

WYMIAROWANIE W ŻELBECIE na właściwe momenty zginające

Piotr Noakowski

Technische Universität Dortmund

Exponent Industrial Structures Düsseldorf

CONTENT

Sources

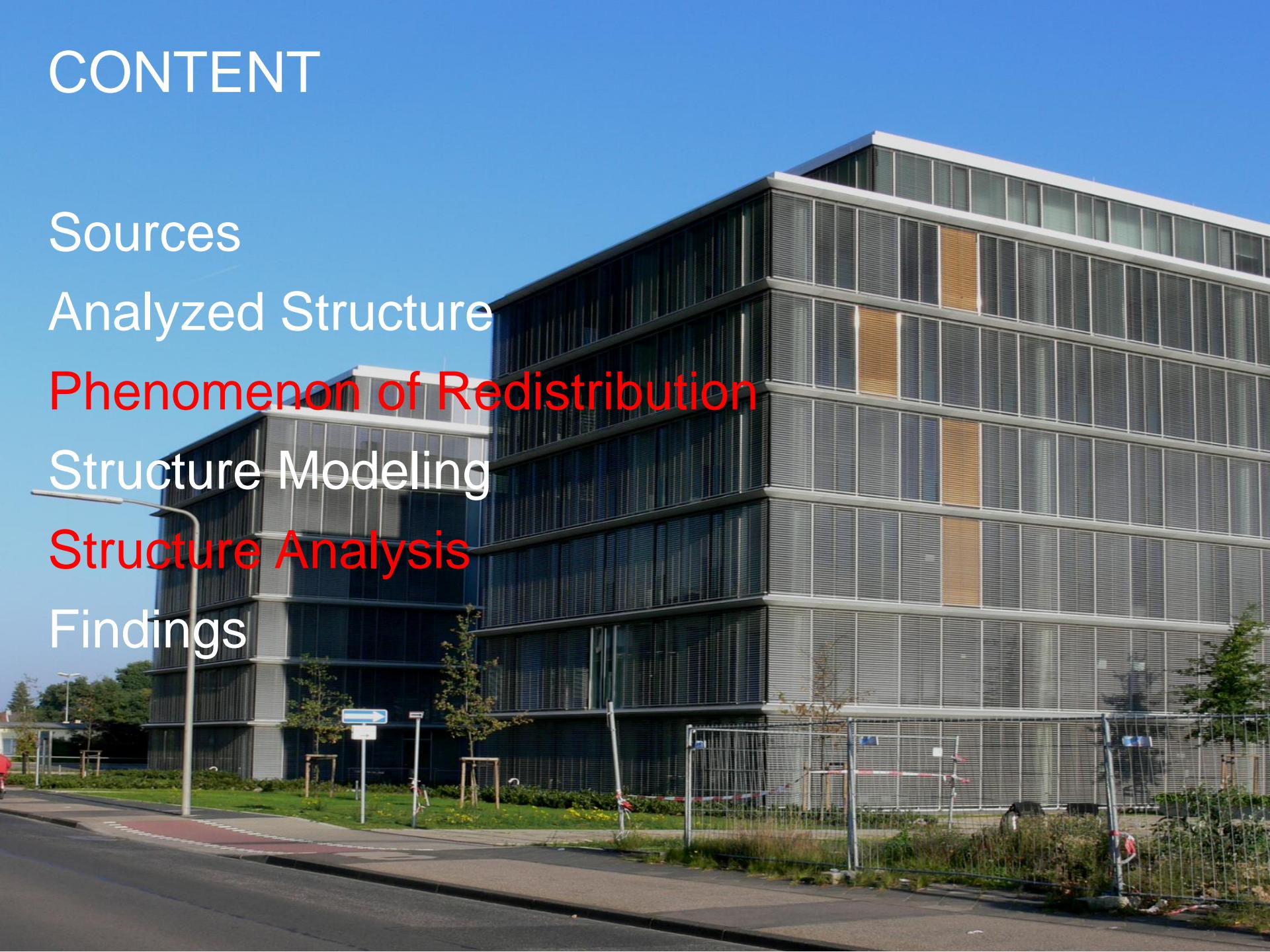
Analyzed Structure

Phenomenon of Redistribution

Structure Modeling

Structure Analysis

Findings



SOURCES, Lectures

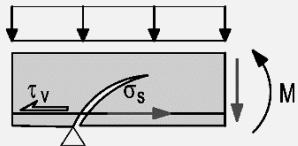
Statics of reinforced Concrete

Piotr Noakowski
Horst G. Schäfer

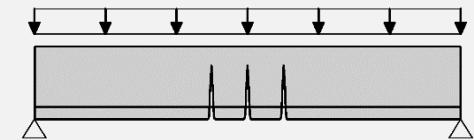
Steifigkeitsorientierte Statik im Stahlbetonbau

Stahlbetontragwerke
einfach richtig berechnen

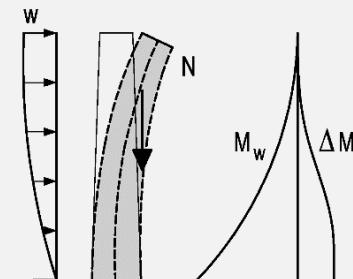
a) Endverankerung



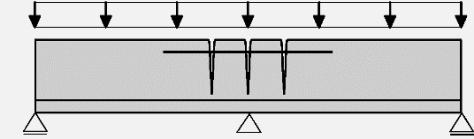
b) Durchbiegungen



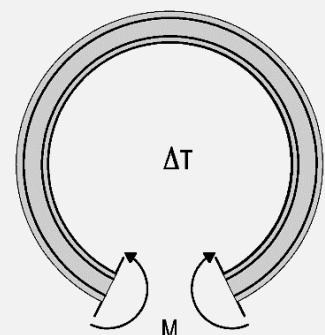
c) Momente 2. Ordnung



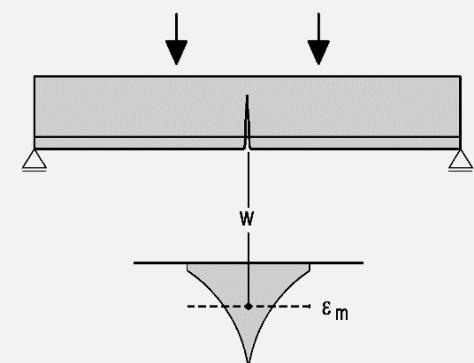
d) Momentenumlagerung



e) Zwang



f) Rissbreite



SOURCES, Trainings



Ingenieurakademie West e.V.

Fortbildungswerk der Ingenieurkammer-Bau NRW



Seminar

Schäden und Verstärkungen bei Industriebauwerken
10. März 2017

Referenten

Prof. Dr.-Ing. Piotr Noakowski
öbuSV (IHK NRW)

Dr.-Ing. Andreas B. Harling
öbuSV (IK-Bau NRW)

Fortbildungswerk der Ingenieurkammer-Bau NRW, Ingenieurakademie

2. BEHÄLTER Qatar
Schäden und Verstärkungen bei Industriebauwerken
Behälter, Bodenplatte, Fernsehtürme, Fundamentplatte, Hallenwände, Industrieboden, Mu
Piotr Noakowski, Prof. Dr.-Ing., öbuSV
Andreas Harling, Dr.-Ing., öbuSV

INHALT

1. Structure
 2. Damage
 3. Structure Analysis
 4. Section Analysis
 5. Explanation
-



SOURCES, Standards

DIN EN 13084-2



ICS 91.060.40

Supersedes
DIN EN 13084-2:2002-04

$$w_k = 3,5 \left(\frac{\sigma_{sr}^{0,88} \times d_s}{f_{cm}^{\frac{2}{3}}} \right)^{0,89} \times \frac{\sigma_s - 0,4 \times \sigma_{sr}}{E_s}$$

w_k

Characteristic crack width [mm]

σ_{cr}(M_{cr}, N_{cr})

Crack stress [MN/m²]

σ_s(M, N)

Real steel stress [MN/m²]

f_{cm}

Tensile strength of concrete [N/m²]

E_s

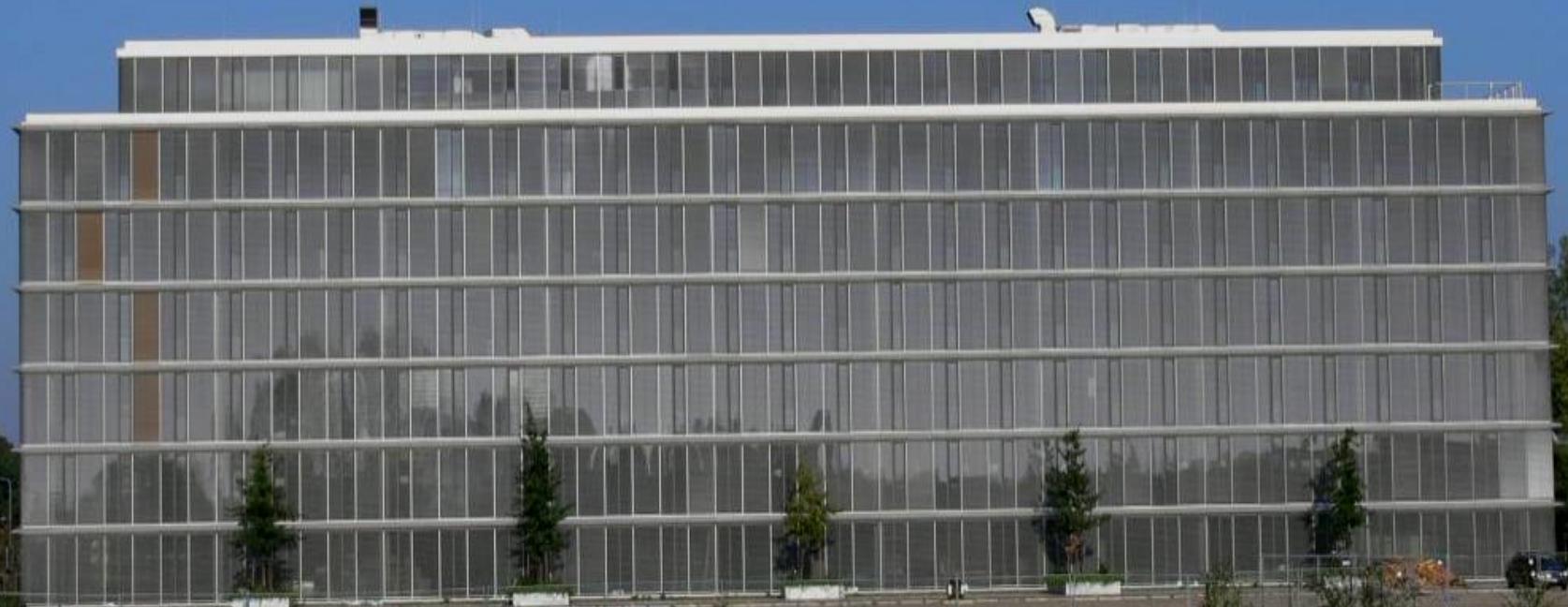
E-Modulus for reinforcement [MN/m²]

d_s

Bar diameter [mm]

