Feuerfest Symposium 2018

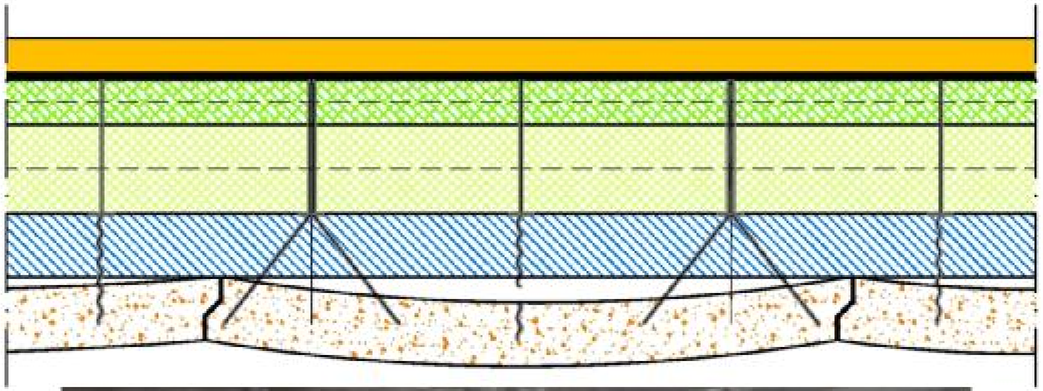
Ankerbrüche in der Flachdecke eines Industrieofens

Piotr Noakowski, Vladimir Lavrentyev

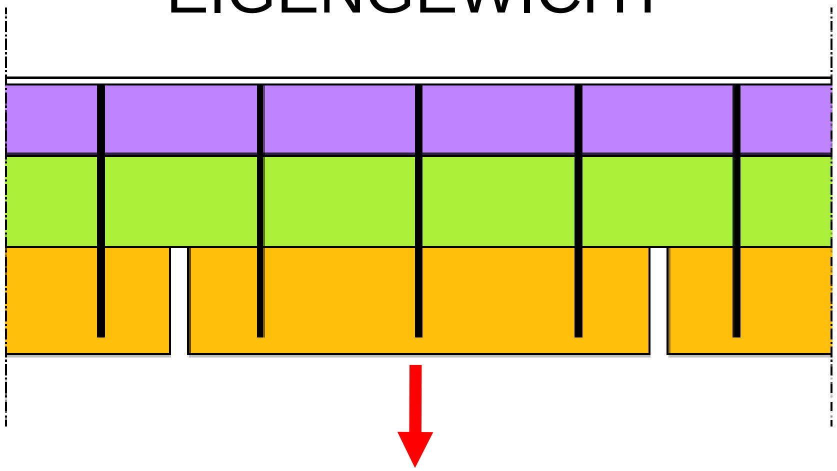
Exponent Industrial Structures

Geheimnis des ANKERBRUCHS in Flachdecken

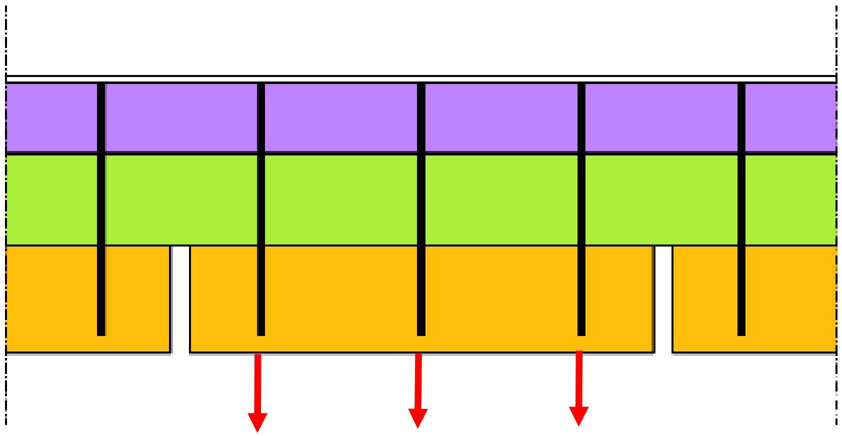
PHÄNOMEN DES ANKERBRUCHS



Beanspruchung
EIGENGEWICHT

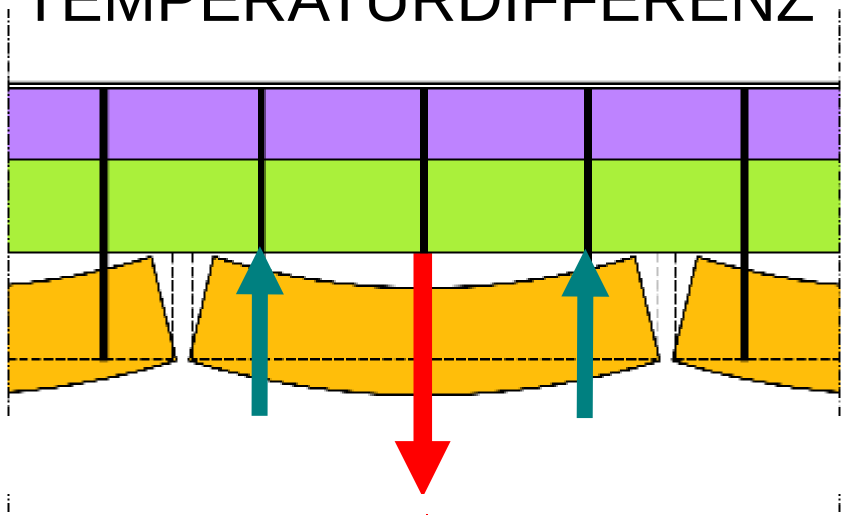


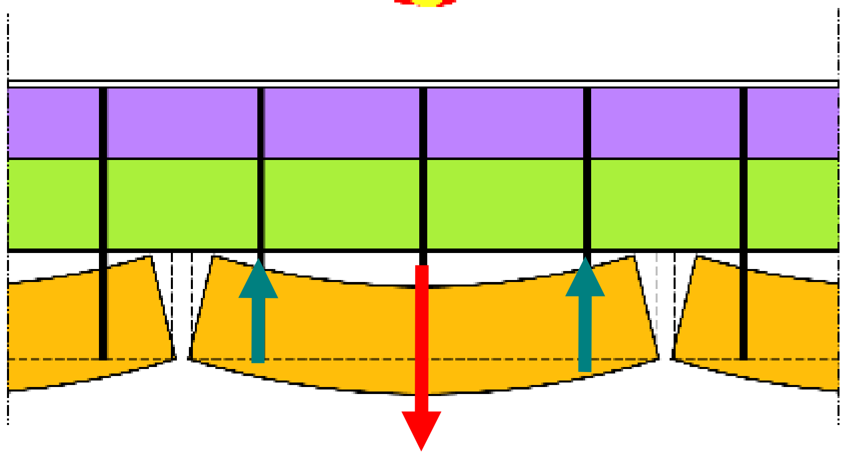
Kleines Plattengewicht
300 kg



Geringe Ankerspannungen
2 MPa

Beanspruchung
TEMPERATURDIFFERENZ





Große Ankerspannungen
100 MPa

Deutsche Gesellschaft
Feuerfest- und Schornsteinbau e.V.

dgfs

Refractory Engineering

Materials – Design – Construction

2nd revised and updated edition

VULKAN-VERLAG ESSEN

3.8 Static Calculations of Load-Bearing Parts

P. Noakowski, U. Posingis

3.8.1 General

In planning and designing refractory linings it is often noticed that the bearing (support) capacity of proven constructions can often not be proven with traditional calculation methods. Static verifications generally provide for higher loads than actually occur. Consequently, refractory engineering is still one of the few construction sectors where extensive static verifications are seldom made or requested. The experience of the experts is of primary importance in the planning and design stage of a refractory lining.

This situation is explained by the special importance and indeed "cleverness" of materials in their behavior as part of a refractory construction. These peculiarities can often not be taken into consideration by mathematical calculations. Therefore, one must rely on theory and practical experience.

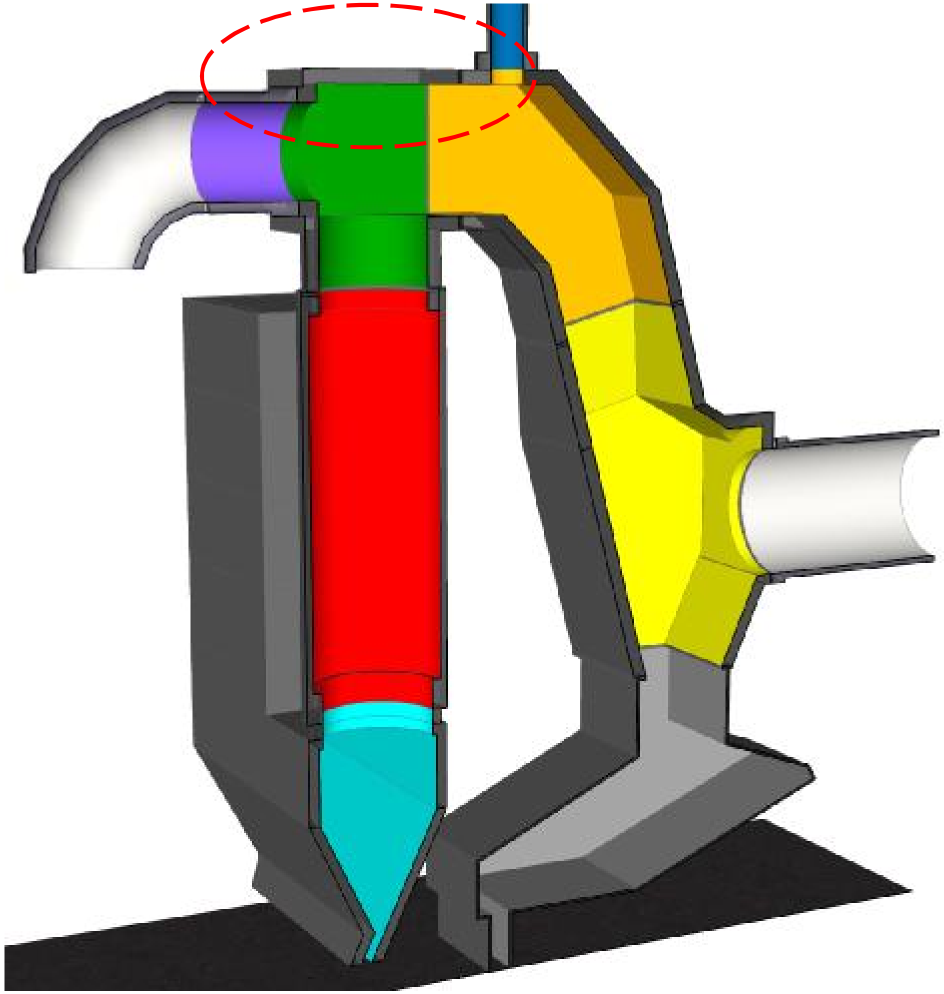
The most important factors to be considered for a static analysis of a refractory construction part are:

- The walls consist of several layers which have different functions to fulfill such as refractoriness, heat insulation, and load-bearing capability.
- Stress consists of load and constriction as a result of temperature. Usually constriction is predominant.
- Temperatures are often at 1,500 °C and above.
- Furnaces are heated up quickly resulting in predominantly non-stationary temperature conditions.
- The individual layers/courses are usually bricked. There are small gaps in the joints which can in part absorb the thermal expansion.
- In regard to tensile strength at high temperatures the brickwork joints are weak spots. They open up as soon as the low tensile strength of the mortar is surpassed.
- In order to prevent larger deformations due to the temperature stress, the construction parts are often designed with a system of expansion joints.
- The materials do not deform linearly once subjected to greater pressure loads.

