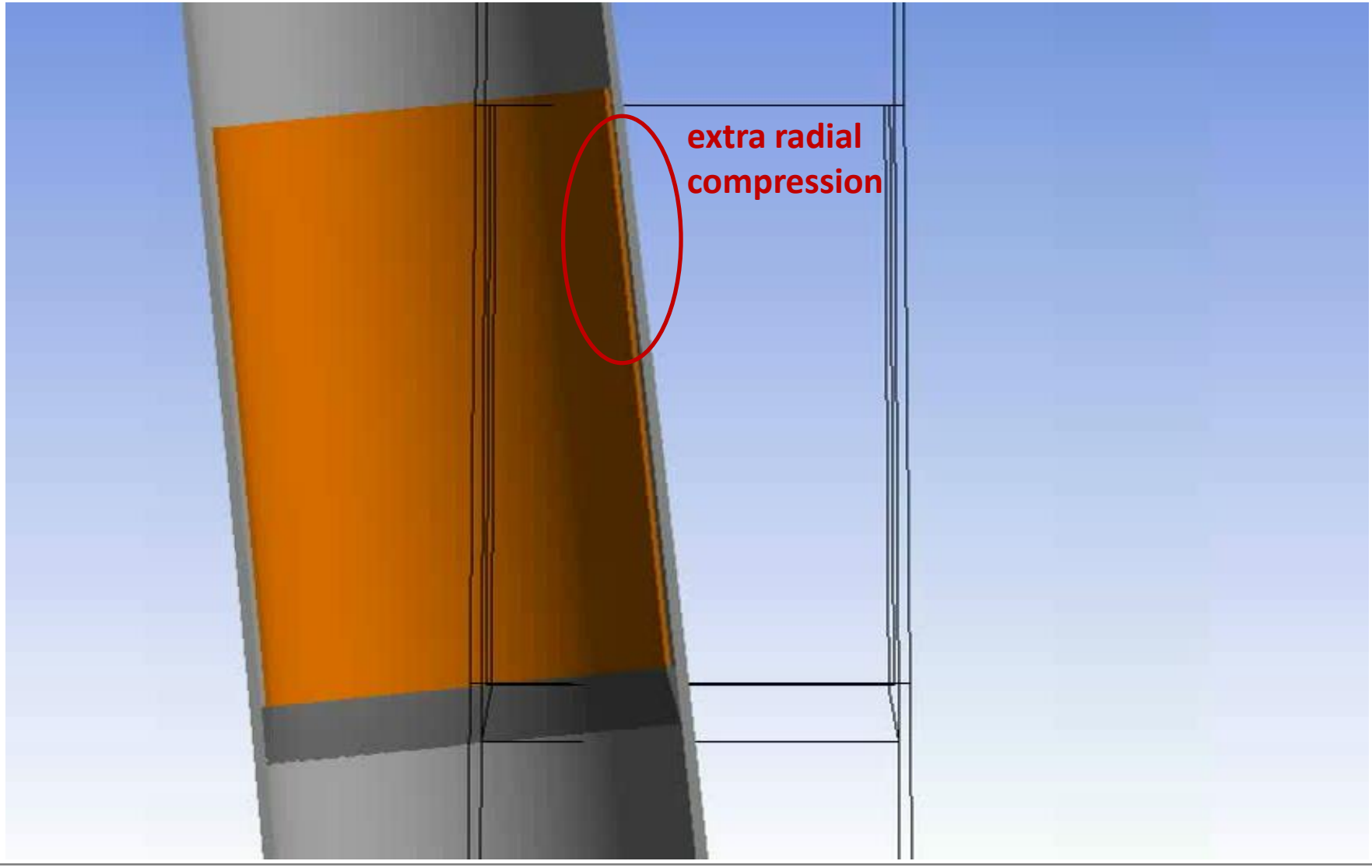

Opposite oscillation increases radial compression in upper areas!

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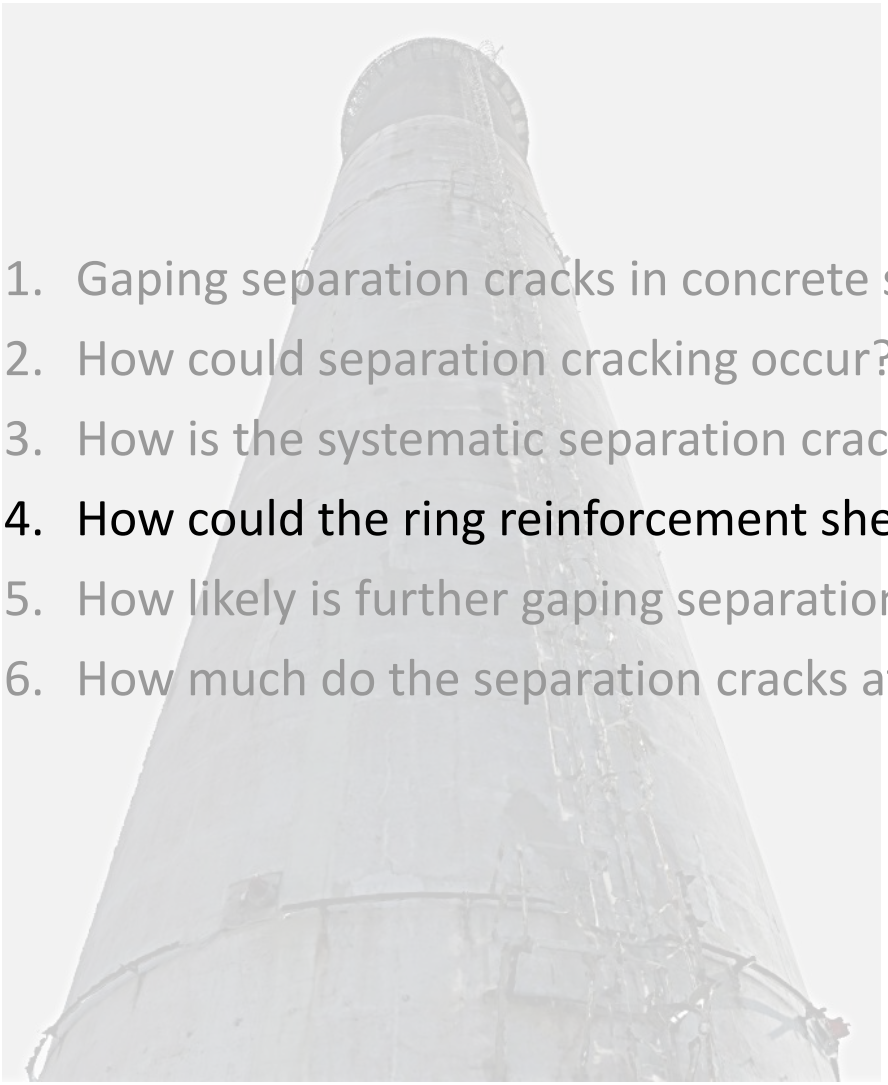