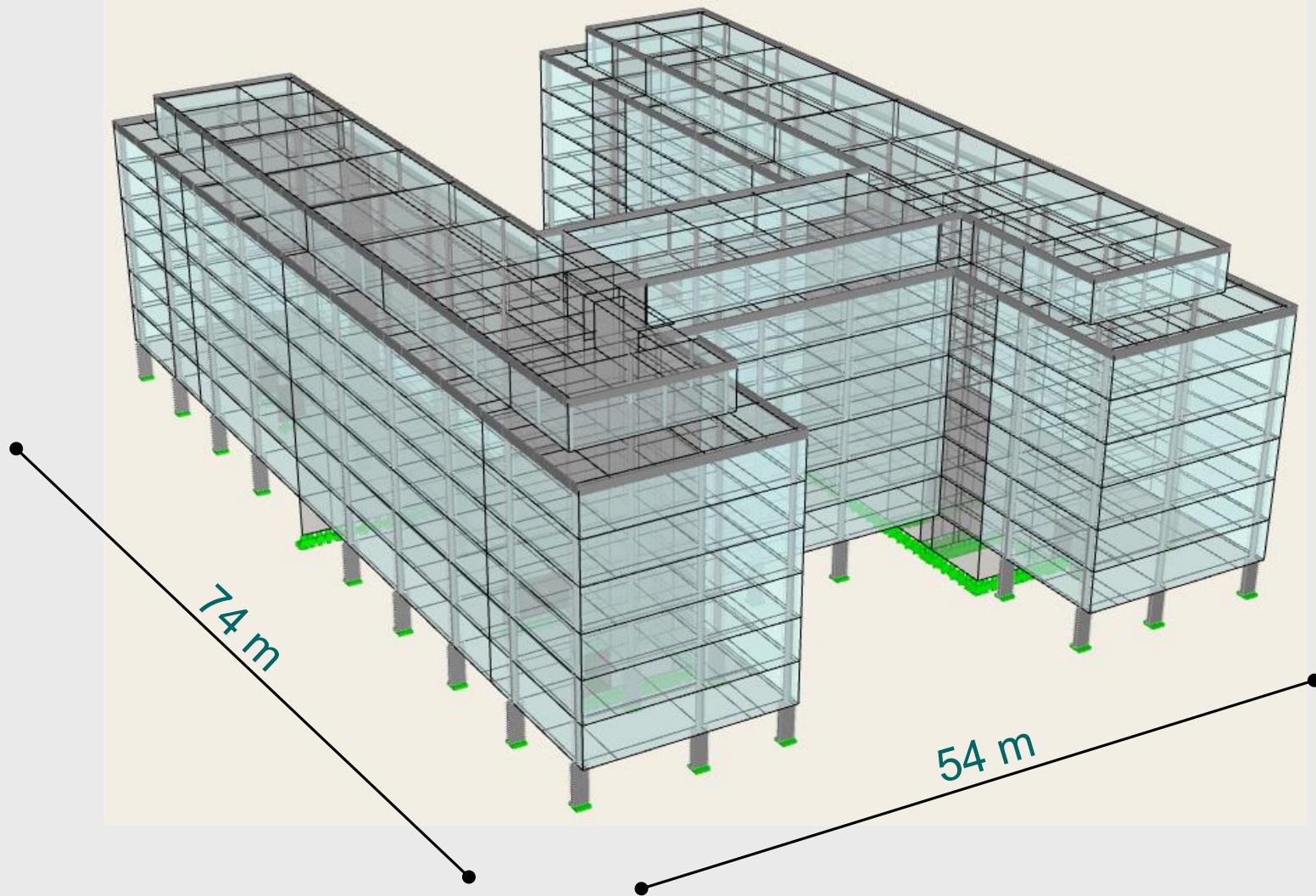
ANALYZED STRUCTURE

Front View



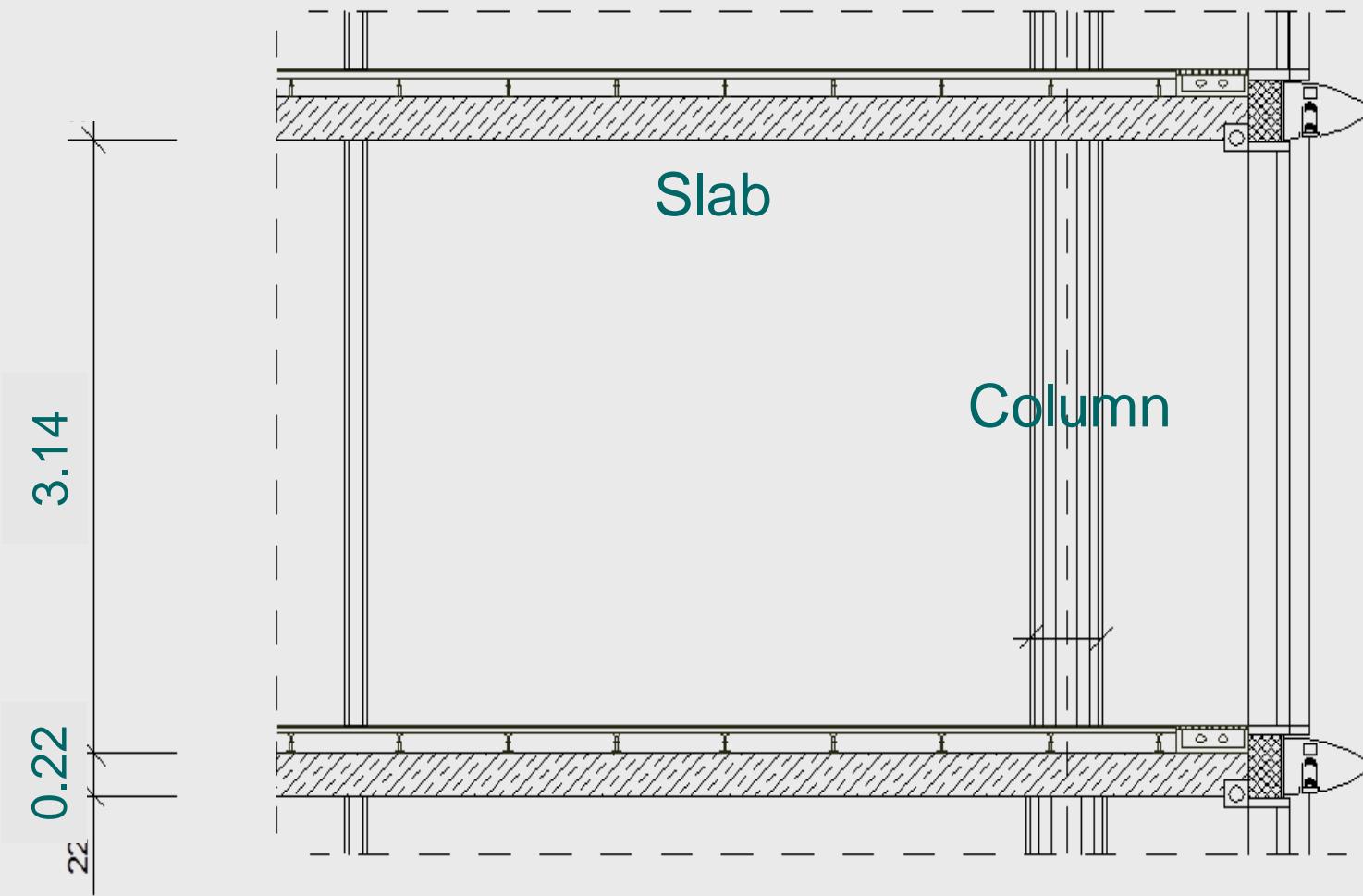
ANALYZED STRUCTURE

Building body



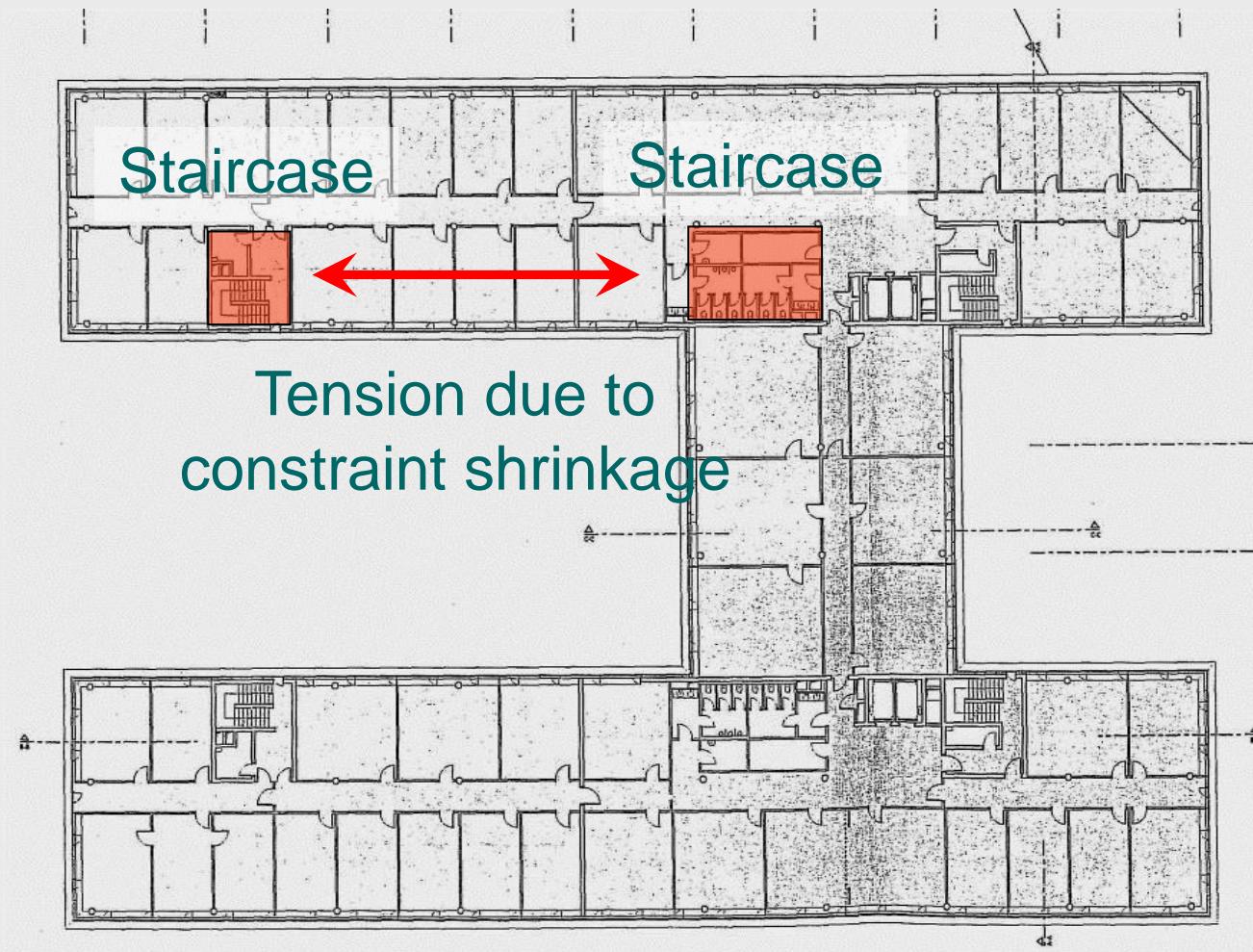
ANALYZED STRUCTURE

Slab-Column System



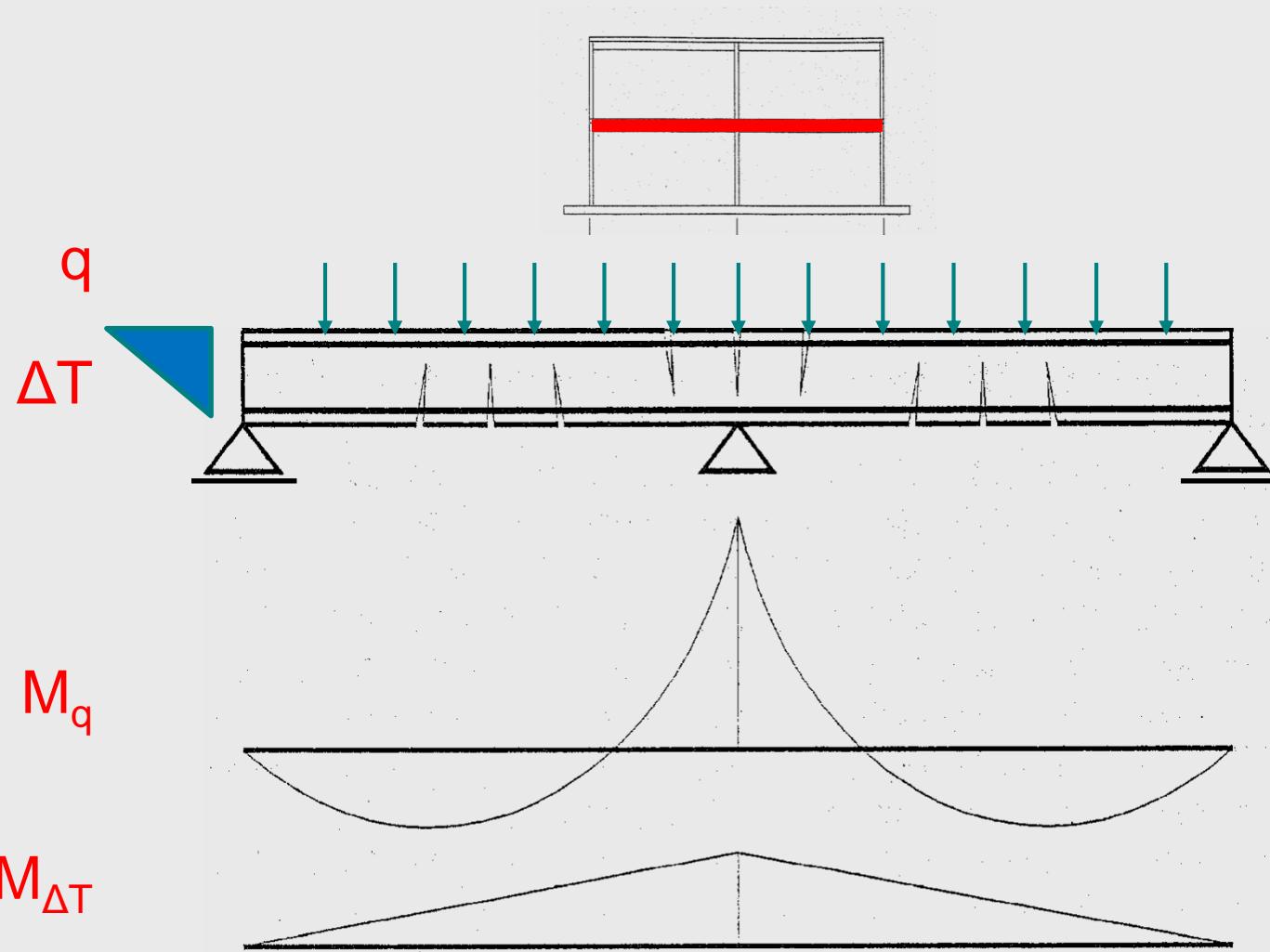
ANALYZED STRUCTURE

Bending Moments + Tension Forces



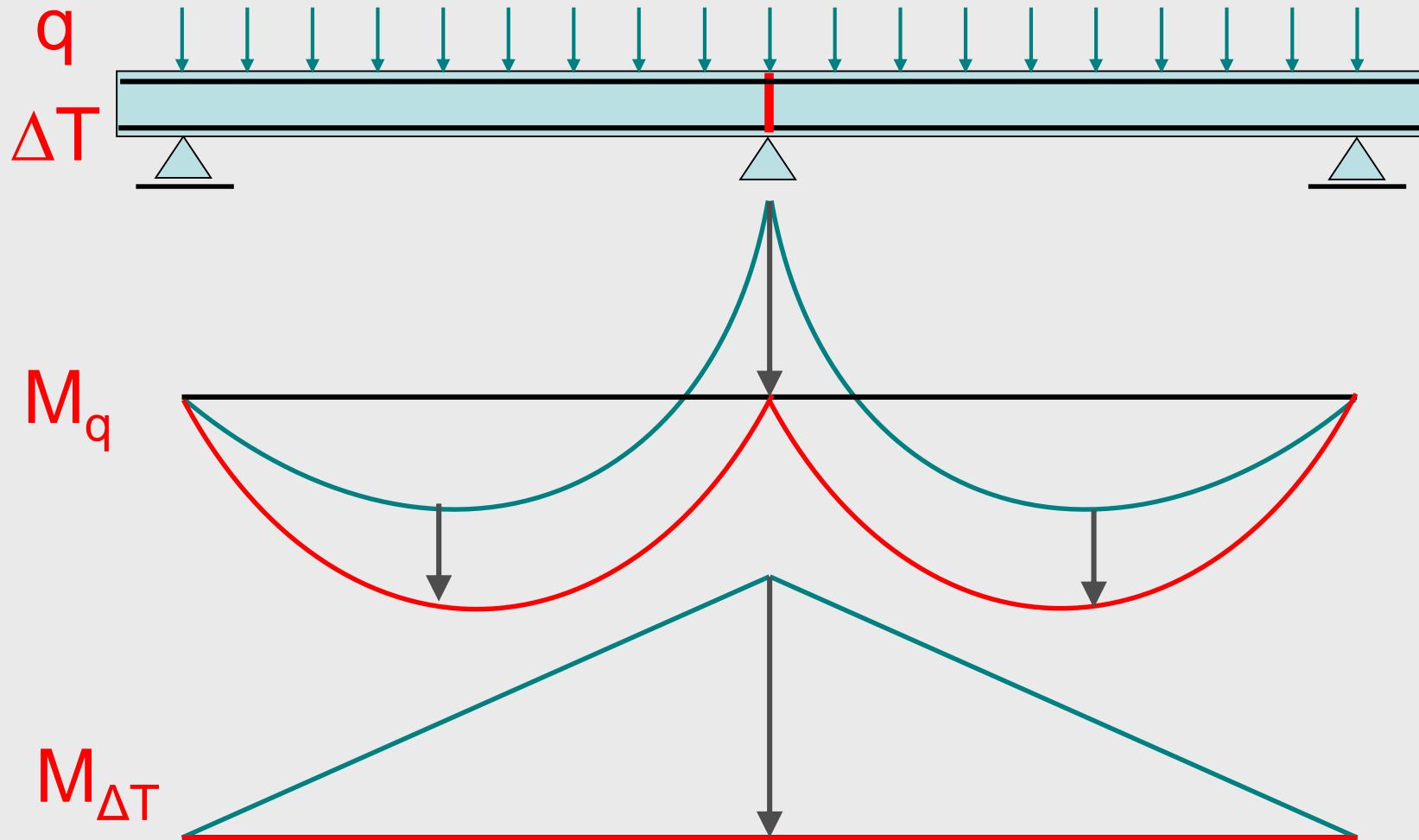
PHENOMENON of REDISTRIBUTION