1. Ausbildung der Flachdecke
2. Analyse der Anker
3. Analyse der Decke
4. Ursachen des Versagens
5. Verlängerung der Lebensdauer

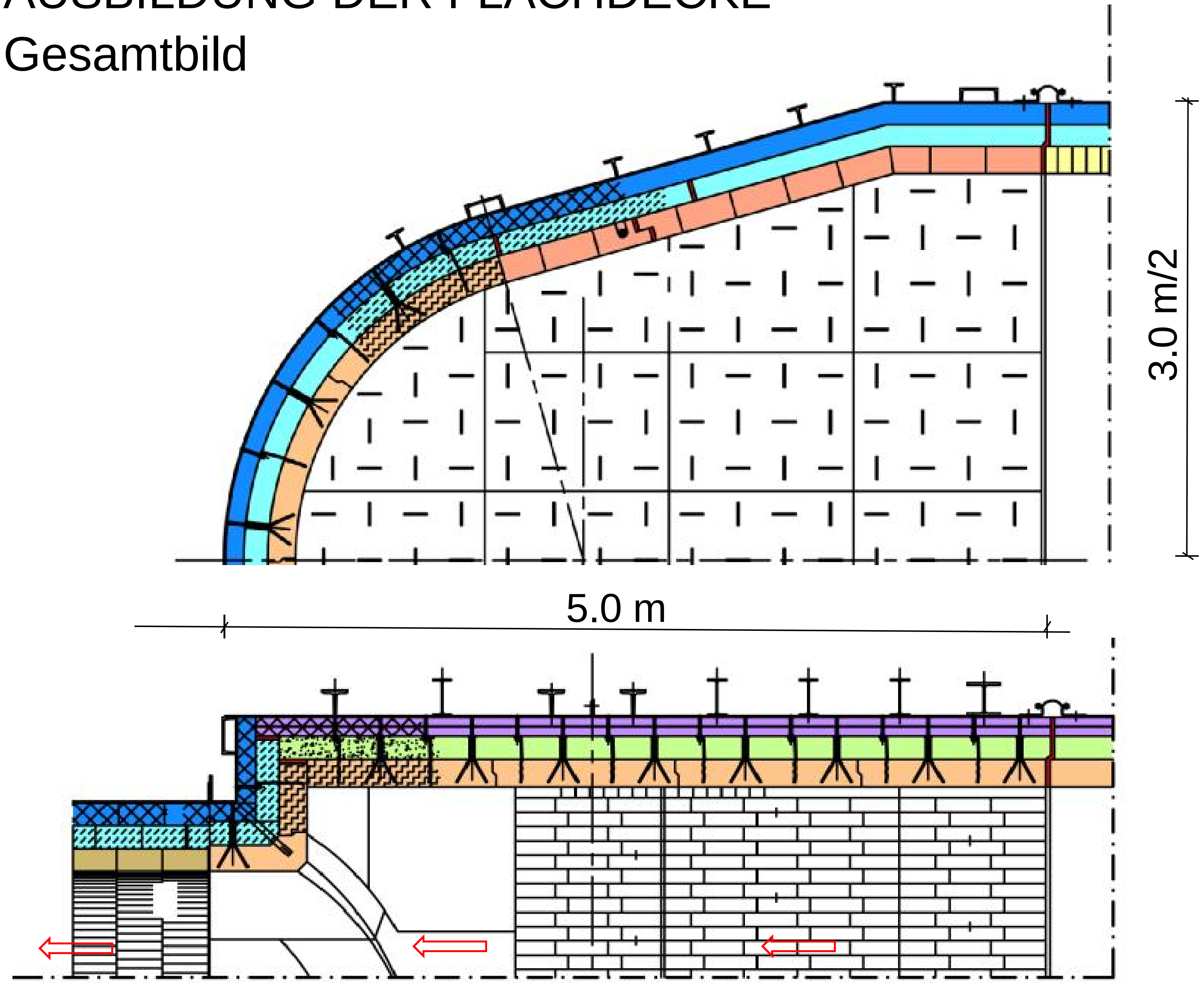
AUSBILDUNG DER FLACHDECKE
Anordnung

Obere Umlenkkammer 975°C



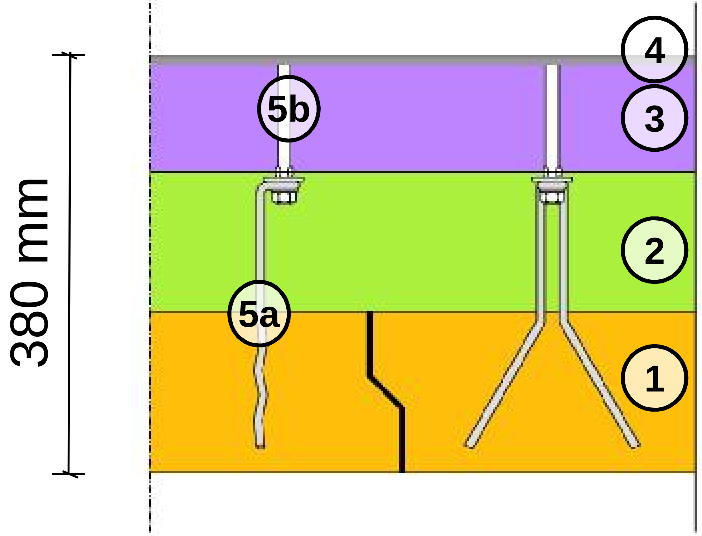
AUSBILDUNG DER FLACHDECKE

Gesamtbild



AUSBILDUNG DER FLACHDECKE

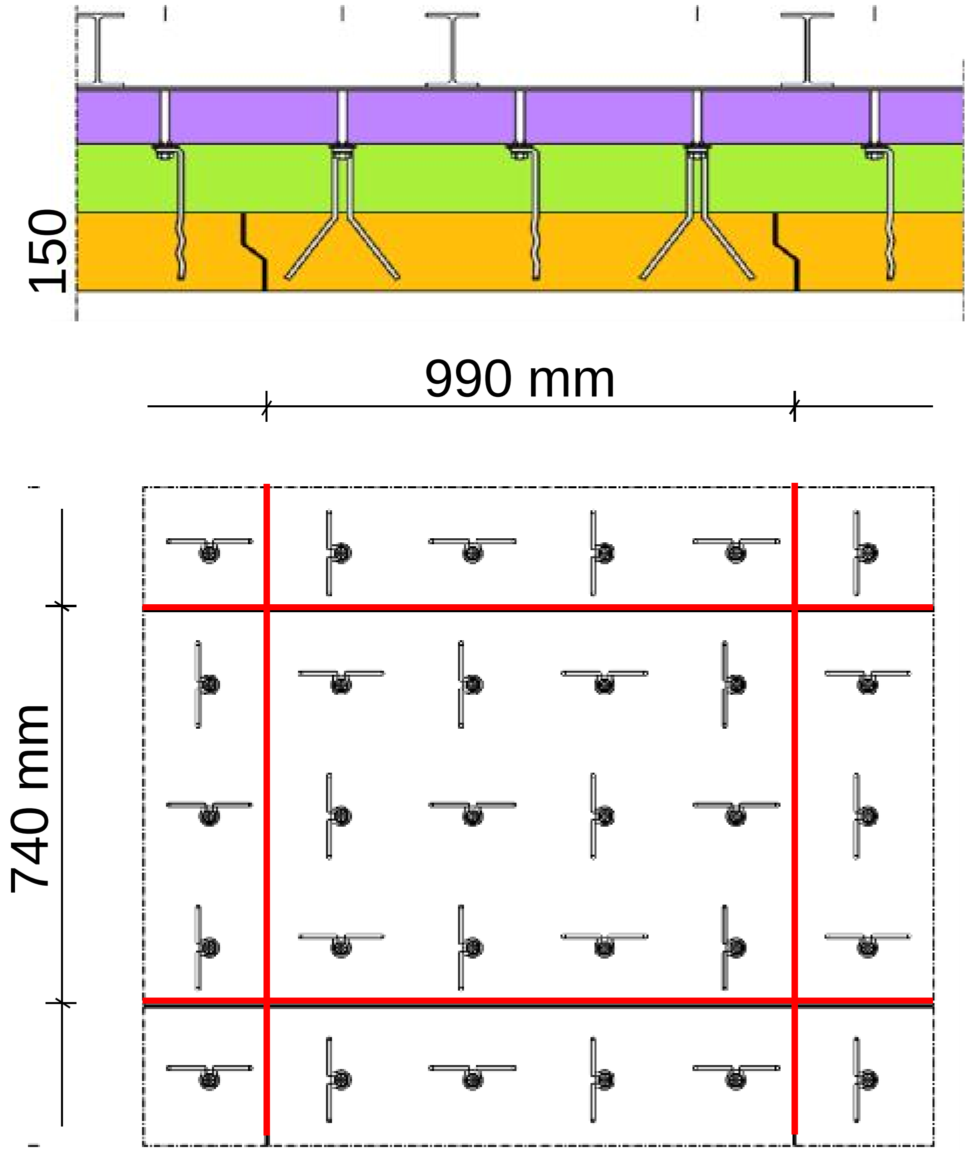
Schichtaufbau



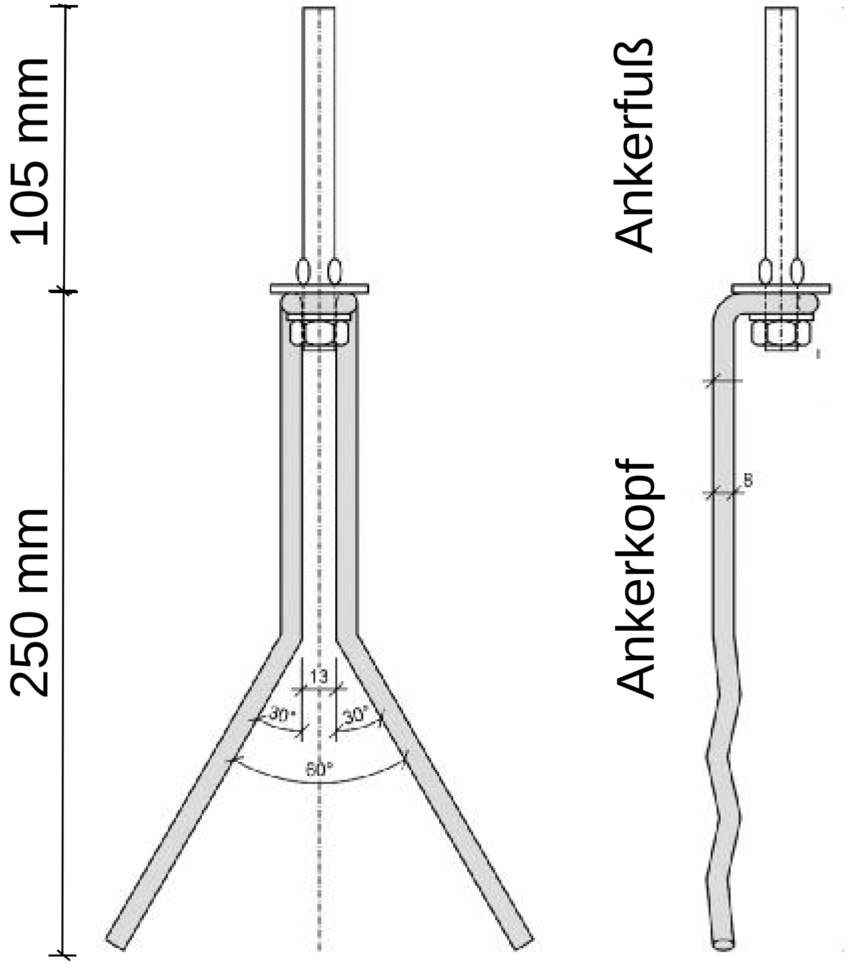
SCHICHT	MATERIAL	t [mm]	f_U [MPa]	f_t [MPa]	E [MPa]	a_T [-]	e_s [‰]	l [W/mK]
1	FF-Beton Fuge	150 5	60 (800°C)	~5	~20000	~7.0 10^{-6}	~3.0 (800°C)	1.16 (800°C)