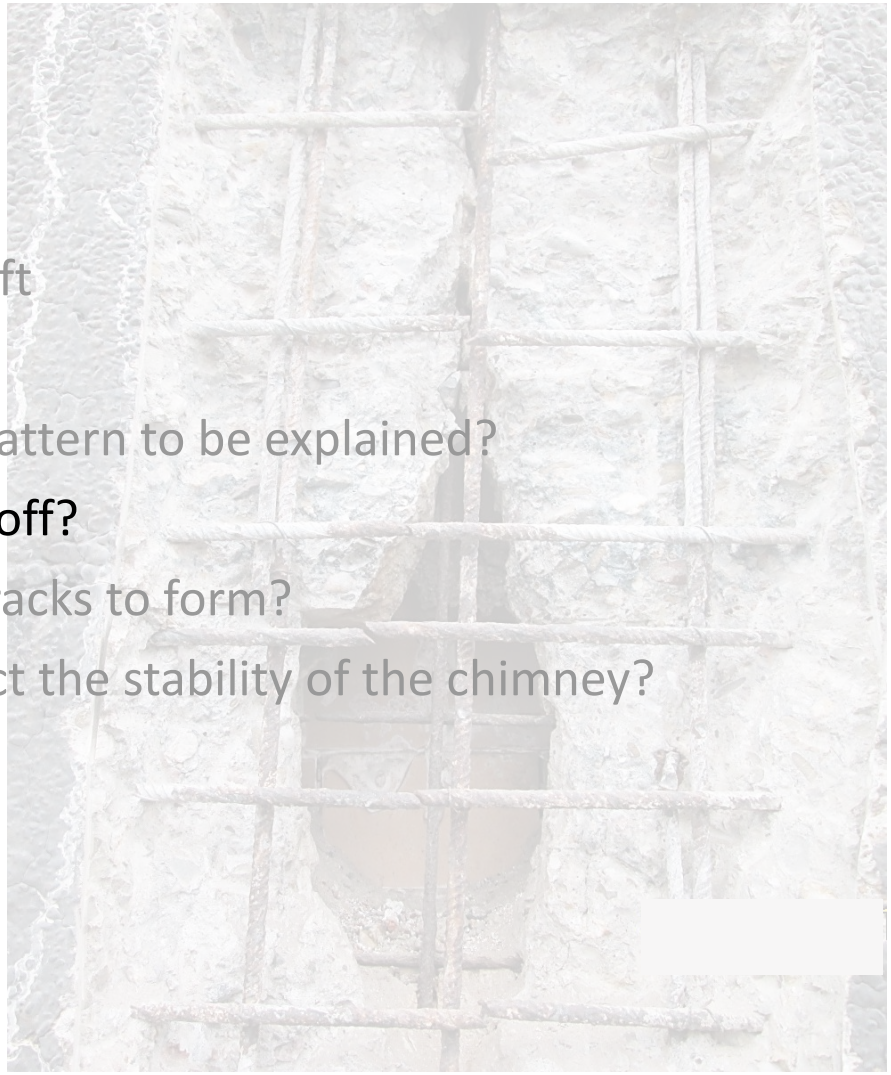

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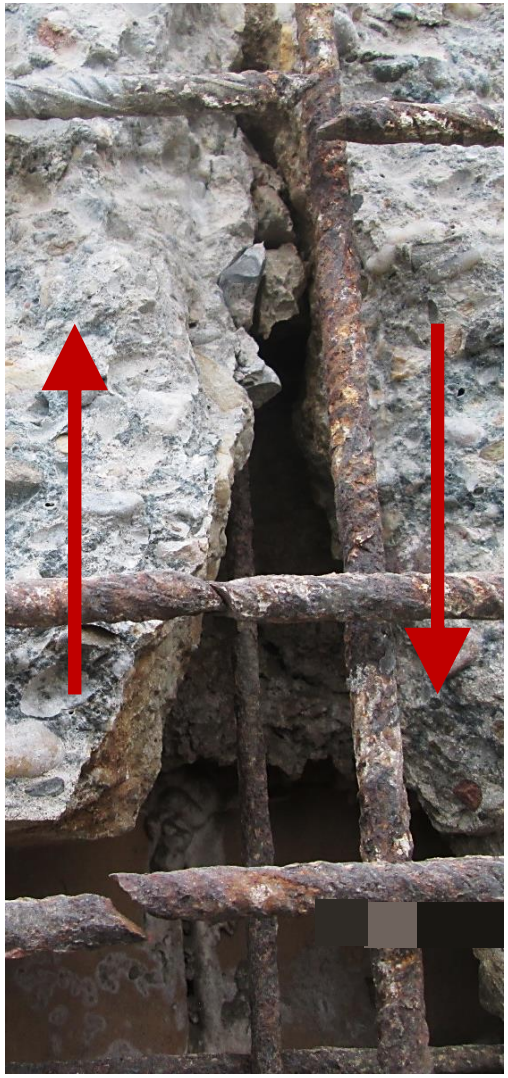