Beam loaded by q and ΔT



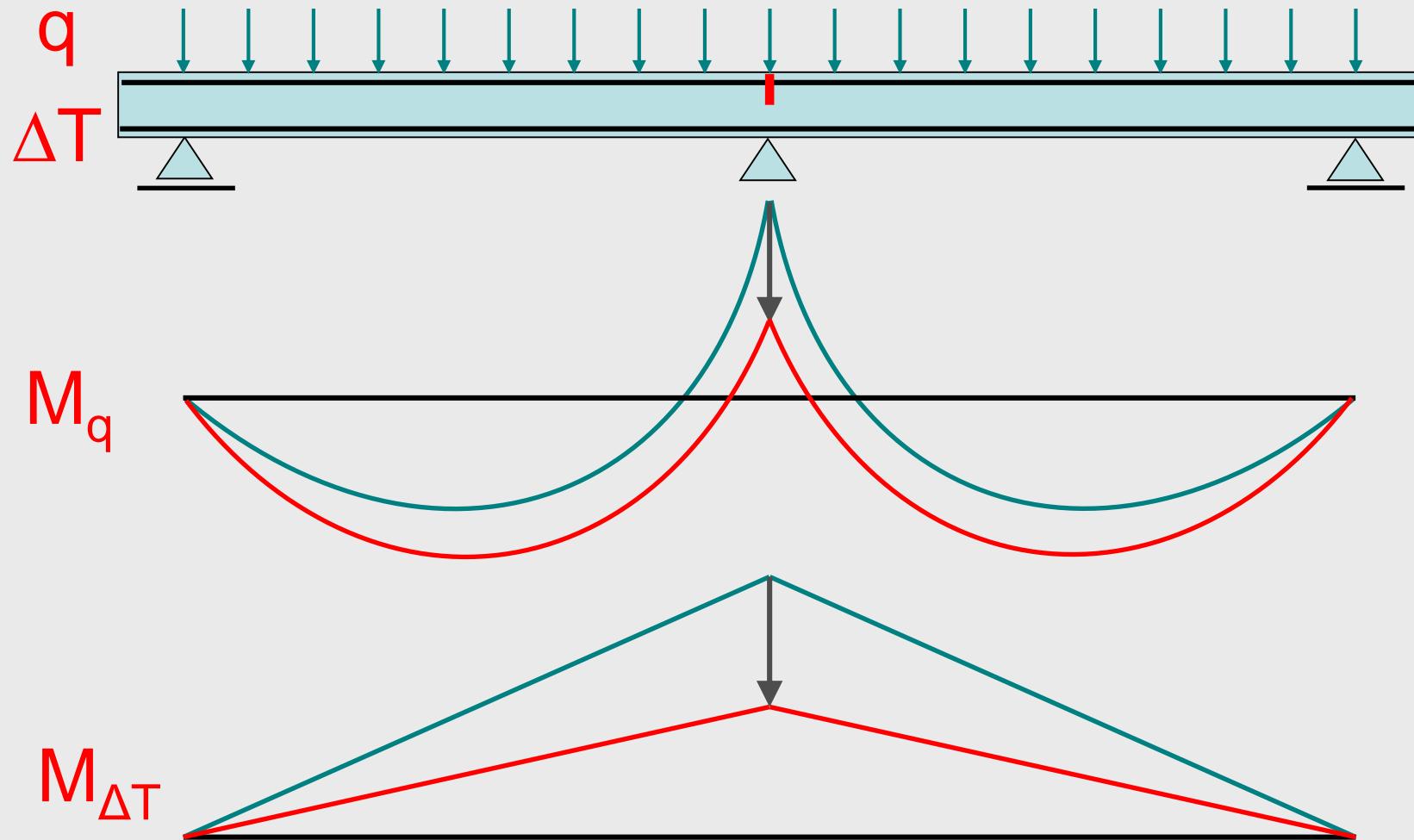
PHENOMENON of REDISTRIBUTION

Moment drop caused by a total cut



PHENOMENON of REDISTRIBUTION

Moment drop caused by a partial cut



PHENOMENON of REDISTRIBUTION

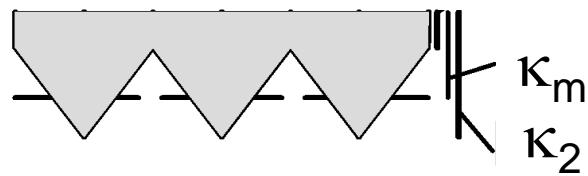
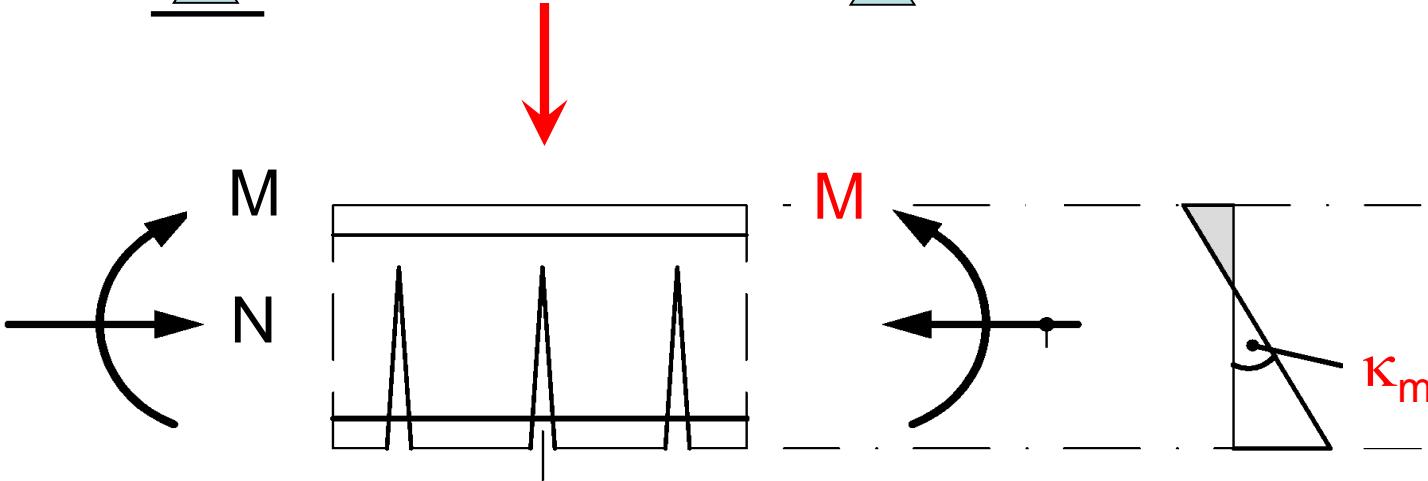
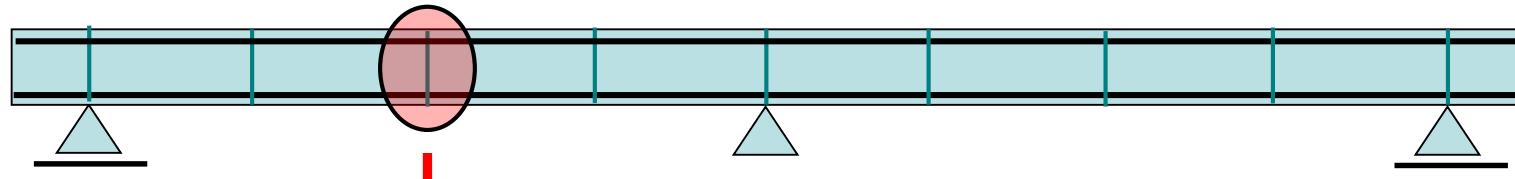
Cracks causing moment redistribution