2	Dämmung 1	130	1,2 (800°C)	~0	~10000	~2.9 10^{-6}	~7.0 (800°C)	0.19 (800°C)
3	Dämmung 2	2 x 50	1,6	~0	-	14.3 10^{-6}	~80.0	0.17 (800°C)
4	Stahlmantel	~10	275 (20°C)	275 (20°C)	210 000 (20°C)	12.0 10^{-6}	-	44,4
5a	Anker Kopf	2 x Ø 8	250 (20°C)	250 (20°C)	196 000 (20°C)	18.8 10^{-6} (600°C)	-	~11.9
5b	Anker Fuß	12	270 (20°C)	270 (20°C)	196 000 (20°C)	18.8 10^{-6} (600°C)	-	~12.6

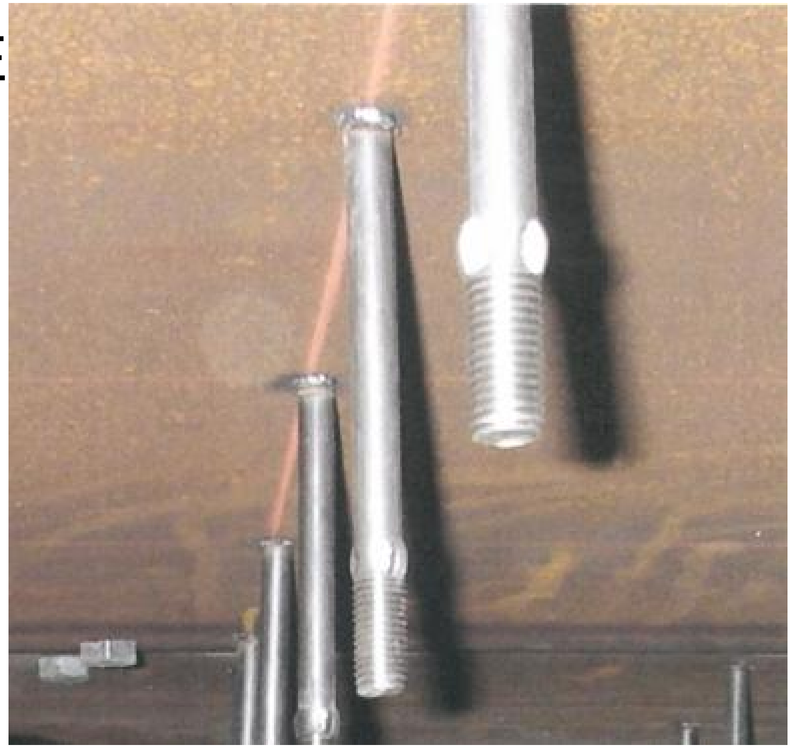
AUSBILDUNG DER FLACHDECKE

Ankeranordnung

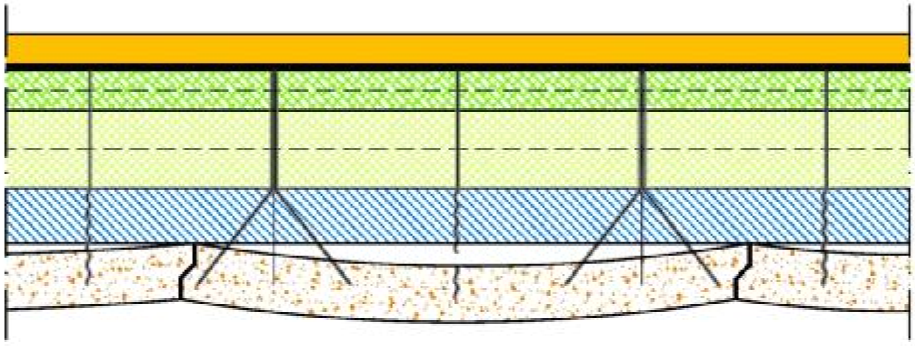


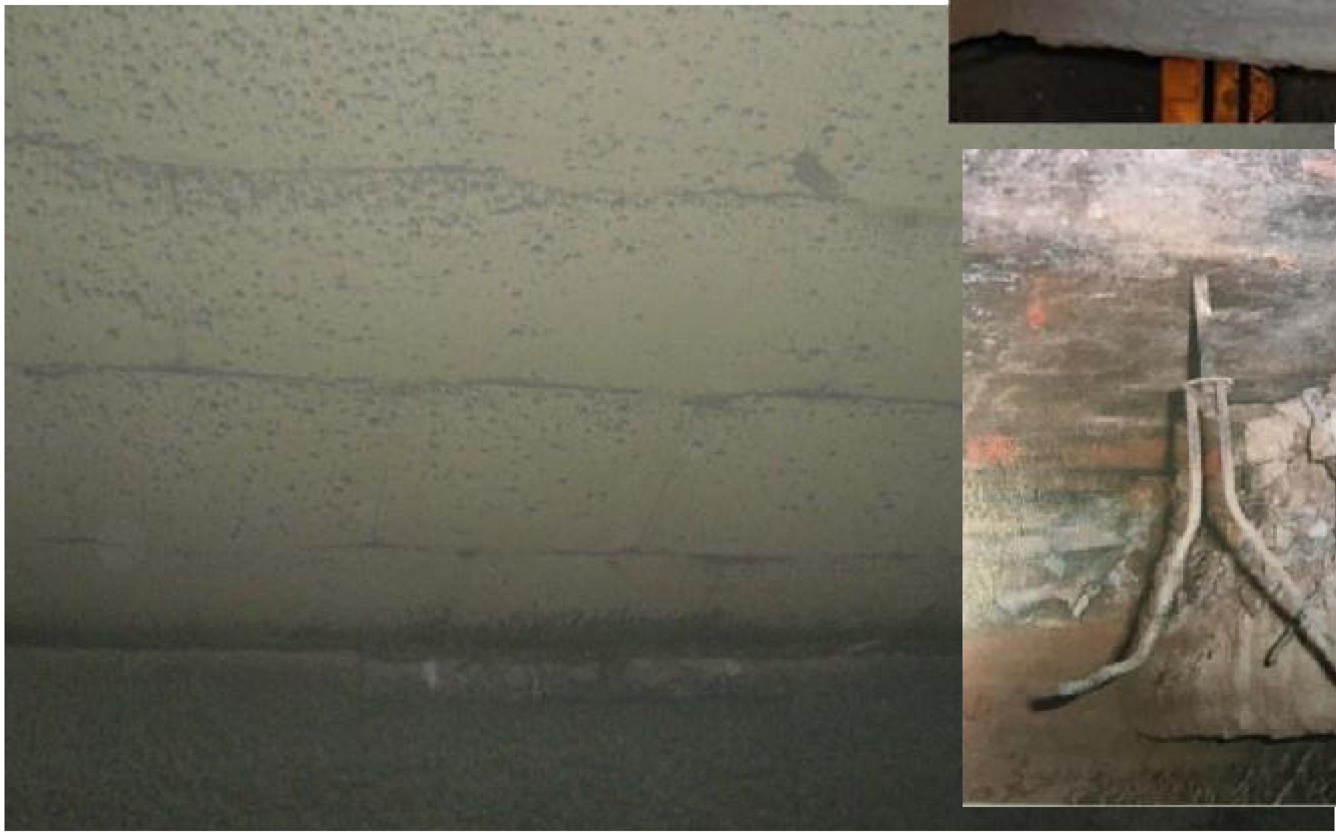
AUSBILDUNG DER FLACHDECKE
Ankerausbildung