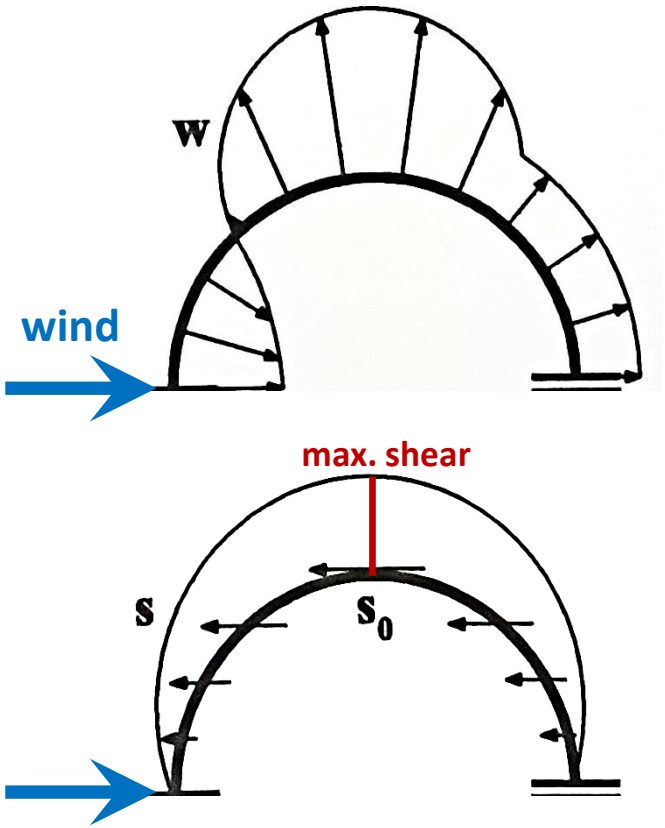

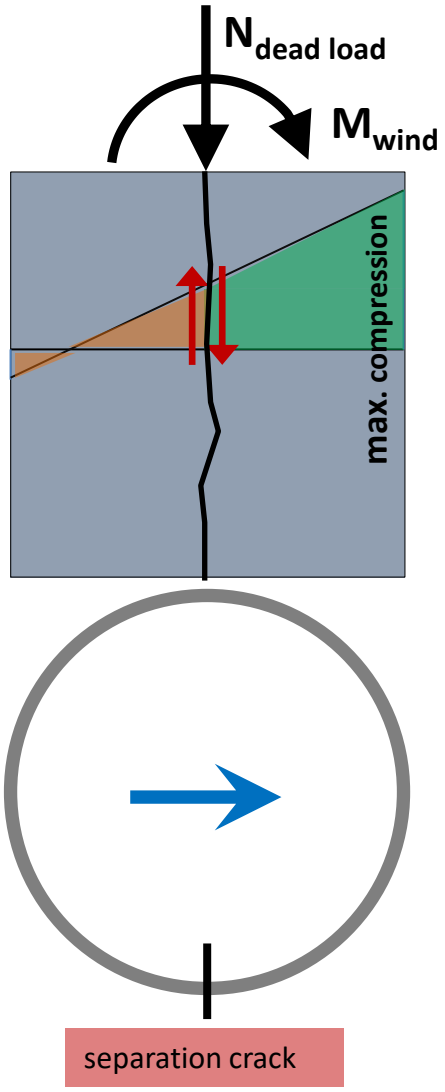

Maximum shear forces with wind crosswise to the crack

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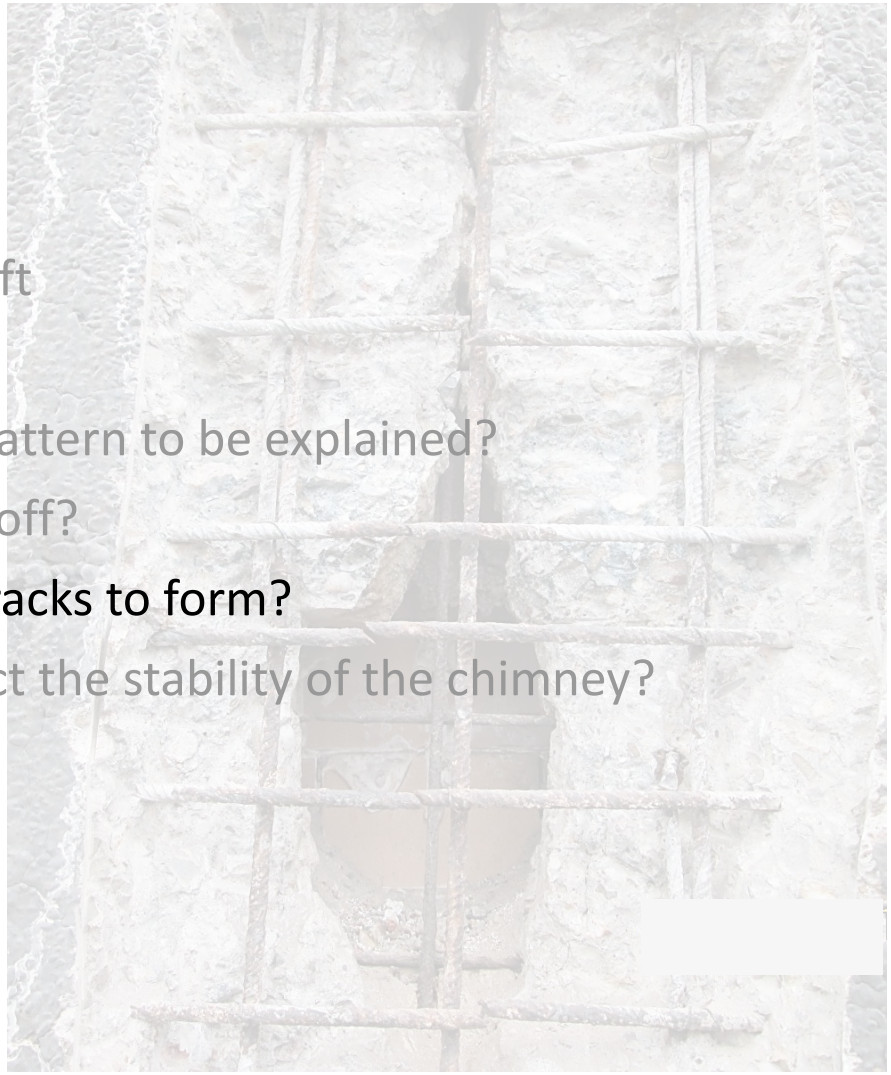

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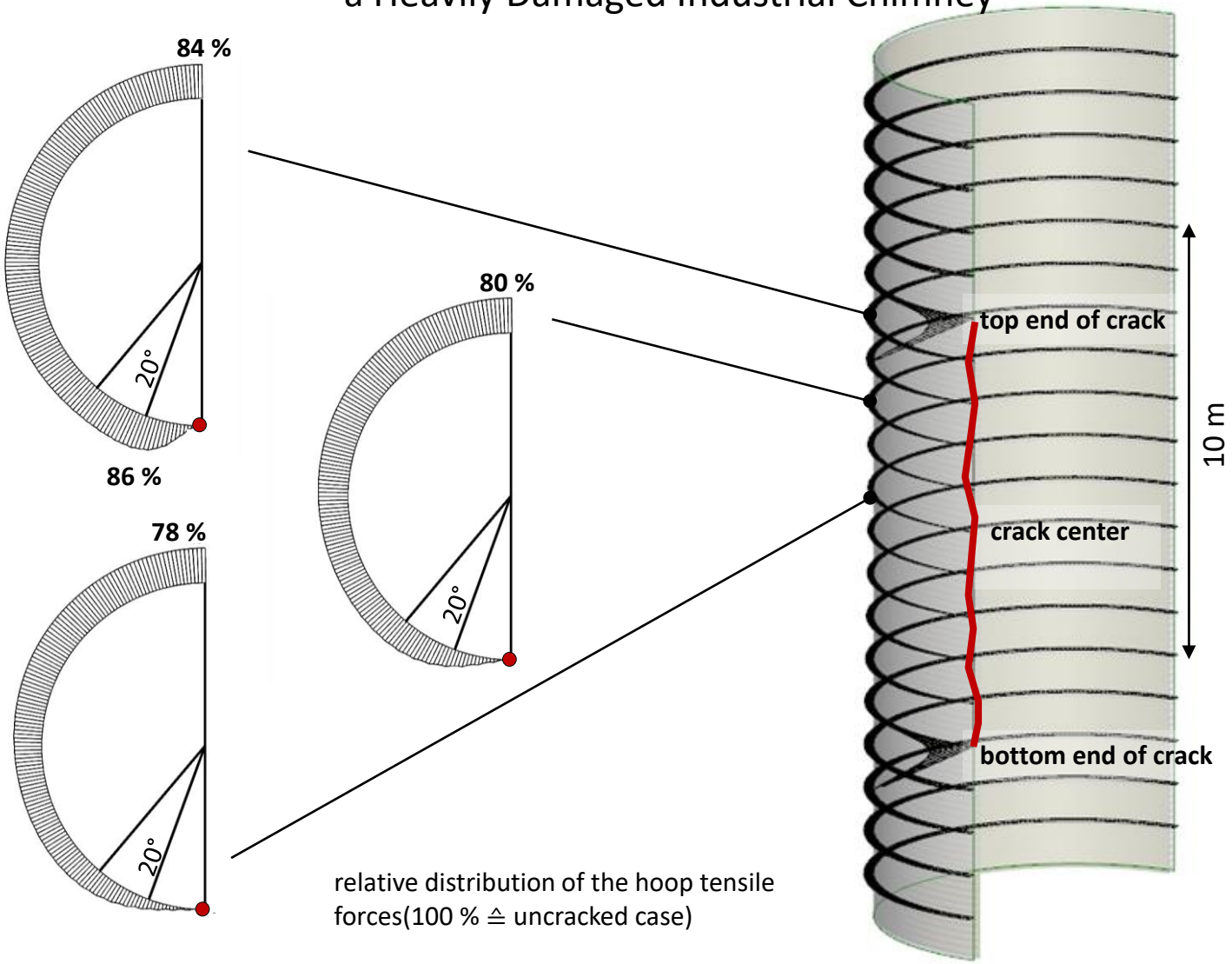

relative distribution of the hoop tensile forces(100 % ≙ uncracked case)