STRUCTURE MODELING

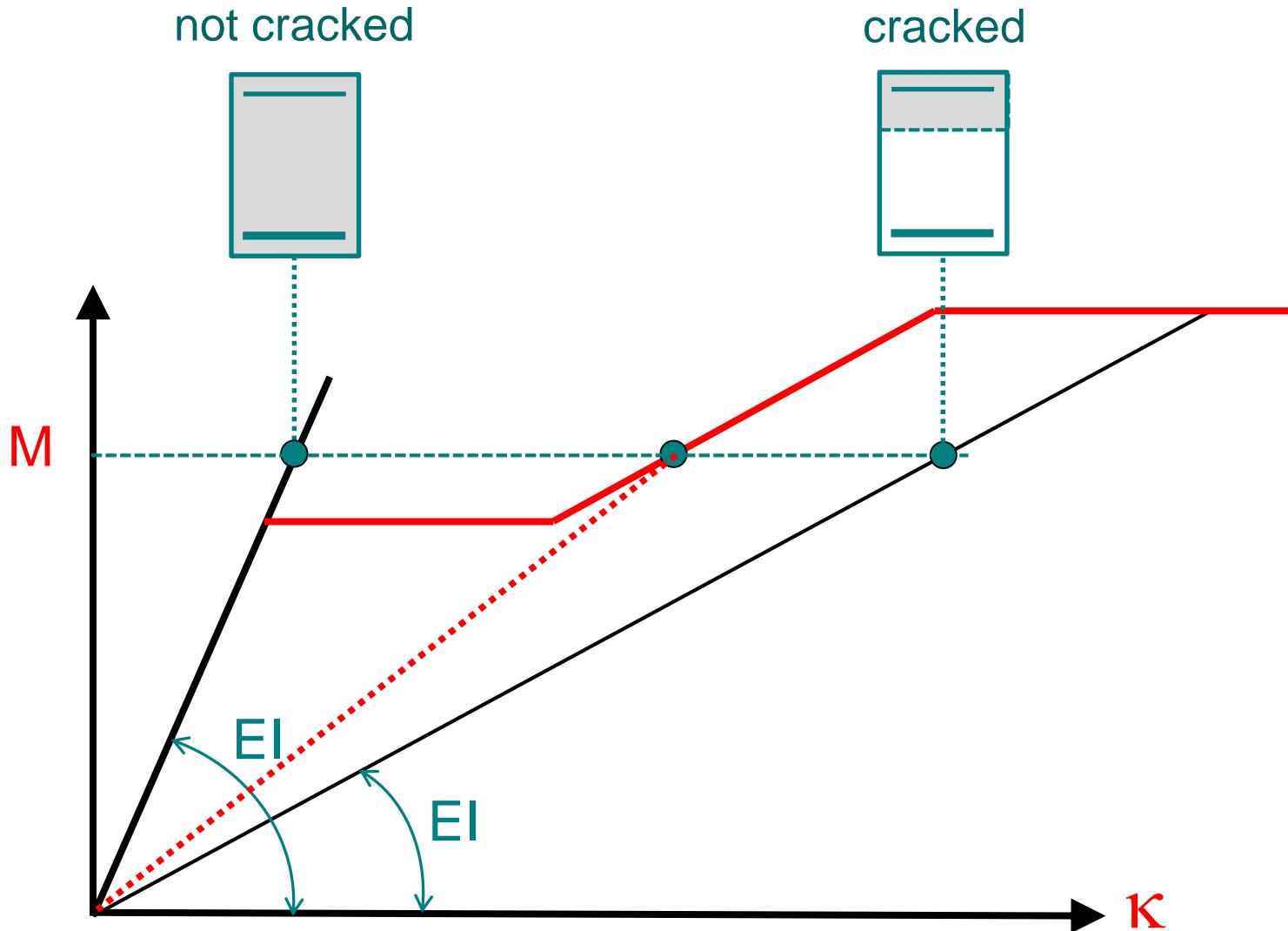
Computation node

Computation node



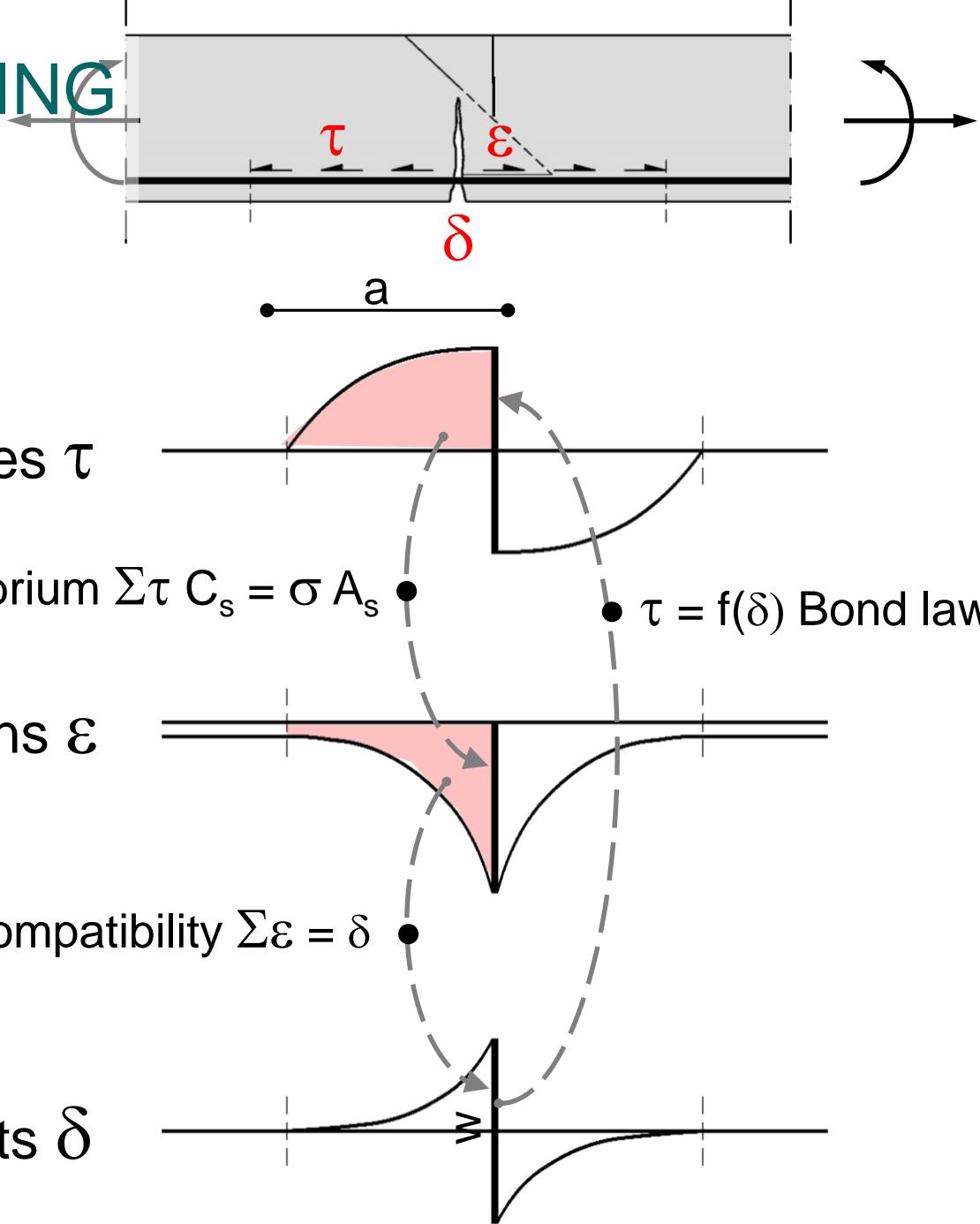
STRUCTURE MODELING

Deformation Low M - κ



STRUCTURE MODELING

General relations



STRUCTURE MODELING

Bond Stress Distribution

(1) Bond equation

$$[\tau(y)/(A f_{cm}^{2/3})]^{1/N} = 4/(d_s E_s) \iint \tau(y) dy dy$$

(2) Bond distribution

$$\tau(y) = k y^p$$

(3) Integration