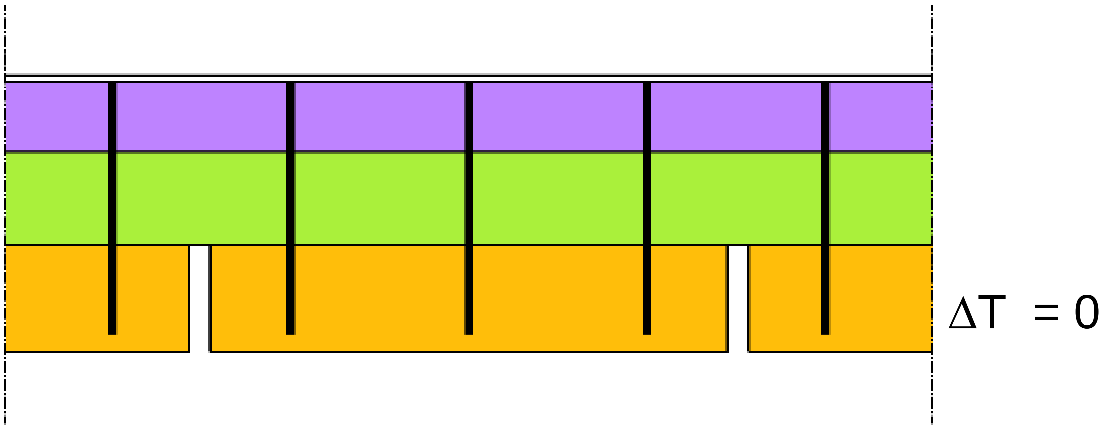


AUSBILDUNG DER FLACHDECKE
Ankerbruch





ANALYSE DER ANKER
Beanspruchung



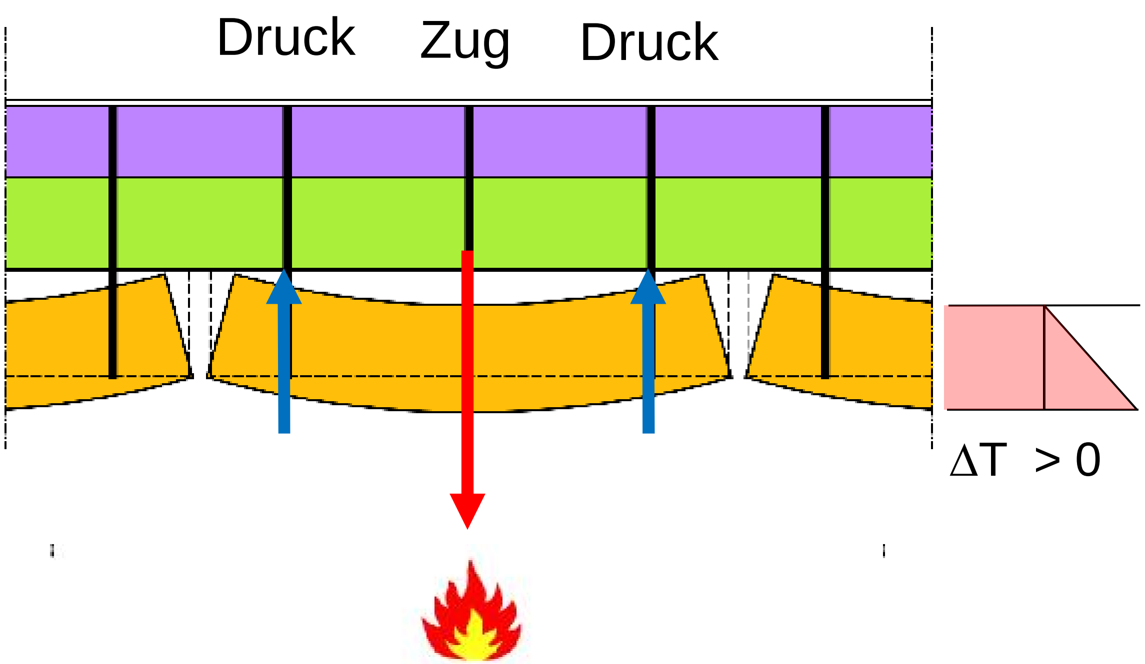
Keine Ankerbeanspruchung

Keine Temperaturdifferenz ΔT

Keine Deckenverkrümmung

Kein Widerstand der Anker

Keine Deckenbeanspruchung



Ankerbeanspruchung

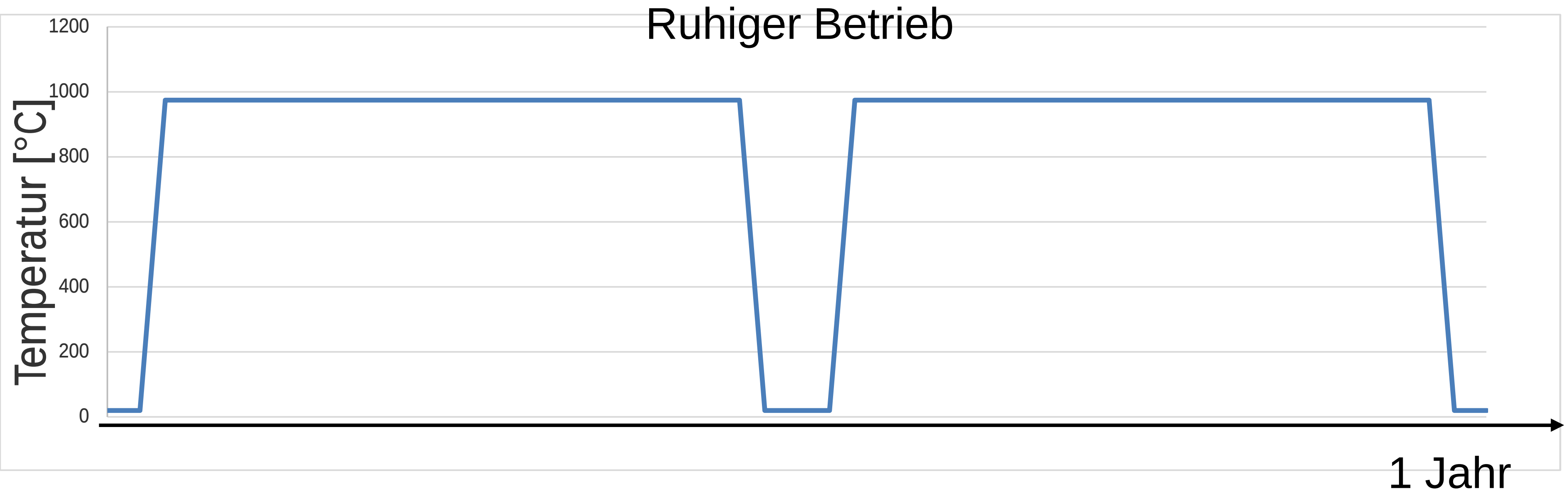
Temperaturdifferenz ΔT

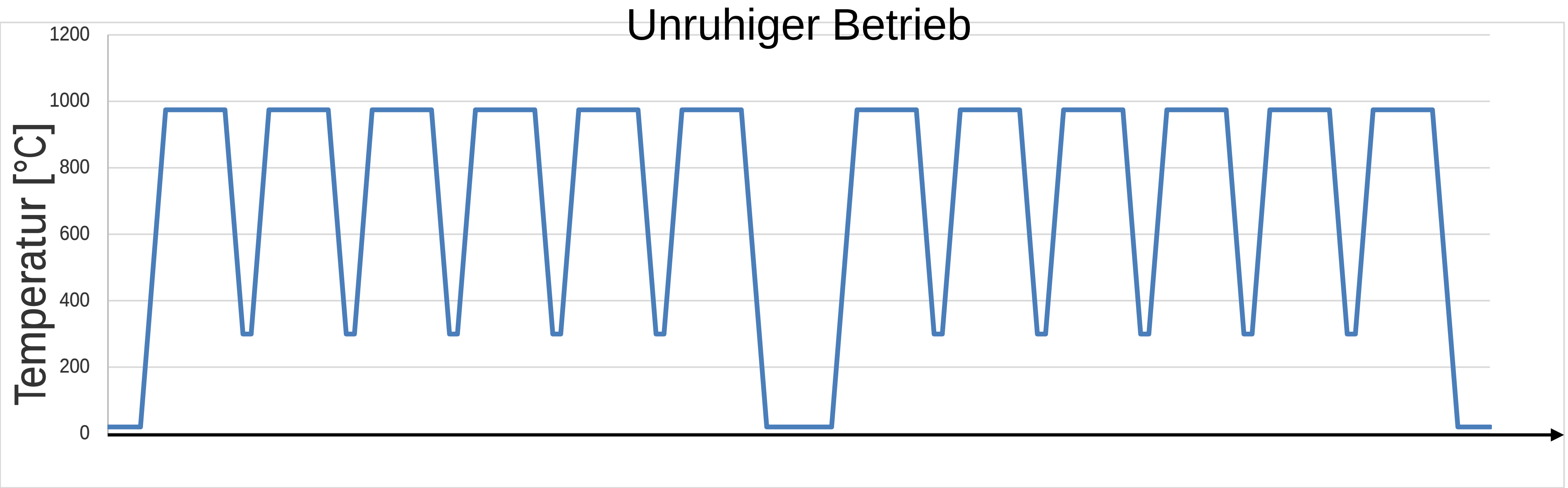
Deckenkrümmung

Widerstand der Anker

Deckenbeanspruchung

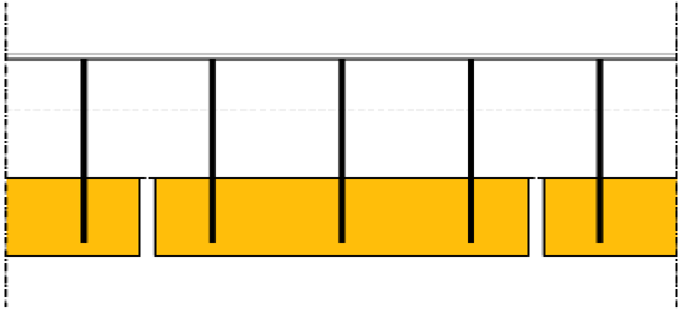
ANALYSE DER ANKER
Unruhiger Betrieb



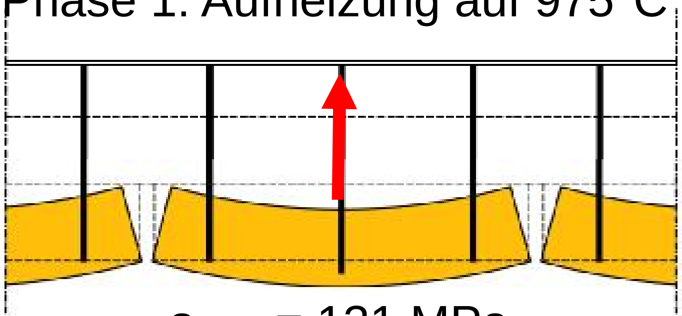