Probability of further through cracking at level of existing separation crack

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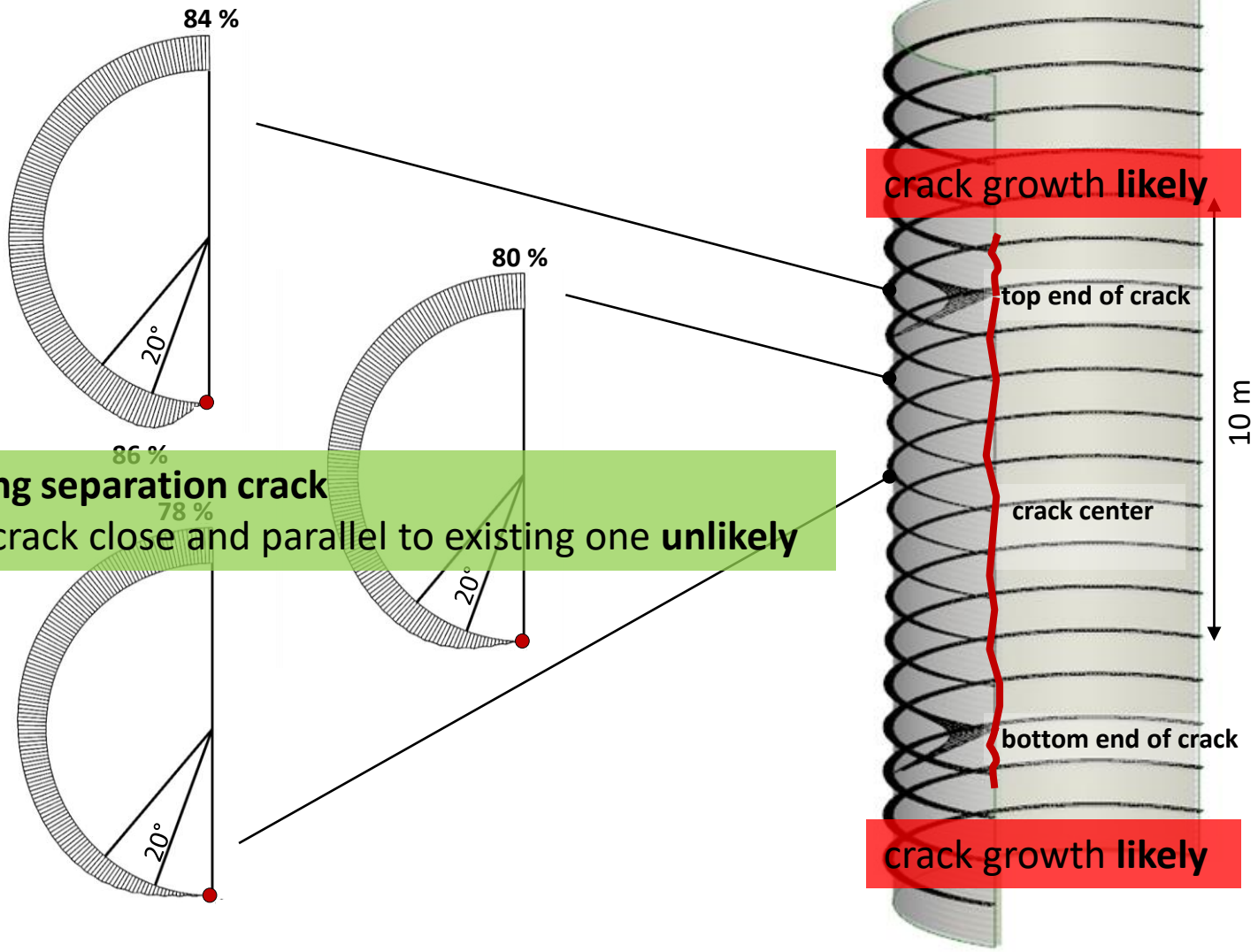

at level of existing separation crack
new separation crack close and parallel to existing one **unlikely**

Probability of further through cracking at level of existing separation crack

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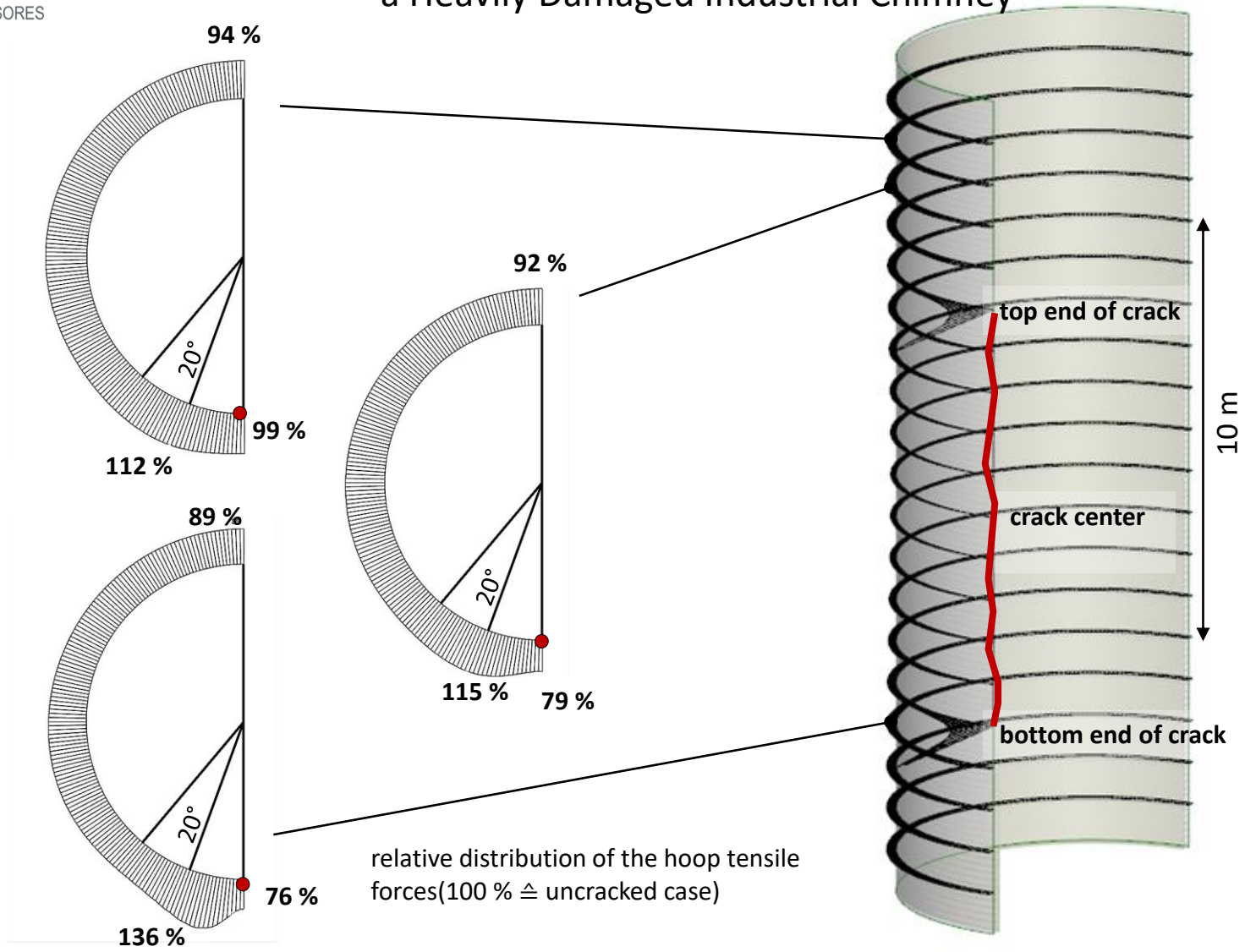

relative distribution of the hoop tensile forces(100 % ≙ uncracked case)

Probability of further through cracking above and below existing separation crack

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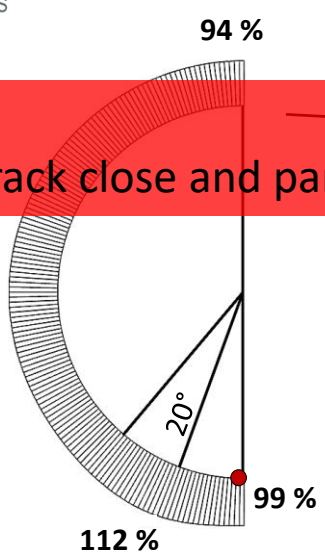
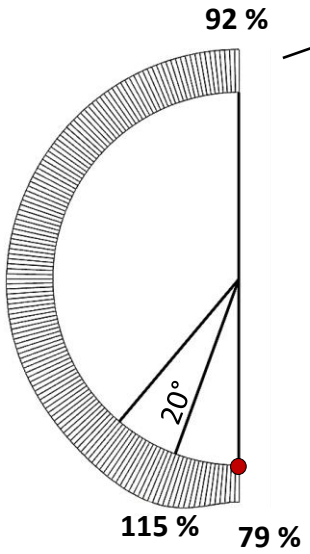
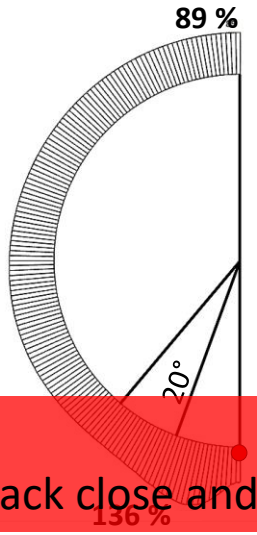
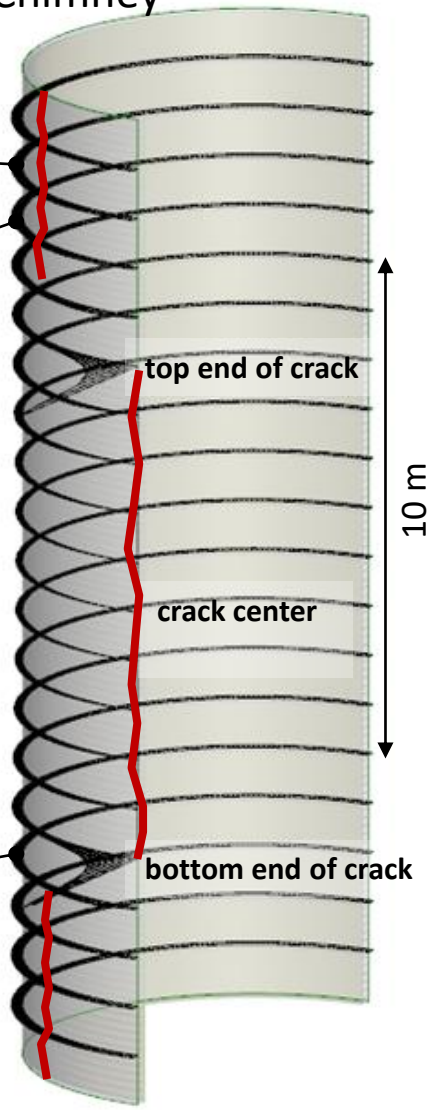
above crack level
new separation crack close and parallel to existing one **not unlikely**