$$[k y^p / (A f_{cm}^{2/3})]^{1/N} = 4 / (d_s E_s) k / [(p+1) (p+2)] y^{(p+2)}$$

(4) Solving for p

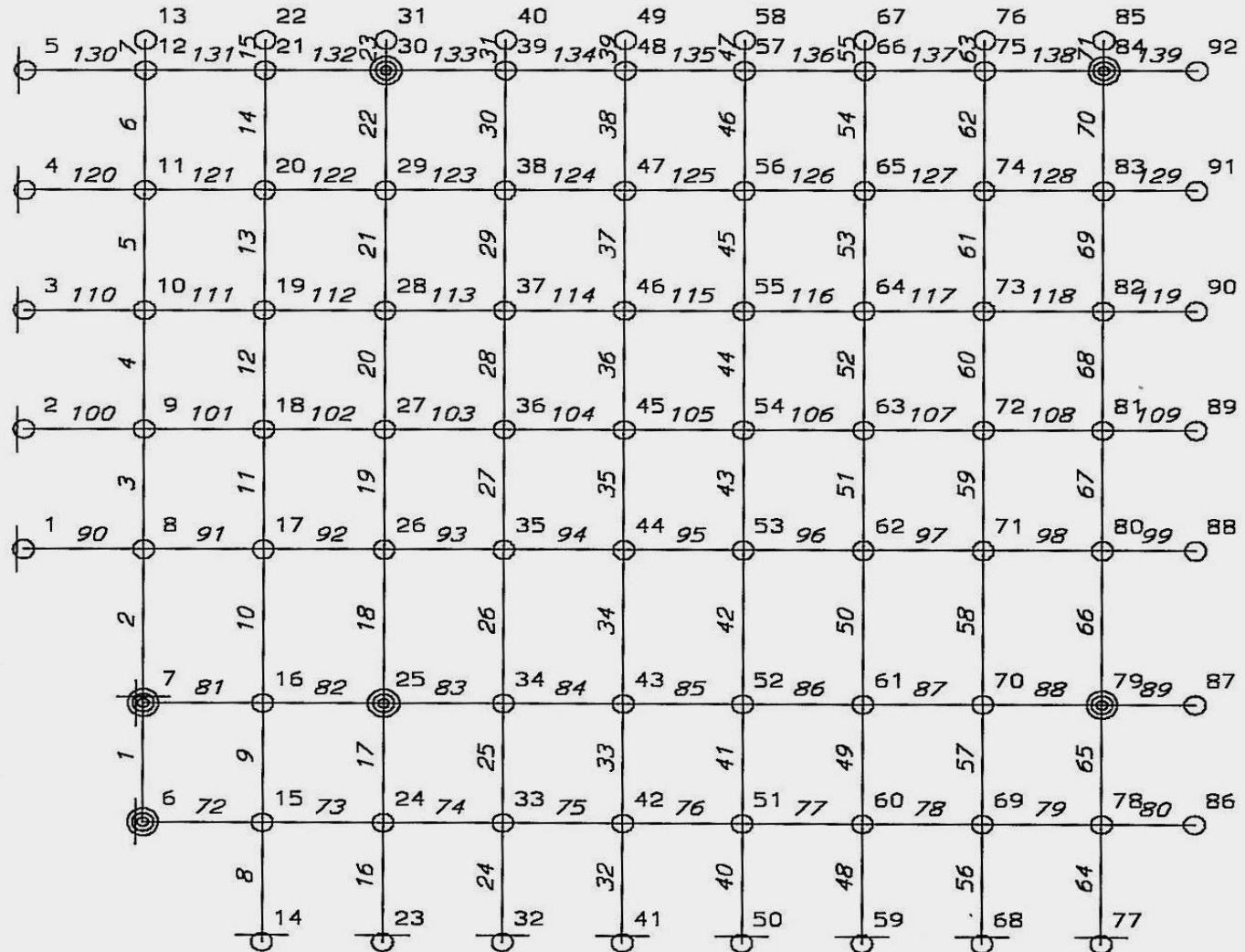
$$p/N = p+2 \rightarrow p = 2 N / (1-N)$$

(5) Solving for k

$$[k / (A f_{cm}^{2/3})]^{1/N} = 4 / (d_s E_s) k / [(p+1) (p+2)]$$
$$\rightarrow k = [2 (1-N)^2 / (1+N) (A f_{cm}^{2/3})^{1/N} / (d_s E_s)]^{N/(1-N)}$$

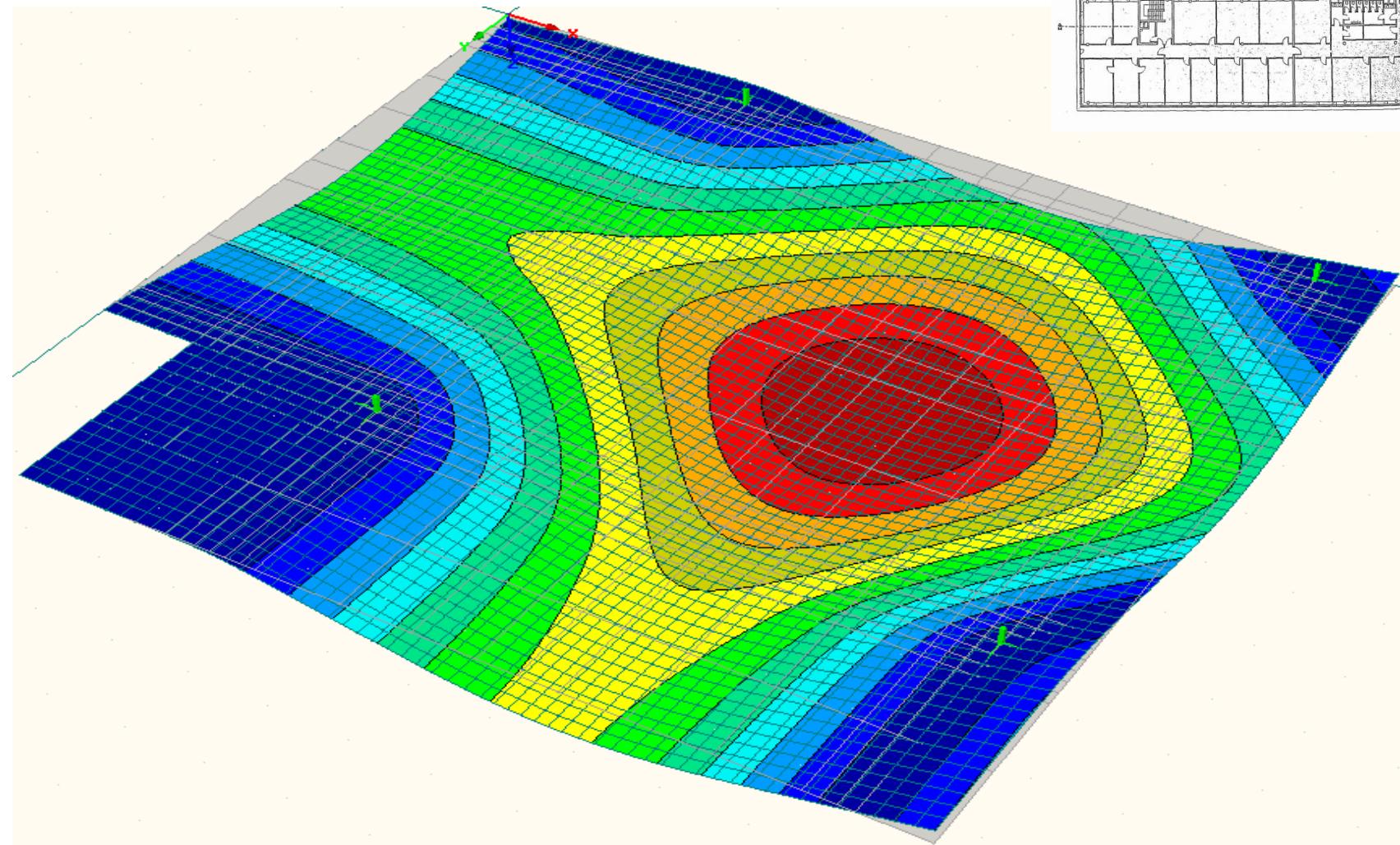
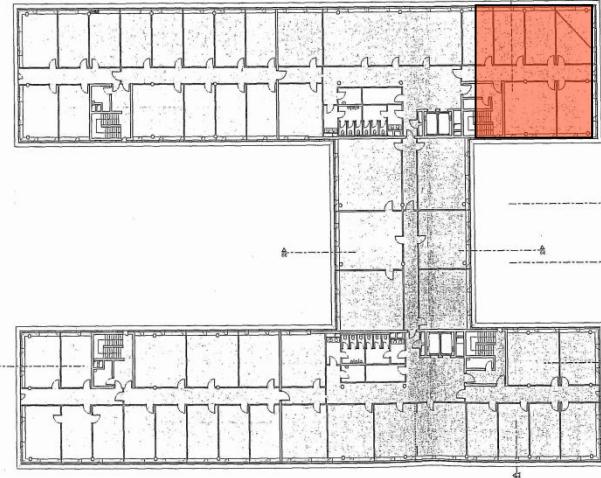
STRUCTURE MODELING