ANALYSE DER ANKER

Wechselbenspruchung der Anker

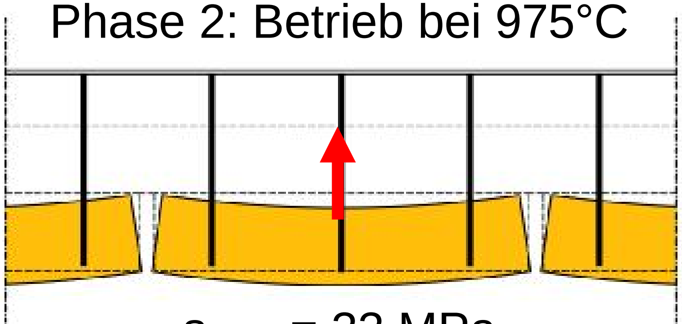


Phase 1: Aufheizung auf 975°C



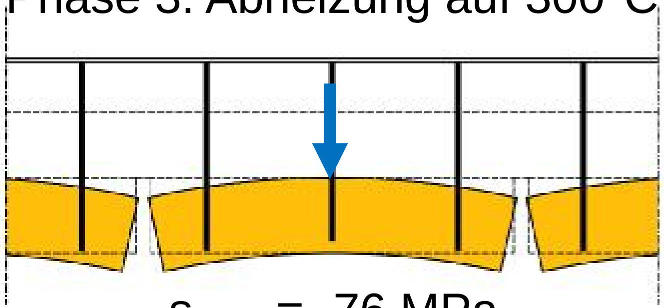
s_{1max}= 131 MPa

Phase 2: Betrieb bei 975°C



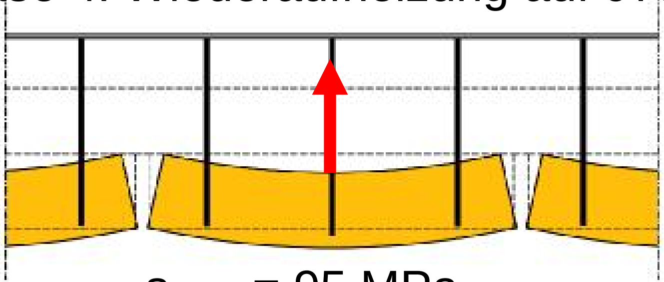
s_{2max}= 33 MPa

Phase 3: Abheizung auf 300°C



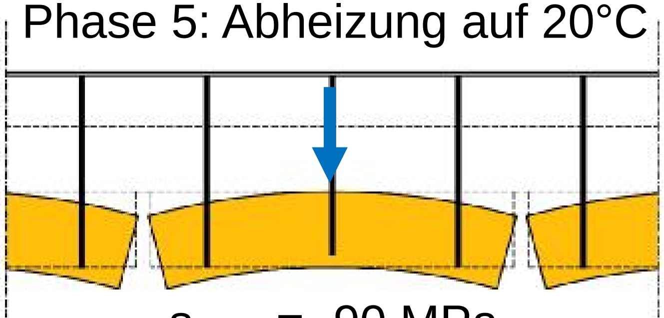
s_{3max}= -76 MPa

Phase 4: Wiederaufheizung auf 975°C



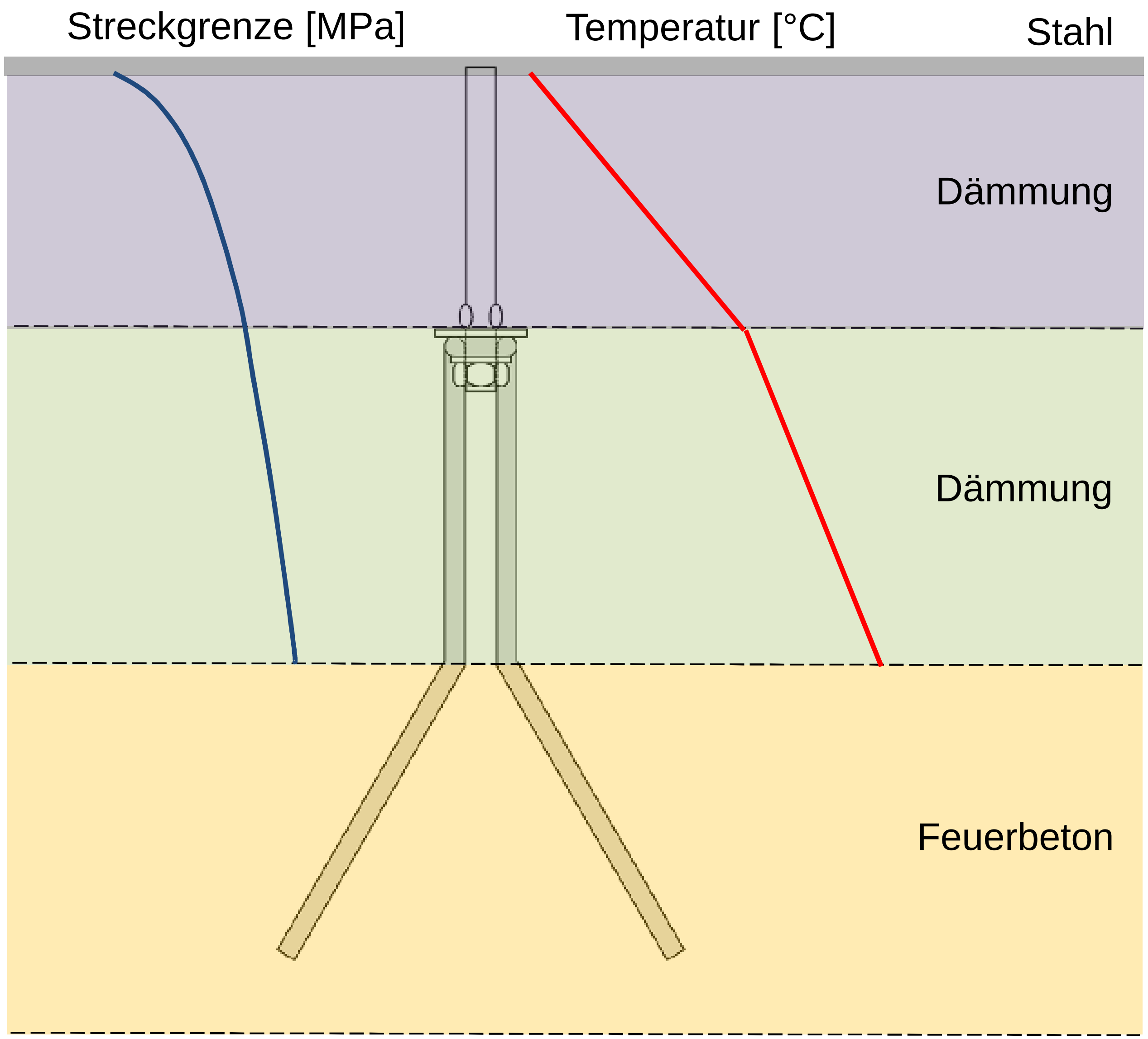
s_{4max}= 95 MPa

Phase 5: Abheizung auf 20°C



s_{5max}= -90 MPa

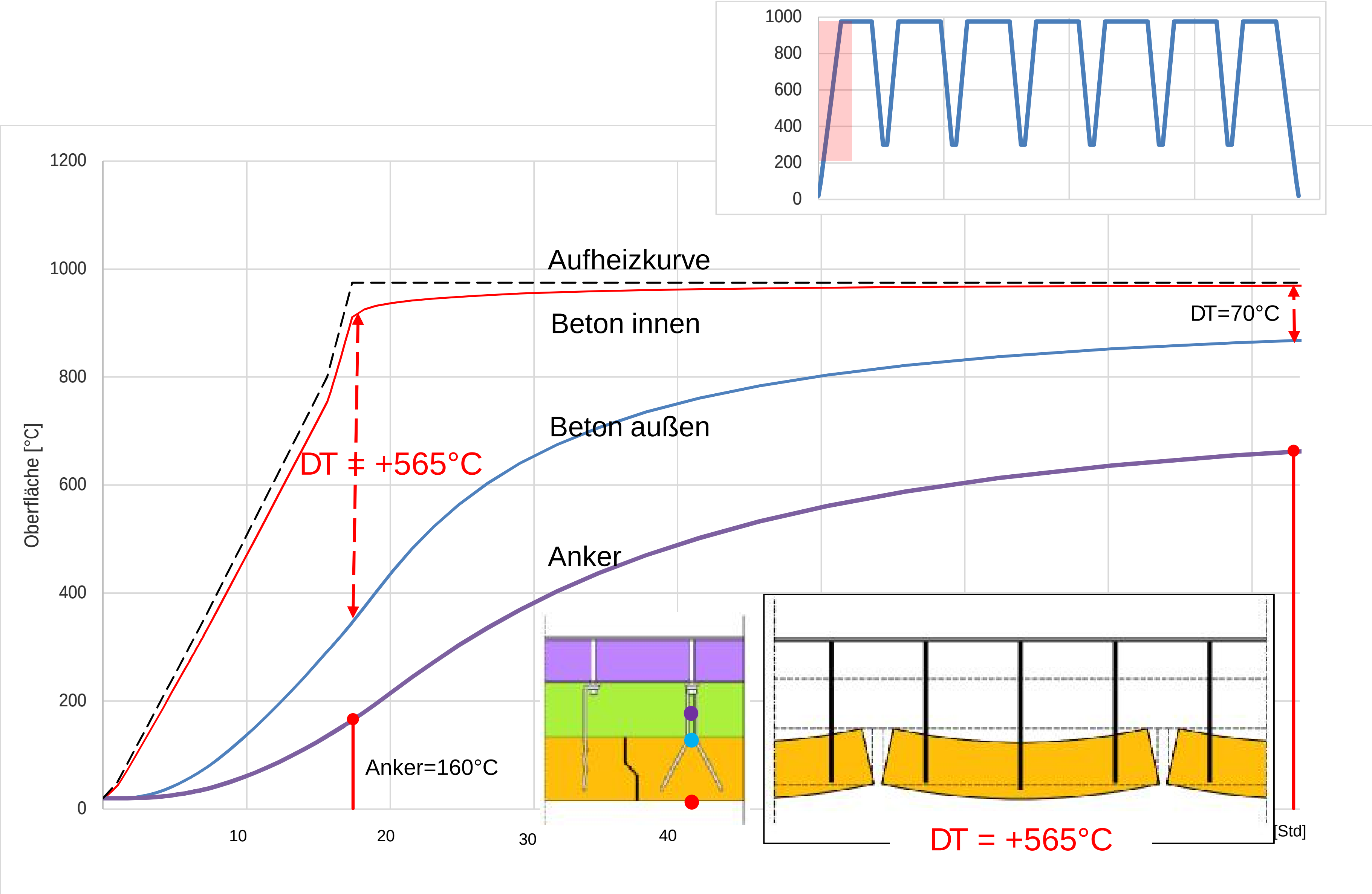
ANALYSE DER ANKER
Verschiedene Versagensarten der Anker