below crack level
new separation crack close and parallel to existing one **not unlikely**

Probability of further through cracking above and below existing separation crack

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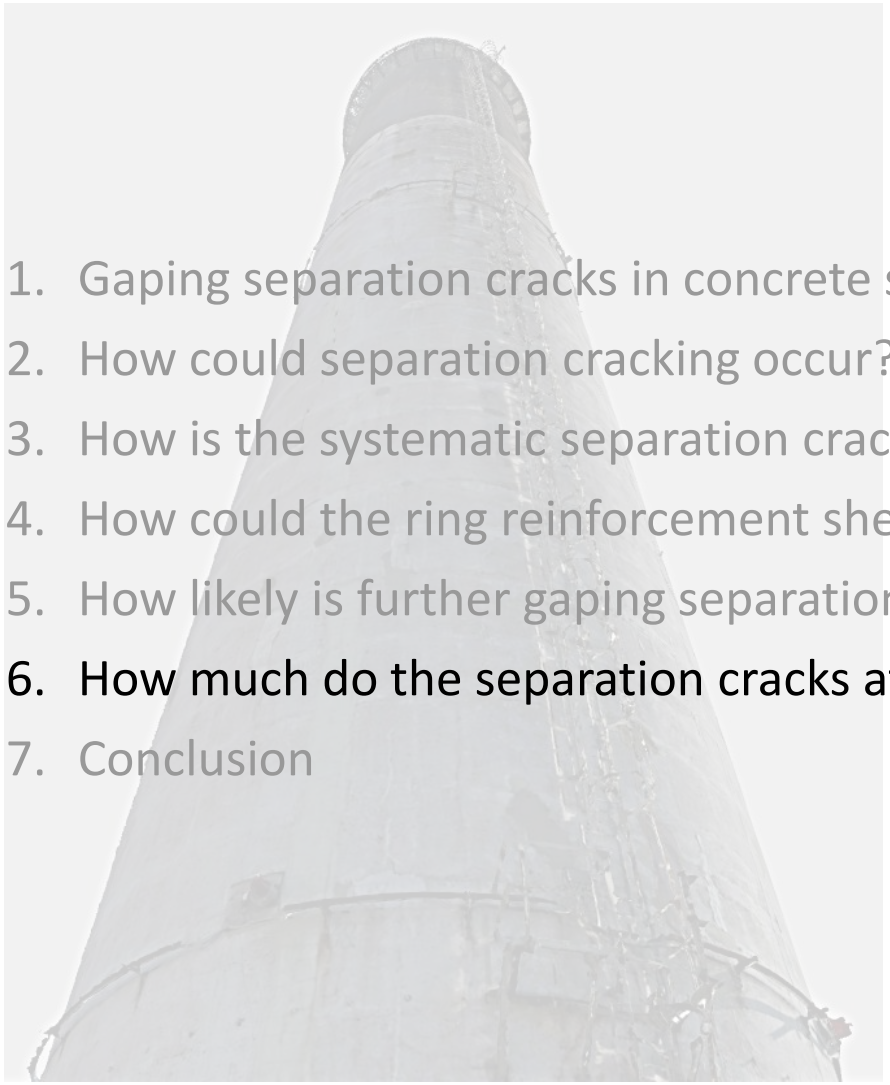

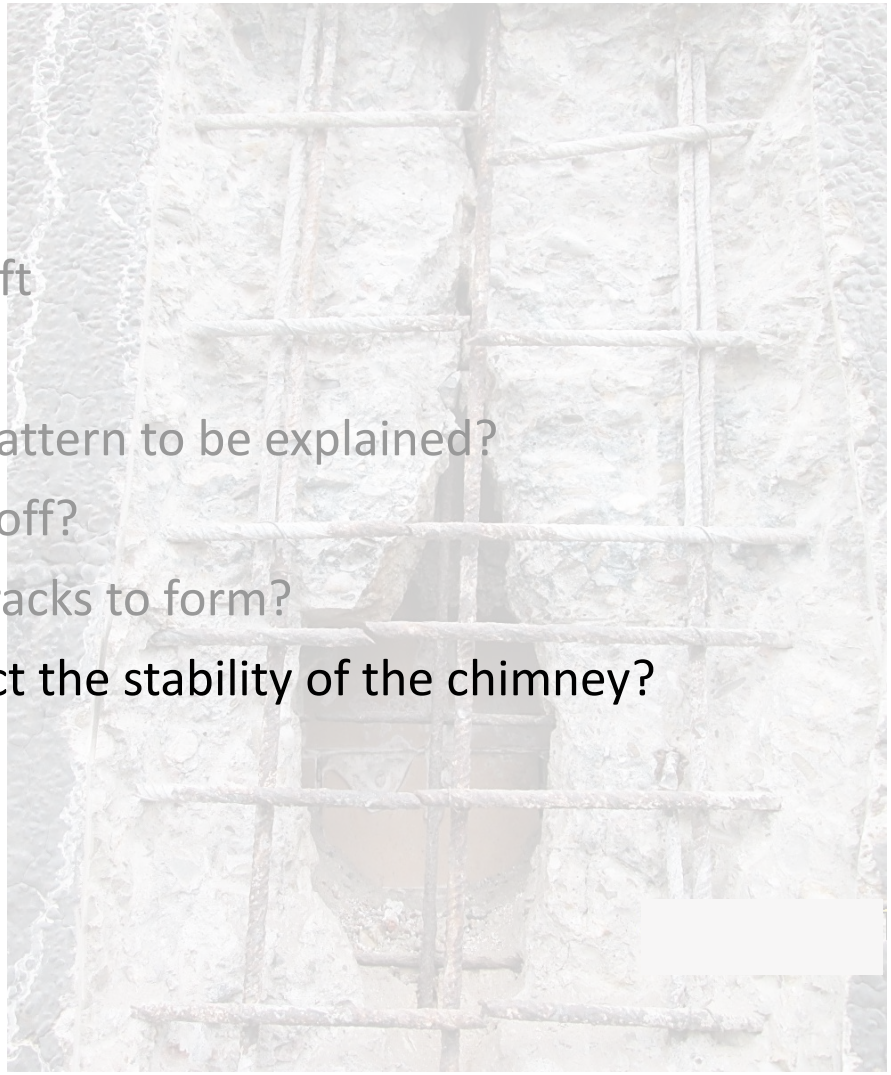

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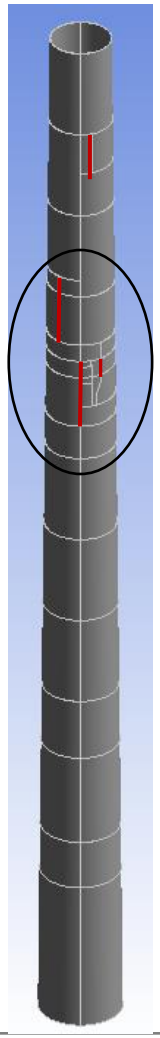