Grid System, 92 nods, 139 bars



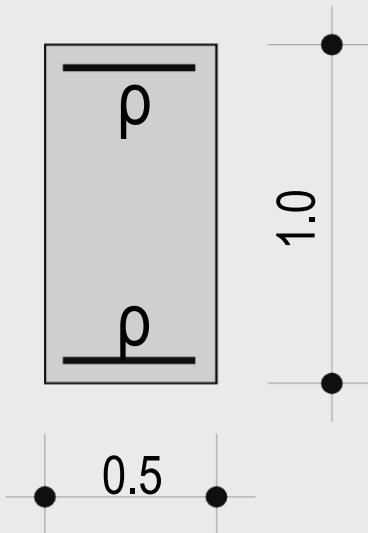
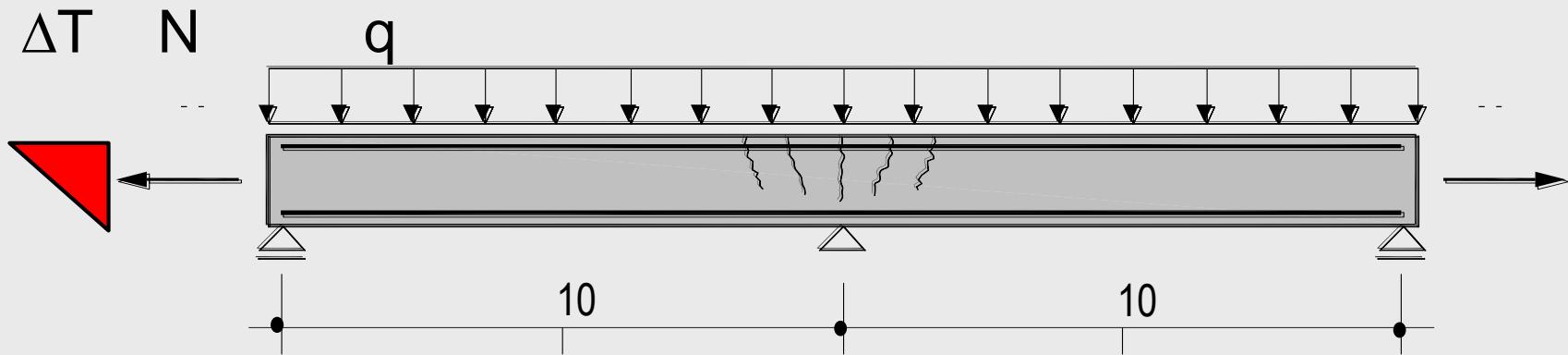
STRUCTURE MODELING

Slab System, 633 elements



STRUCTURE ANALYSIS

Behavior of a beam loaded by ΔT , q and N



Case	1	2	3	4
ΔT [K]	15	15	15	15
q [kN/m]	20	40	20	20
N [kN]	0	0	600	0
ρ [%]	0.4	0.4	0.4	1.2

STRUCTURE ANALYSIS

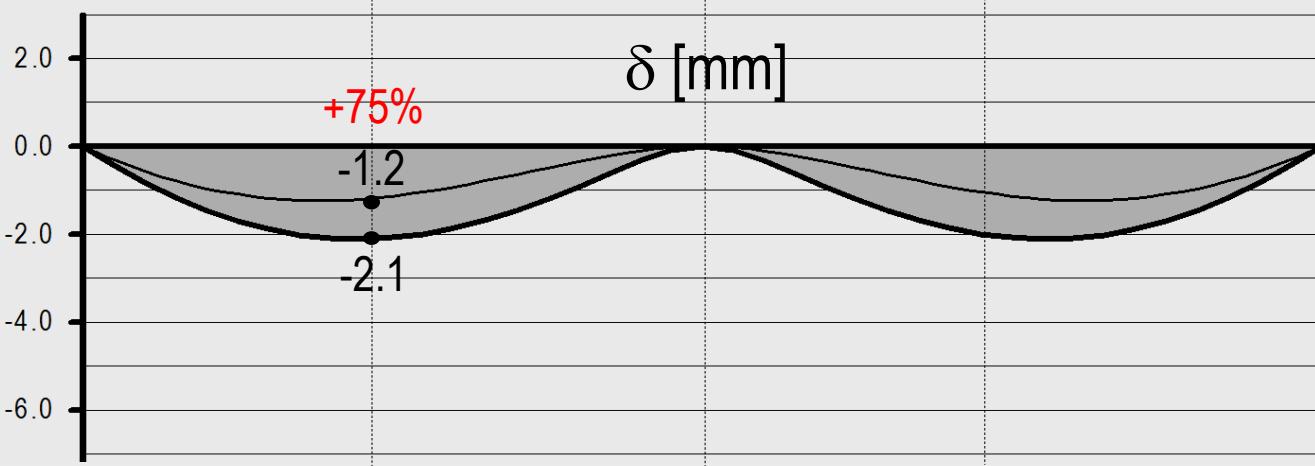
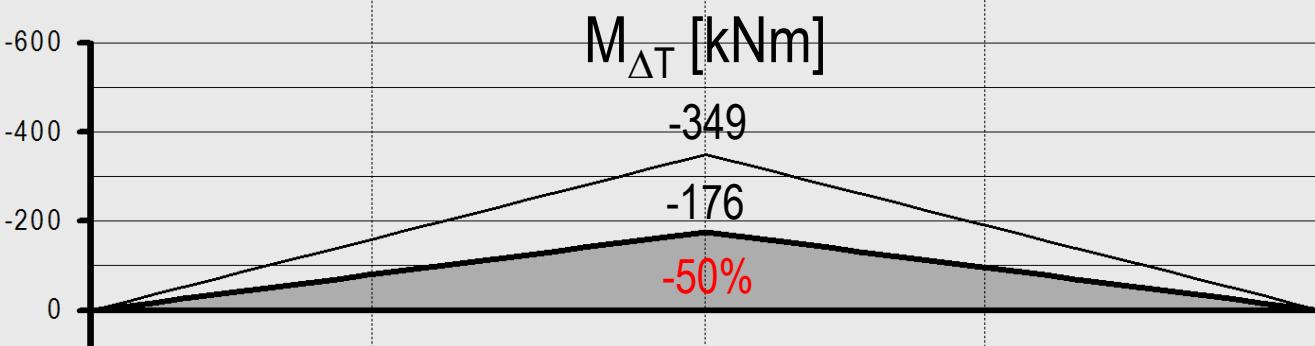
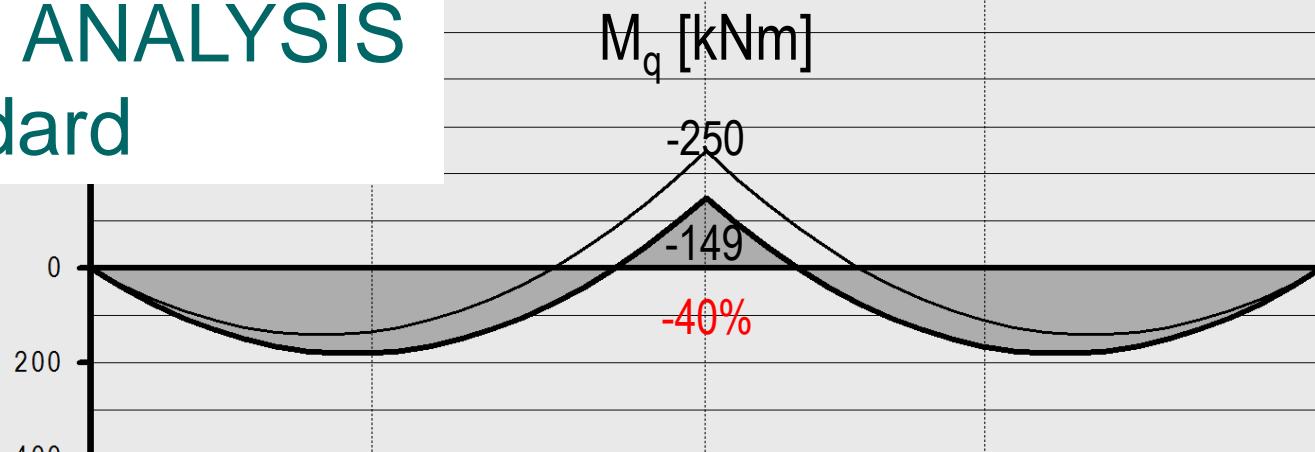
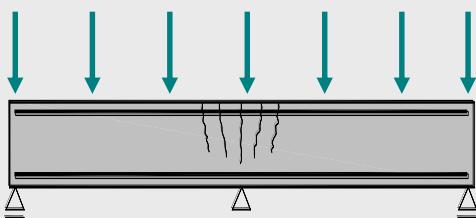
Case 1: Standard