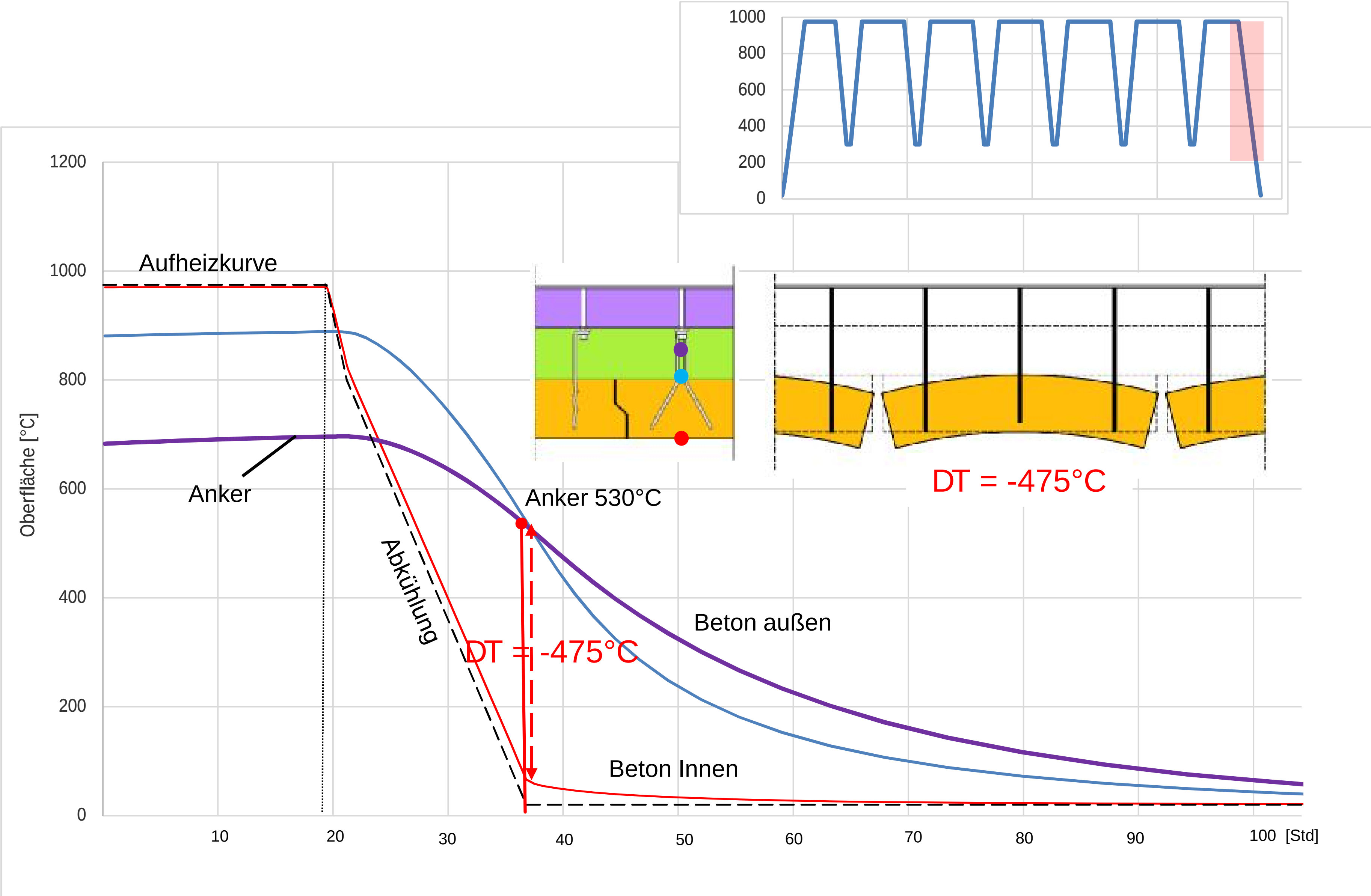
Versagen durch Wechselbeanspruchung der kalten und harten Schweißnähte

Versagen durch Dauerstandbeanspruchung der warmen und weichen Ankerschaftbereiche

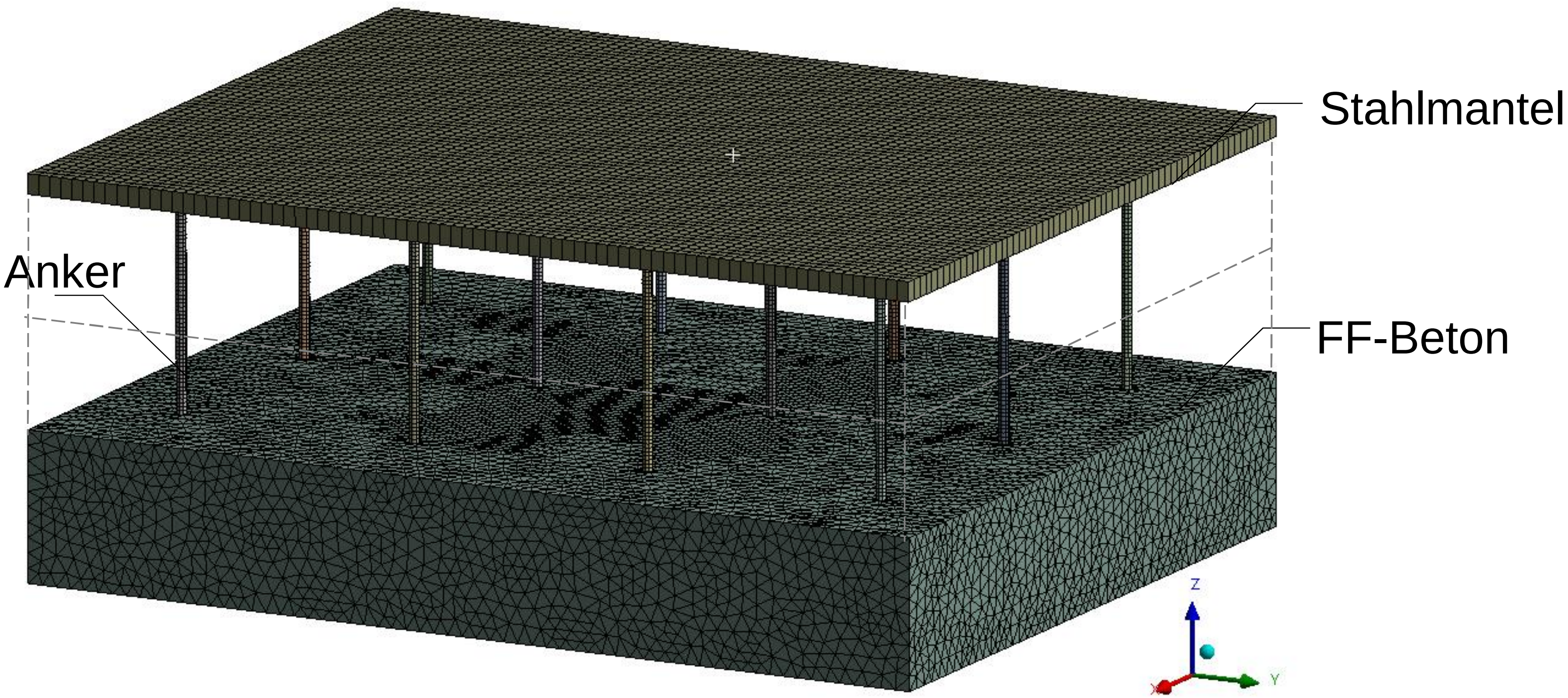
ANALYSE DER FLACHDECKE
DT und Plattenverbiegung bei Anheizen