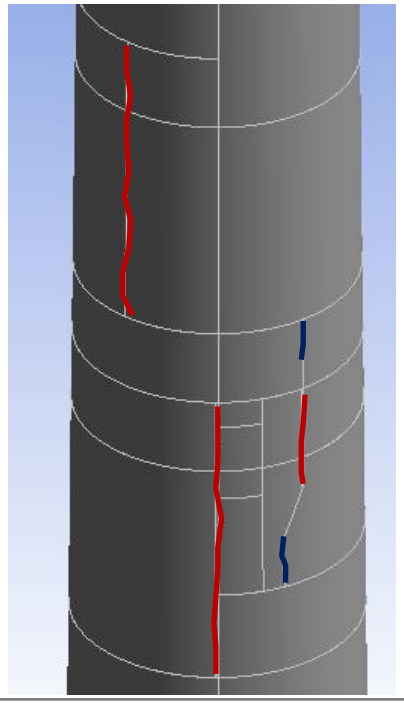

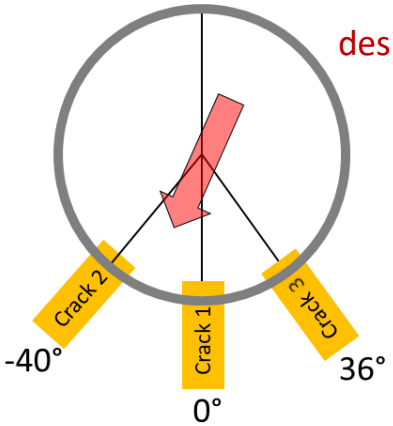

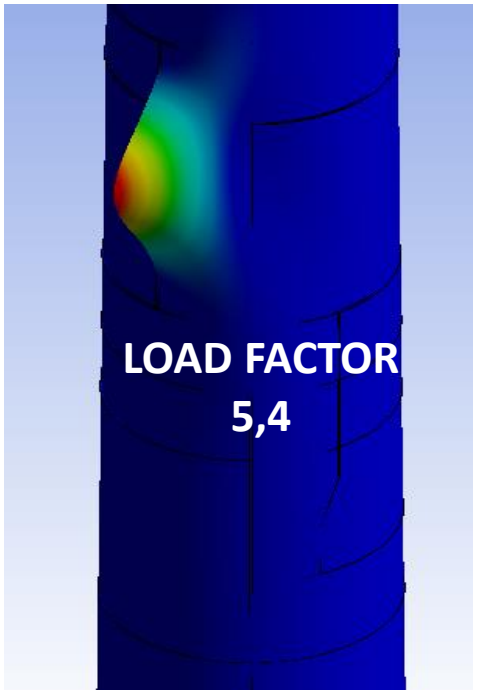

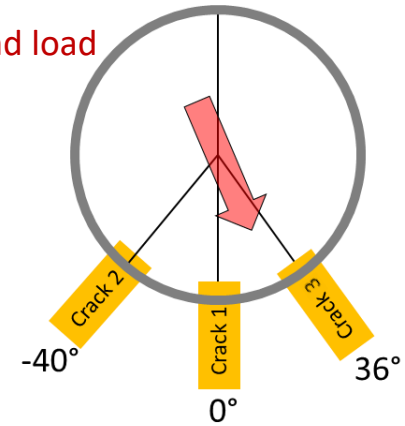

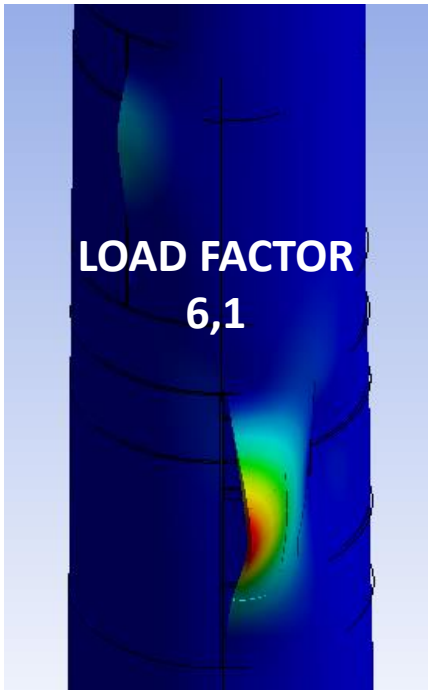

Very high load-bearing reserves with given crack pattern

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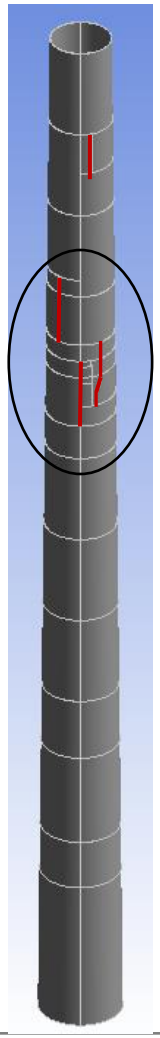
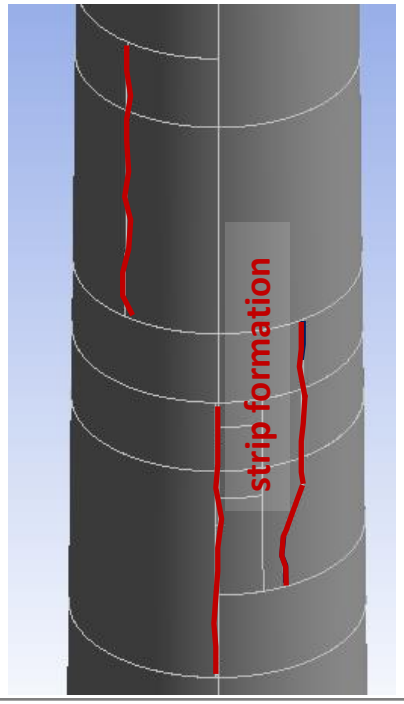
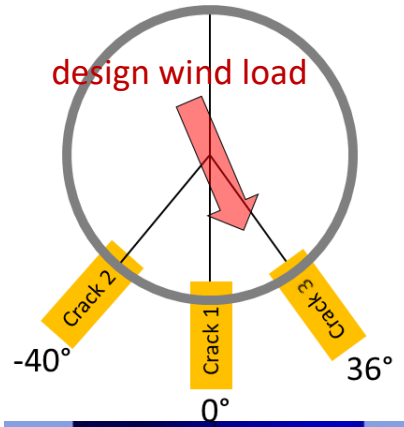
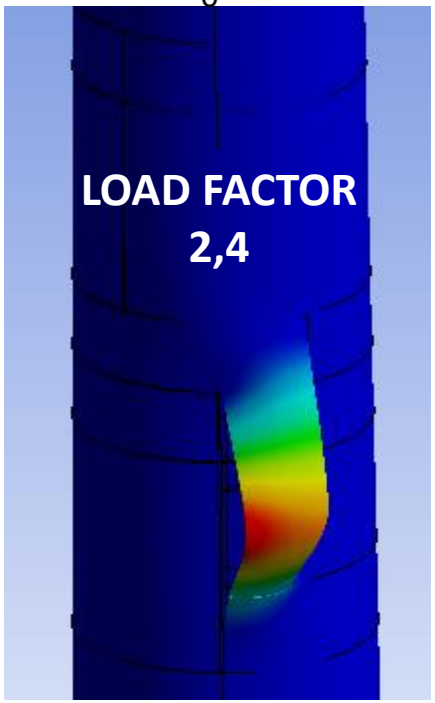






LOAD FACTOR < 1 means buckling!