$$\Delta T = 15 \text{ K}$$

$$q = 20 \text{ kN/m}$$

$$N = 0$$

$$\rho = 0.4 \text{ %}$$



STRUCTURE ANALYSIS

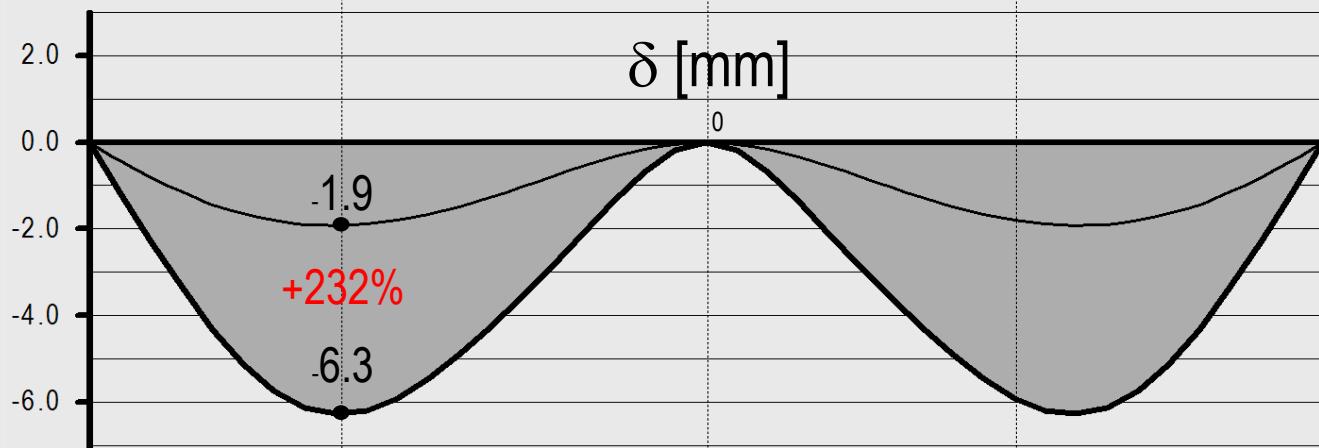
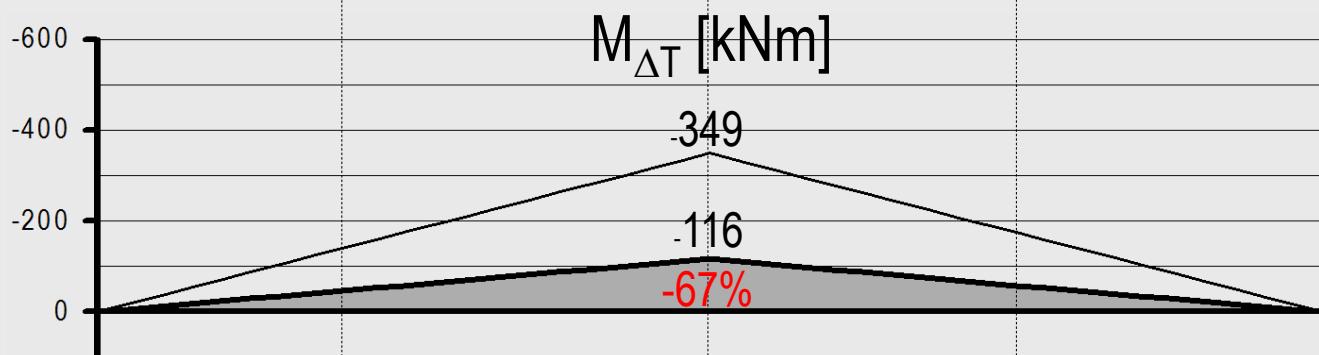
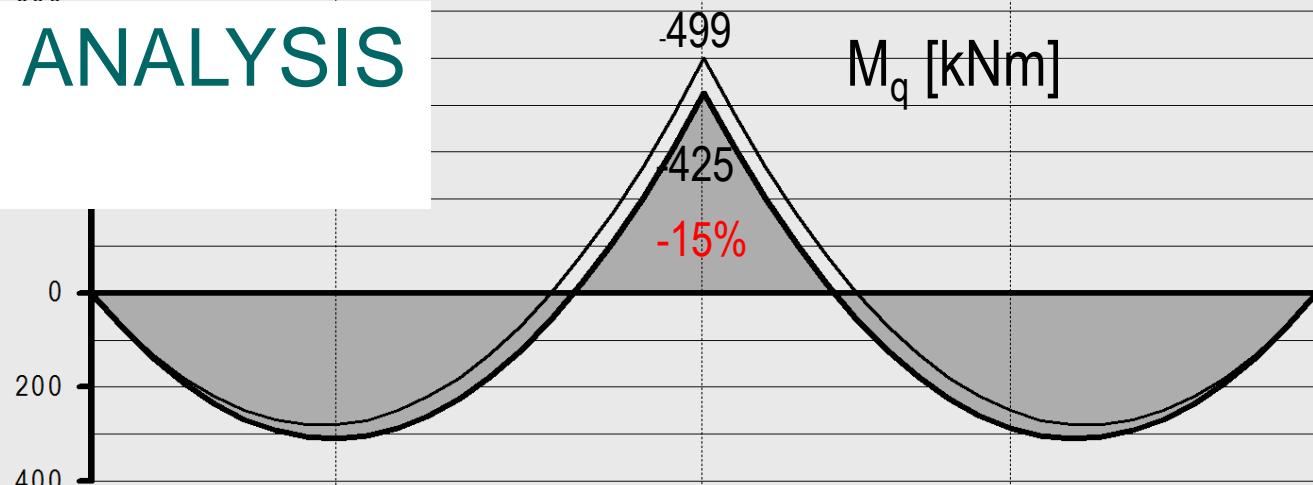
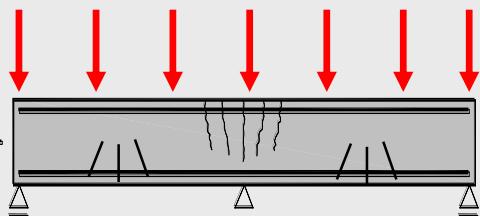
Case 2: Load

$$\Delta T = 15 \text{ K}$$

$$q = 40 \text{ kN/m}$$

$$N = 0$$

$$\rho = 0.4 \%$$



STRUCTURE ANALYSIS

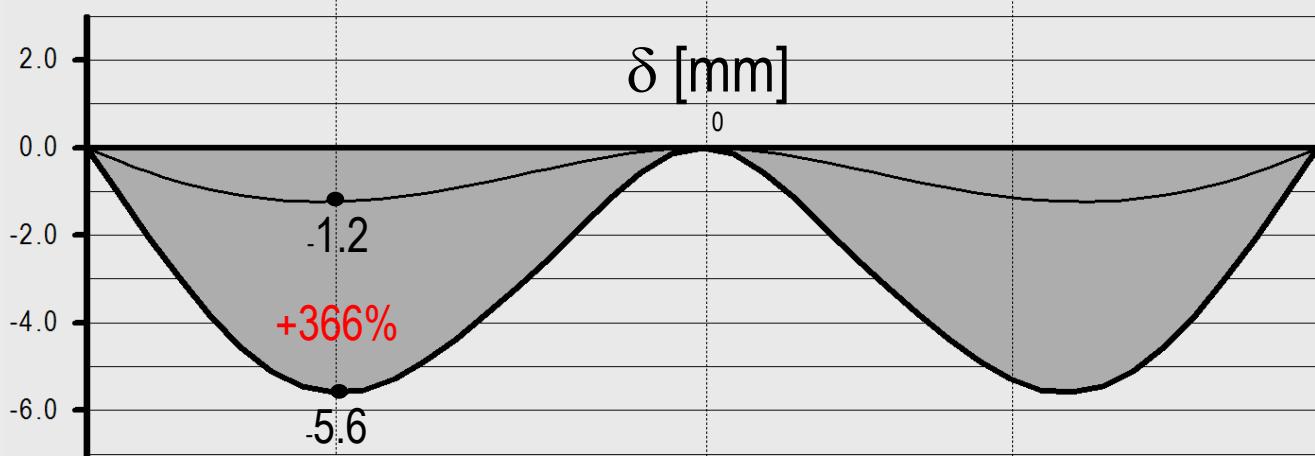
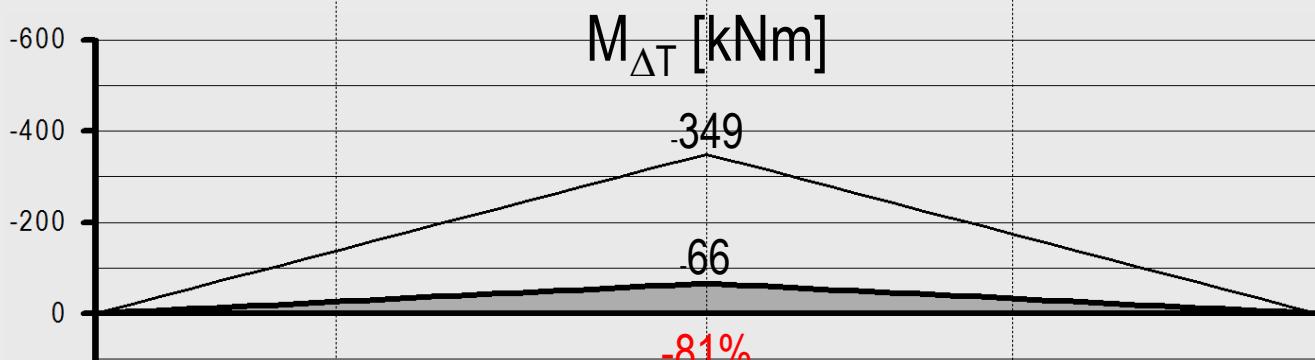
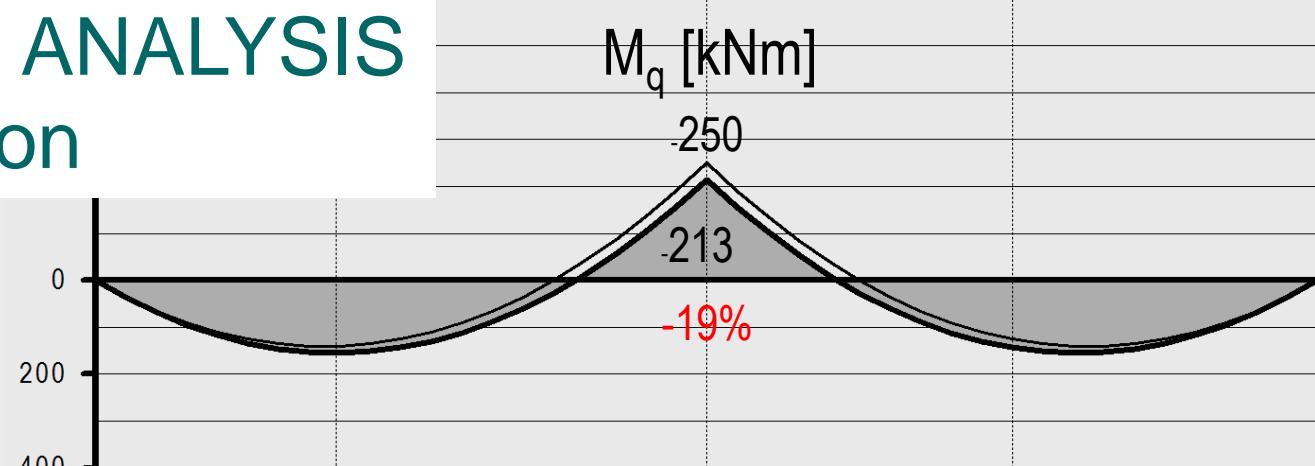
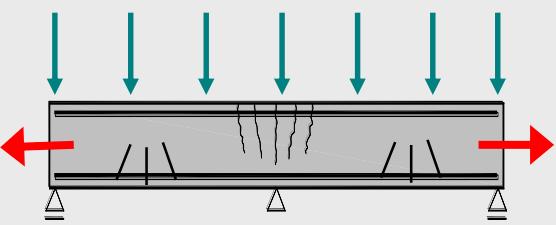
Case 3: Tension