ANALYSE DER FLACHDECKE
DT und Plattenverbiegung bei Abheizen

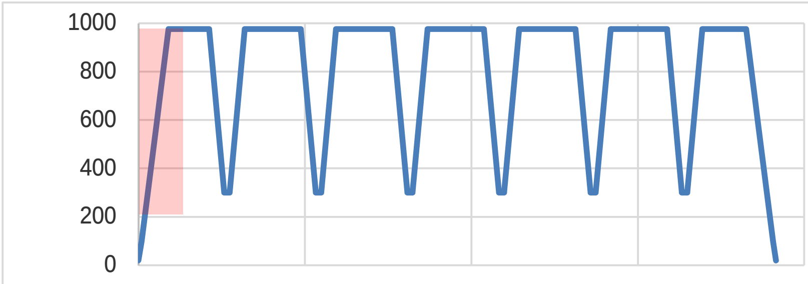


ANALYSE DER FLACHDECKE
Rechenmodell

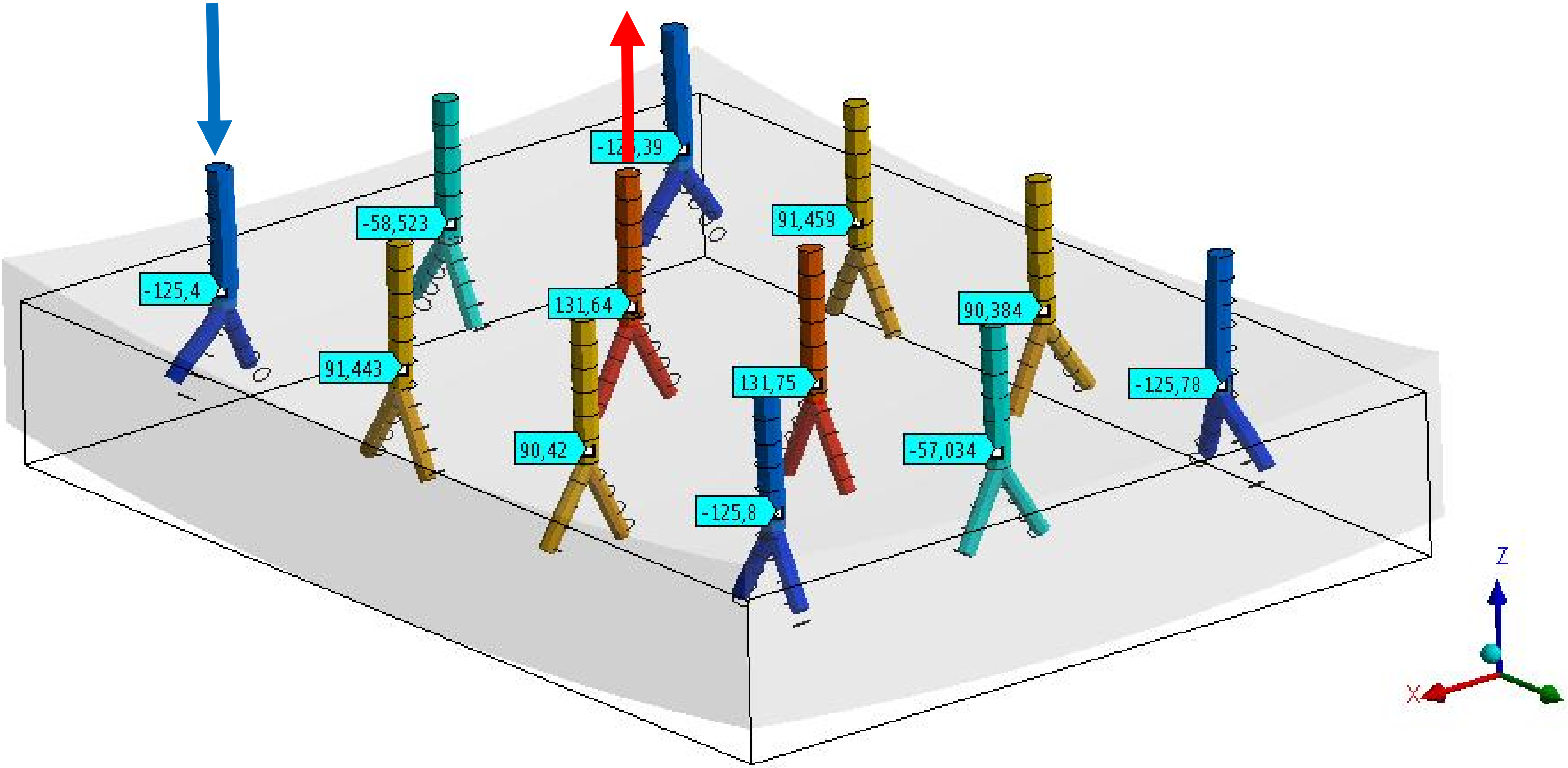


ANALYSE DER FLACHDECKE

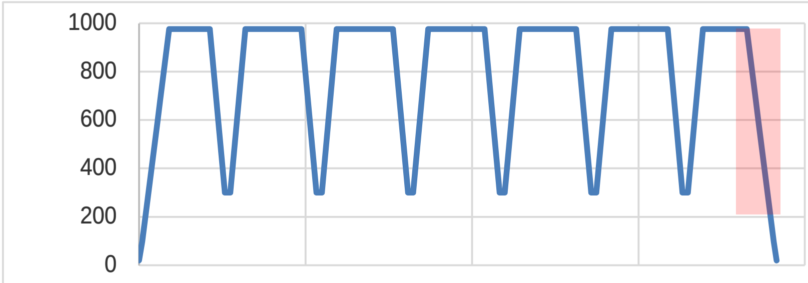
Ankerspannungen bei Anheizen



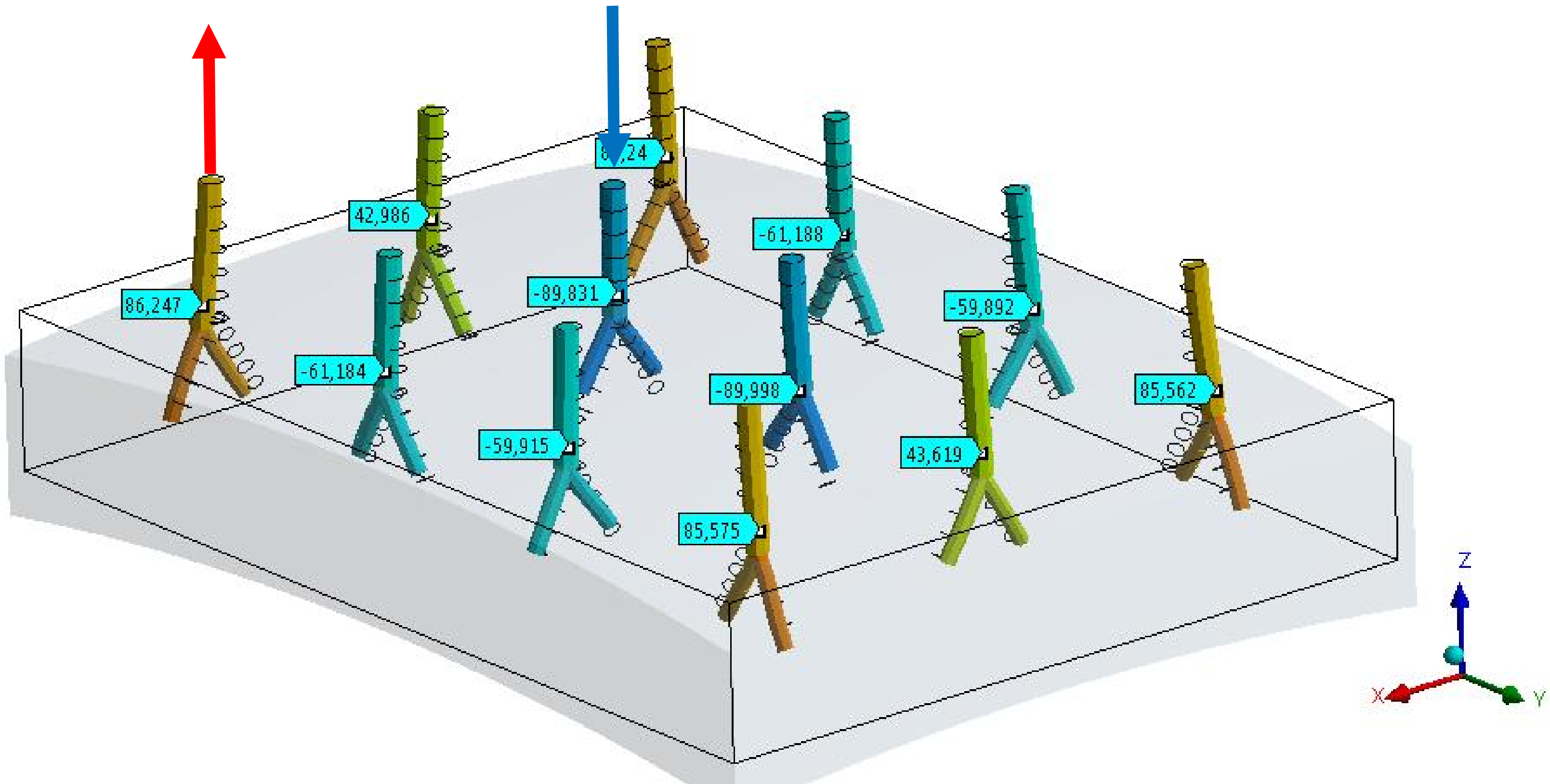
Innere Anker ZUG
Randanker DRUCK



ANALYSE DER FLACHDECKE
Ankerspannungen bei Abheizen

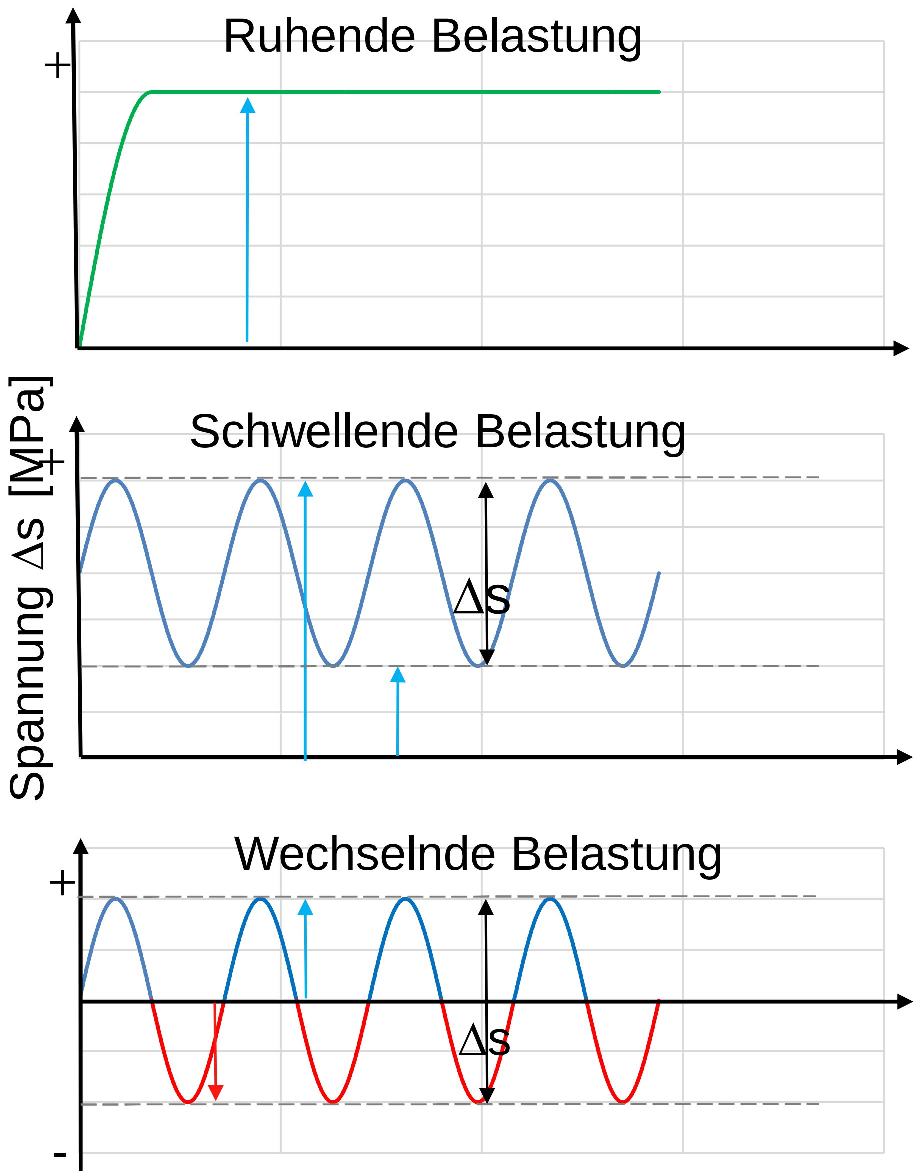


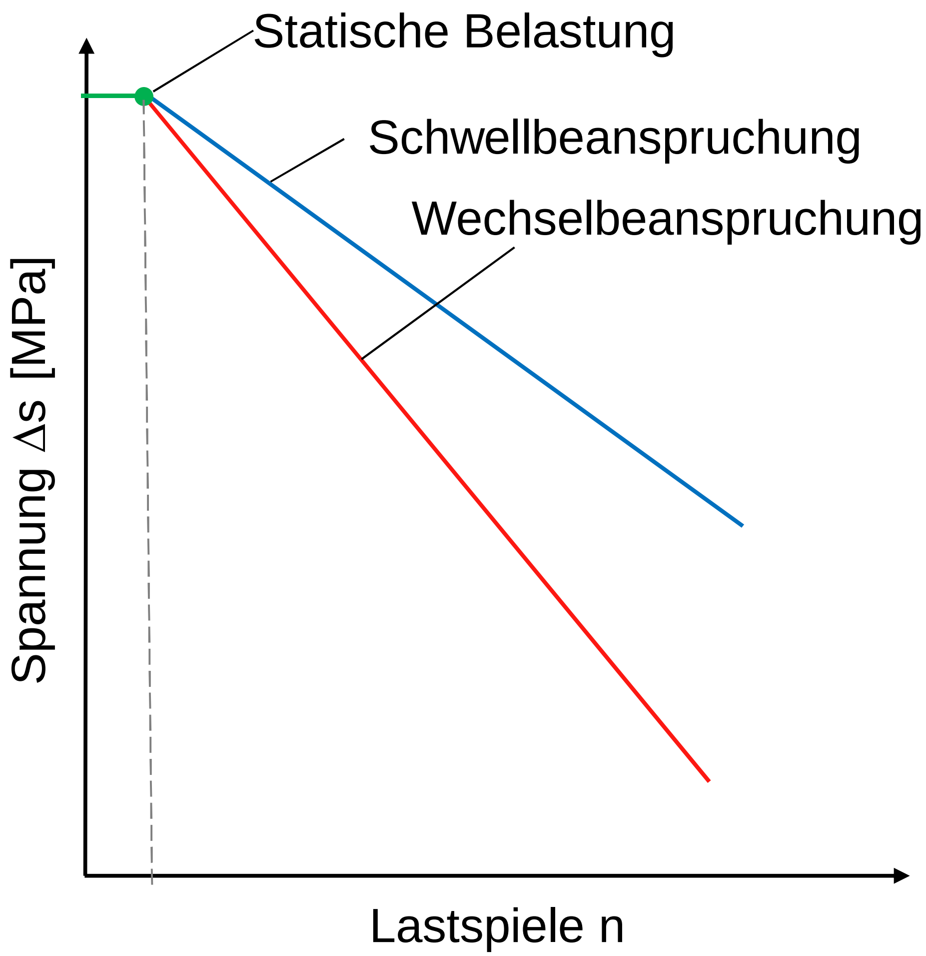