Still quite high load-bearing reserves in case of crack fusion (and strip formation!)

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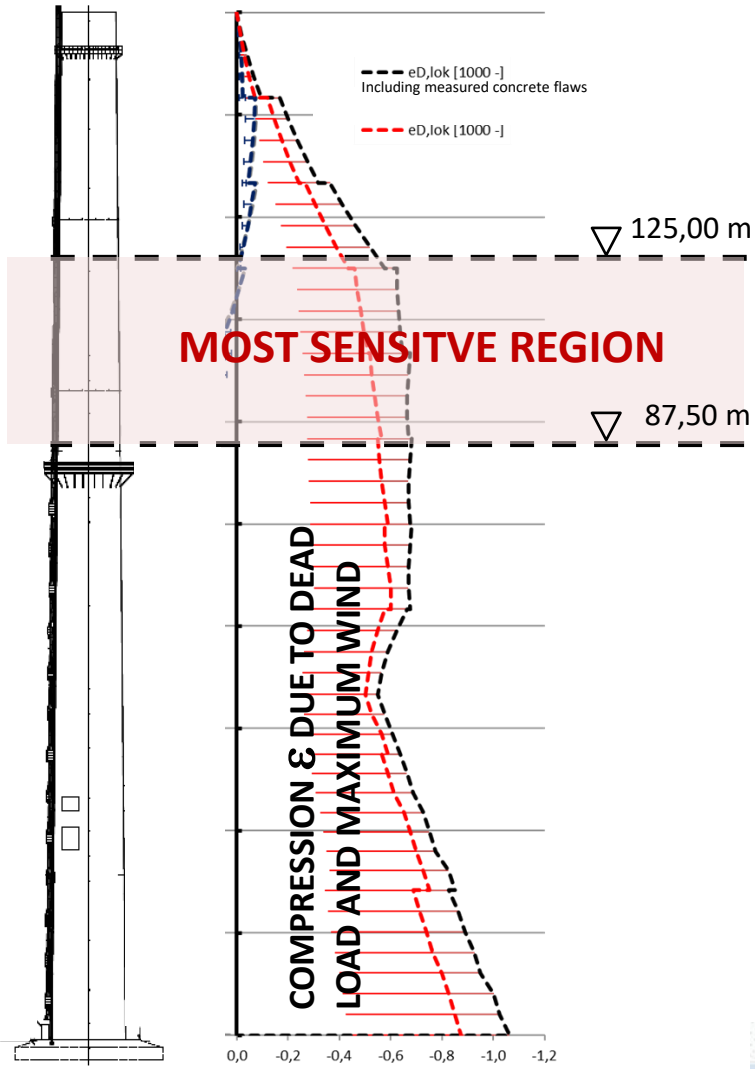
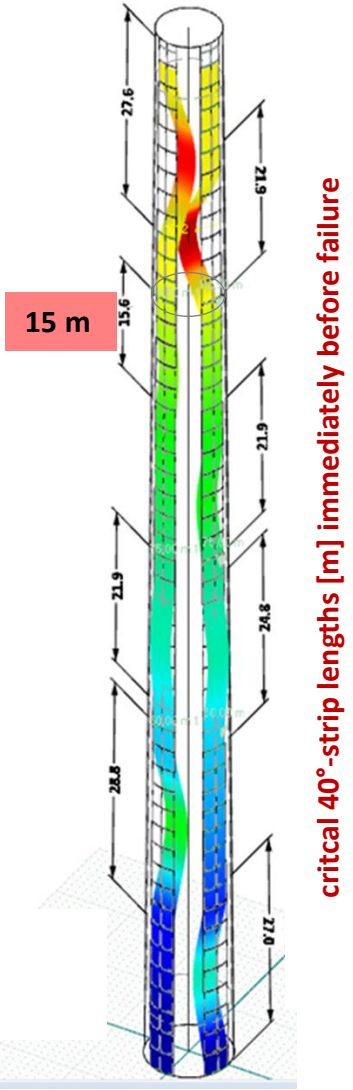
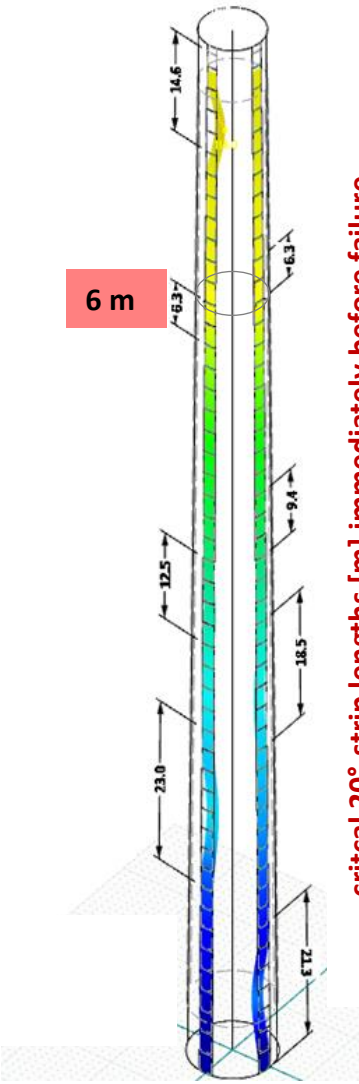




critcal 40°-strip lengths [m] immediately before failure



critcal 20°-strip lengths [m] immediately before failure

Determination of critical strip lengths depending on their location and width

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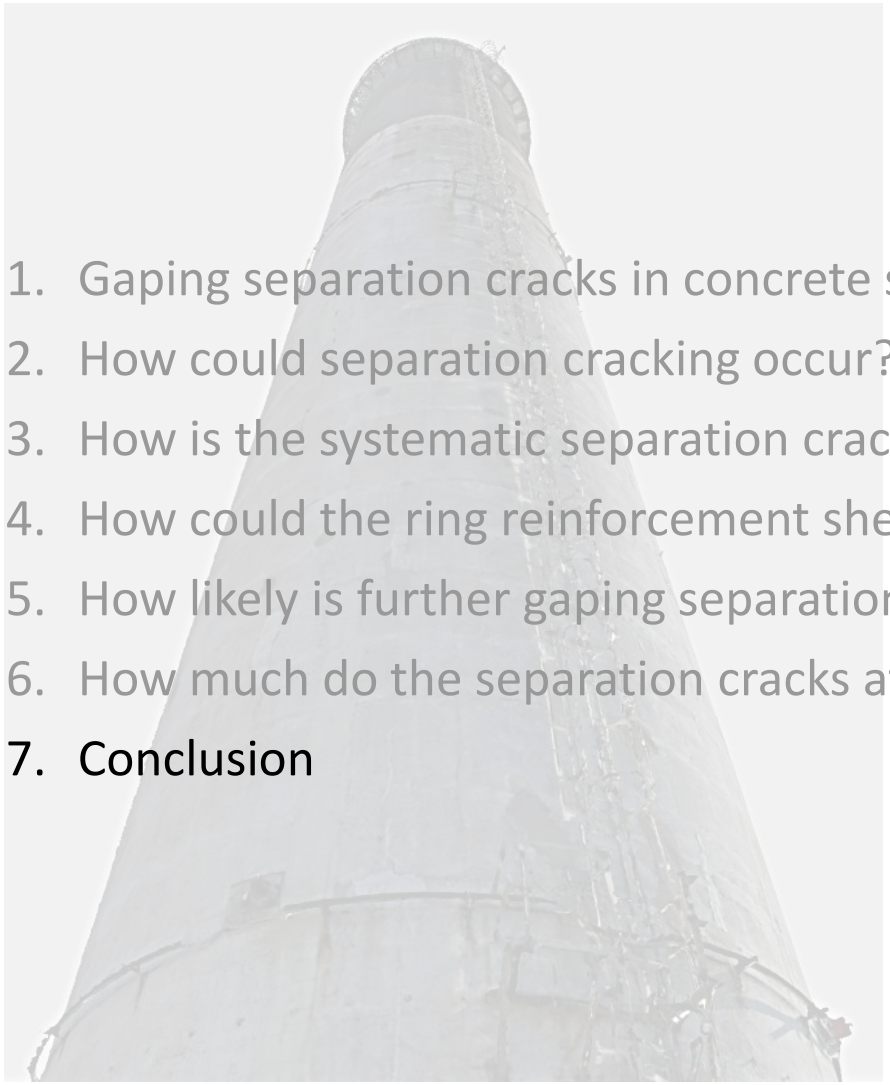