$$\Delta T = 15 \text{ K}$$

$$q = 20 \text{ kN/m}$$

$$N = 600 \text{ kN}$$

$$\rho = 0.4 \text{ %}$$



STRUCTURE ANALYSIS

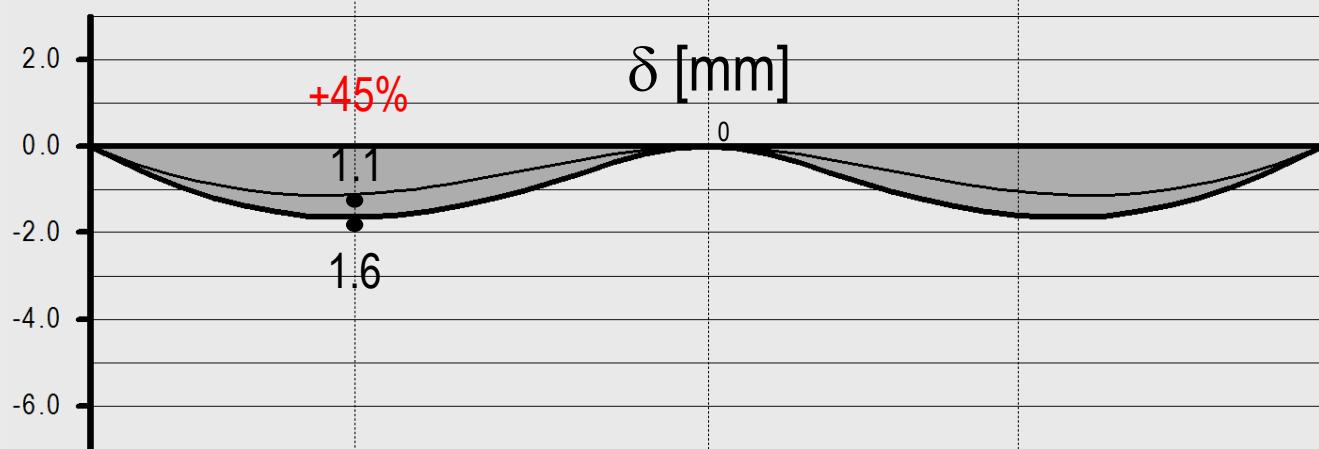
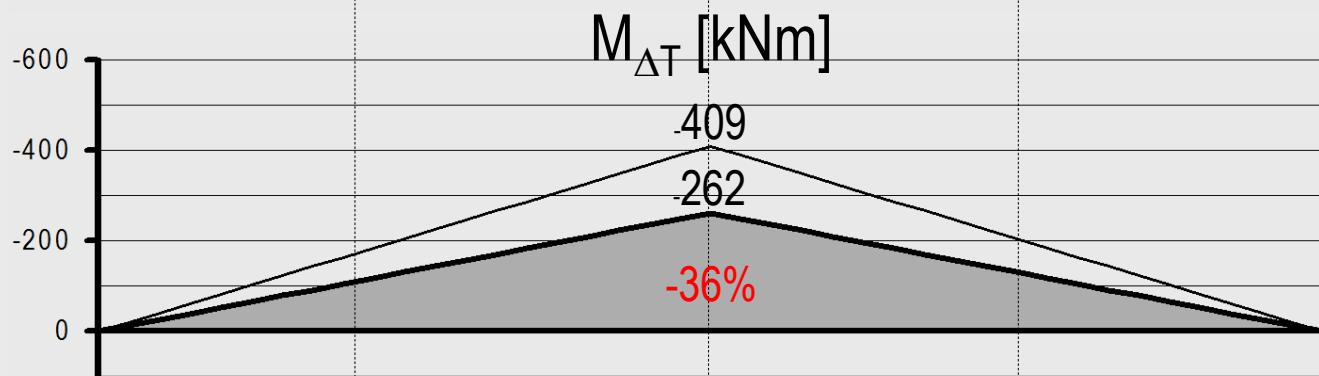
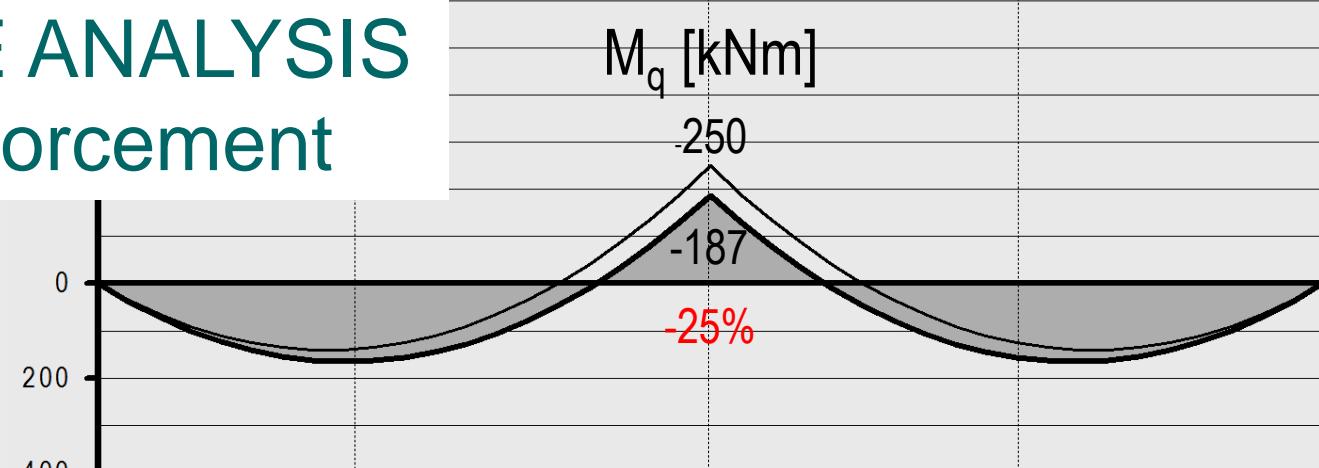
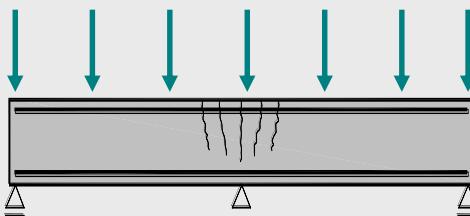
Case 4: Reinforcement

$$\Delta T = 15 \text{ K}$$

$$q = 20 \text{ kN/m}$$

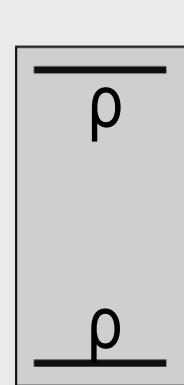
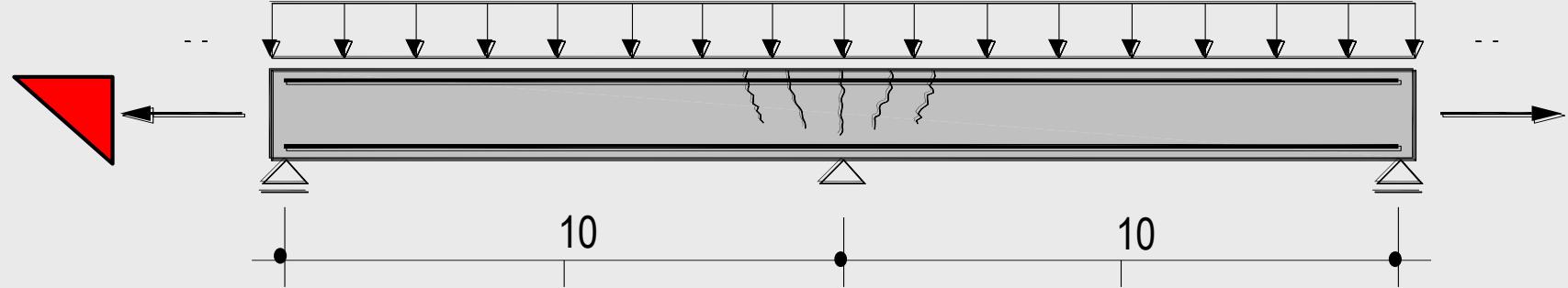
$$N = 0$$

$$\rho = 1.2\%$$



STRUCTURE ANALYSIS

Behavior of a beam loaded by DT, q and N



Case	1	2	3	4
$\Delta T [K]$	15	15	15	15
$q [kN/m]$	20	40	20	20
$N [kN]$	0	0	600	0
$\rho [\%]$	0.4	0.4	0.4	1.2
$\Delta M_q/M_{q1} [\%]$	-40	-15	-19	-25
$\Delta M_T/M_{T1} [\%]$	-50	-67	-36	-36
$\Delta \delta/\delta_1 [\%]$	+75	+232	+366	+45

FINDINGS

Zarysowanie betonu jest ważne, bo sprawia, że
..momenty M znakomicie maleją a
..ugięcia δ znakomicie rosną.

Zarysowanie betonu jest „tajemnicze”, bo
..spadek momentów ΔM zależy od q , N i ρ a
..przyrost ugięć δ nie zależy od E_c a od N i ρ

Zarysowania betonu musi być uwzględniane gwoli
..właściwych momentów M i
..właściwych ugięć δ .

Dziękuję bardzo



Düsseldorf