Innere Anker ZUG
Randanker DRUCK



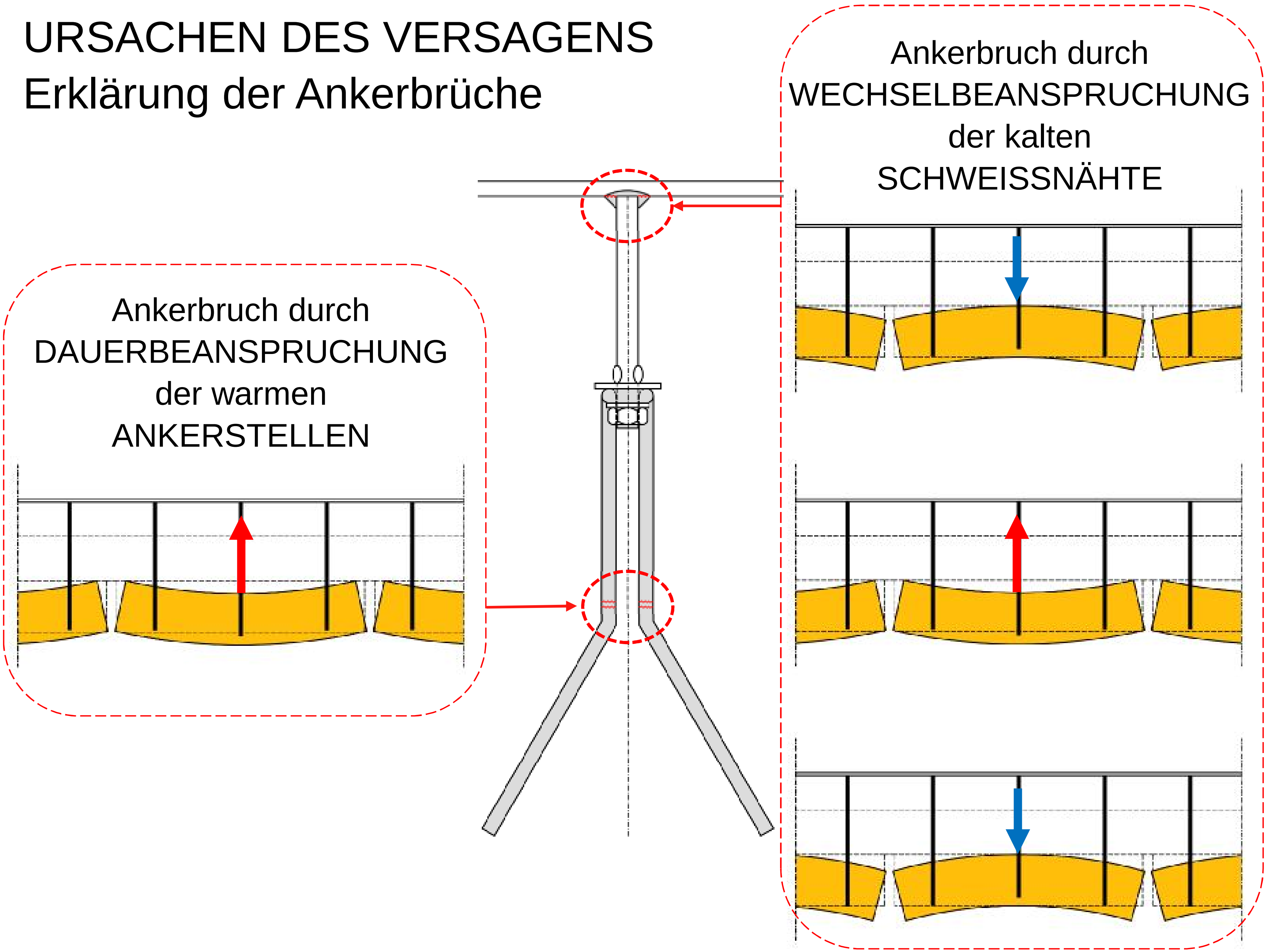
URSACHEN DES VERSAGENS

Ungünstige Wechselbeanspruchung





URSACHEN DES VERSAGENS
Erklärung der Ankerbrüche



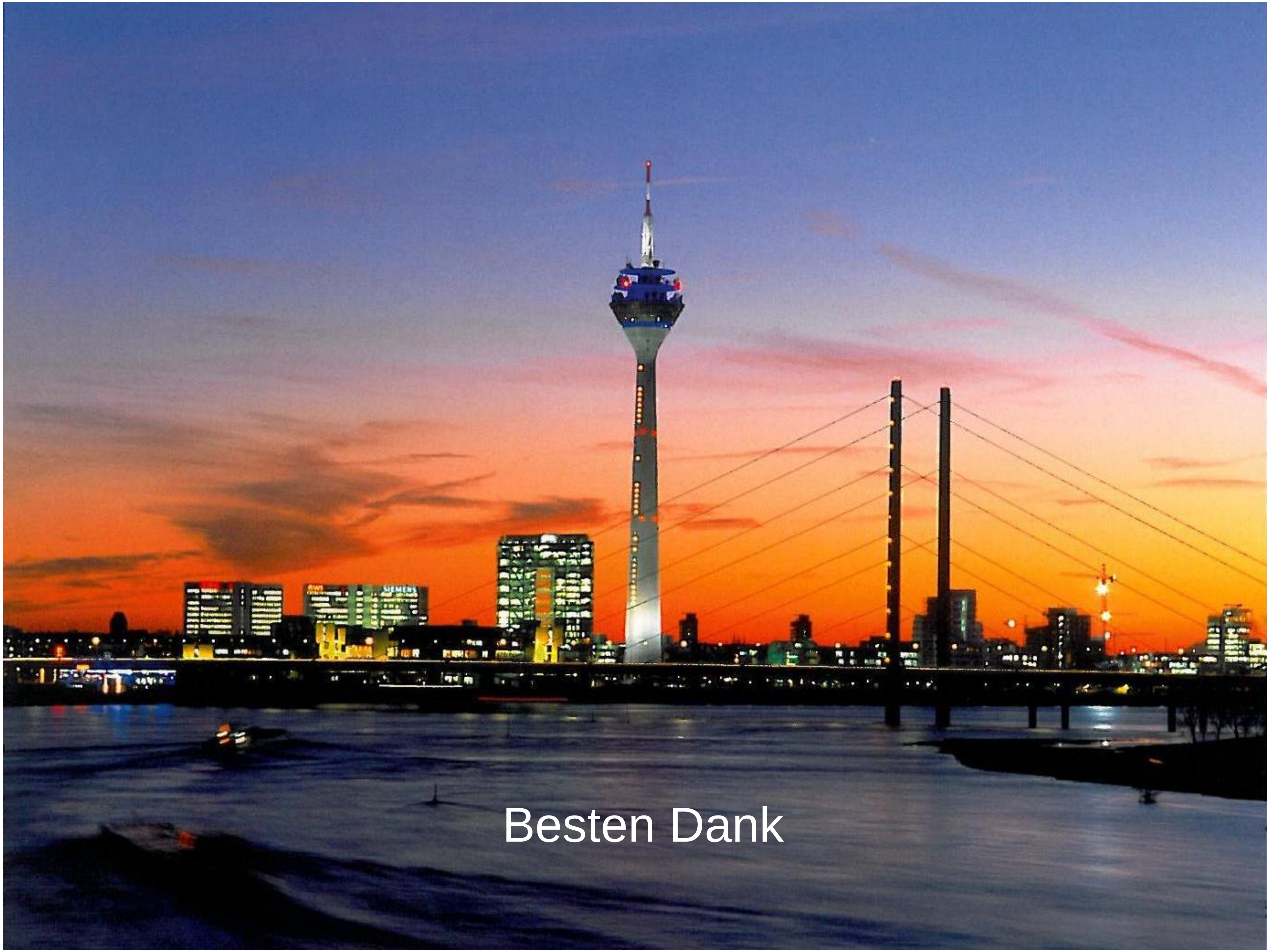
URSACHEN DES VERSAGENS
Maßnahmen zur Verlängerung der Lebensdauer

Kleinhaltung der Temperaturdifferenz in der Decke

Minimierung der Lastzyklen

Verlangsamung der An- und Abfahrvorgänge

Verwendung von ermüdungsfesten Ankern


Besten Dank