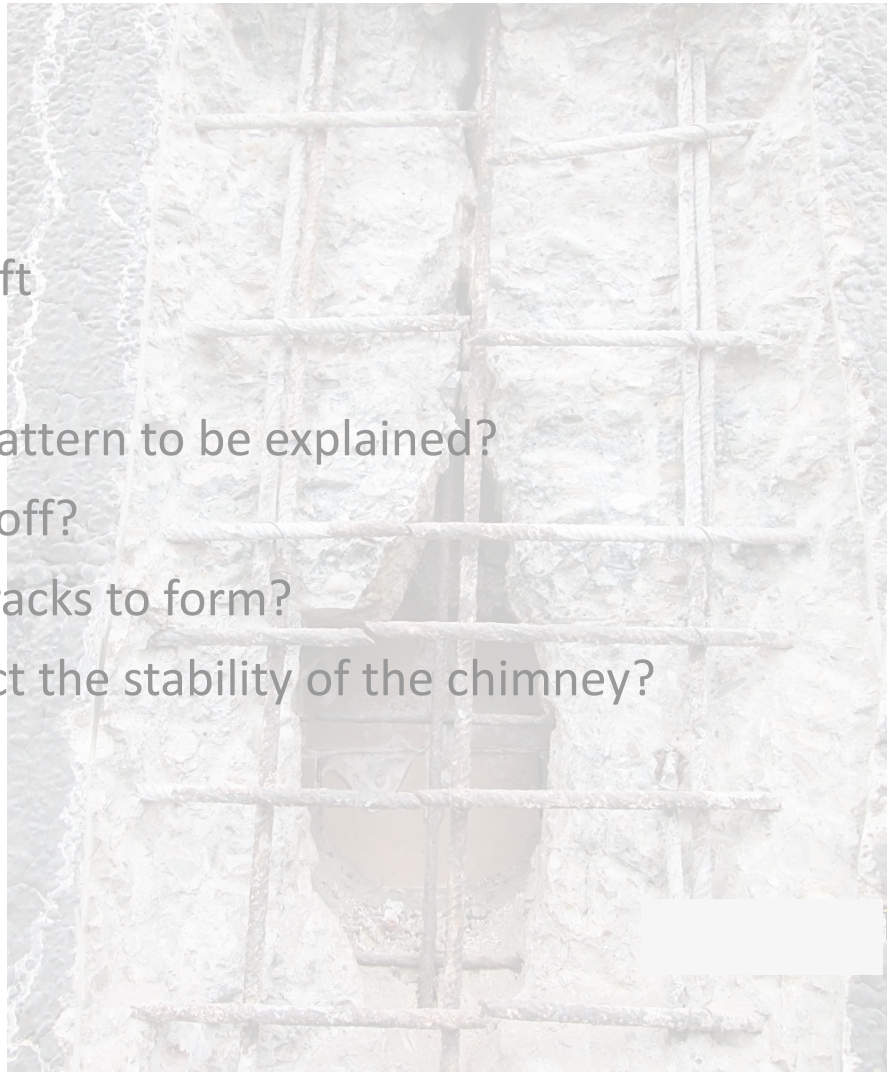

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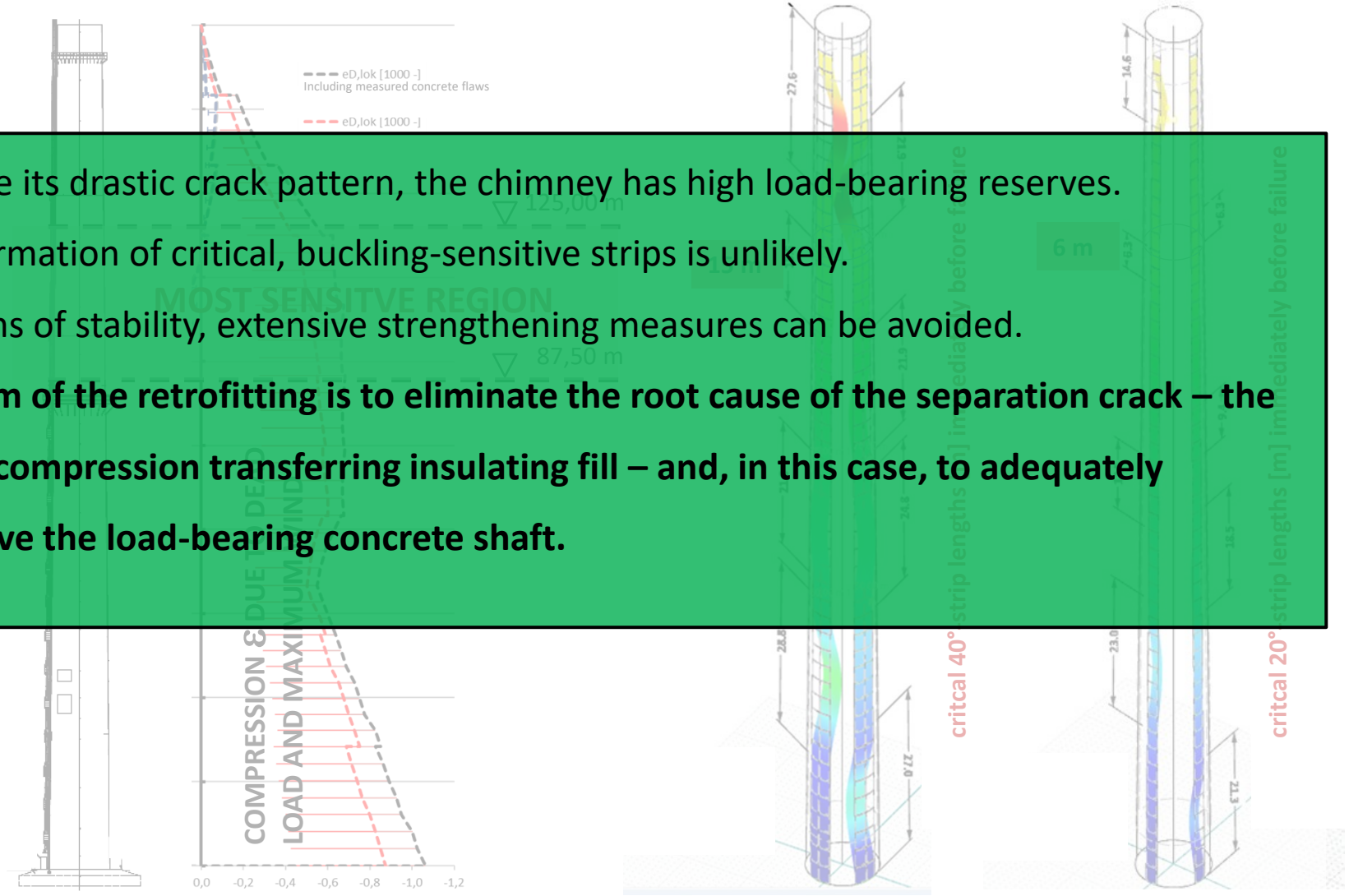

- Despite its drastic crack pattern, the chimney has high load-bearing reserves.
- The formation of critical, buckling-sensitive strips is unlikely.
- In terms of stability, extensive strengthening measures can be avoided.
- **The aim of the retrofitting is to eliminate the root cause of the separation crack – the radial compression transferring insulating fill – and, in this case, to adequately preserve the load-bearing concrete shaft.**

Conclusion