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Dipl.-Ing. (FH) Andreas Hörold
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Sonja von Bloh, M.Sc.
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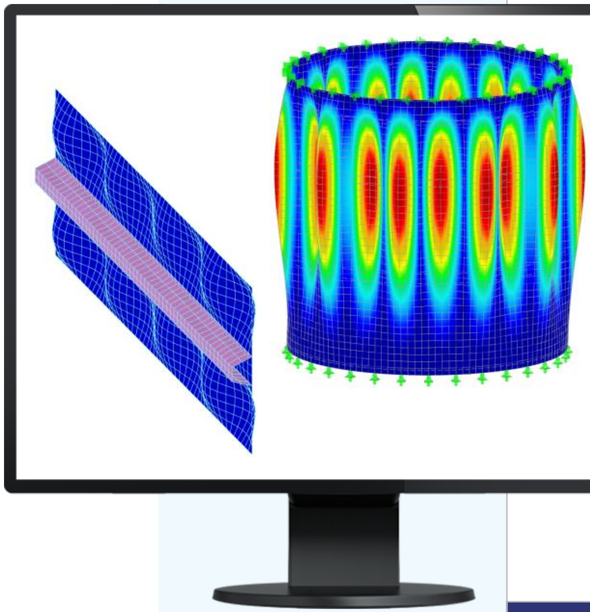
Webinar

Plate and Shell Buckling Utilizing Dlubal Software



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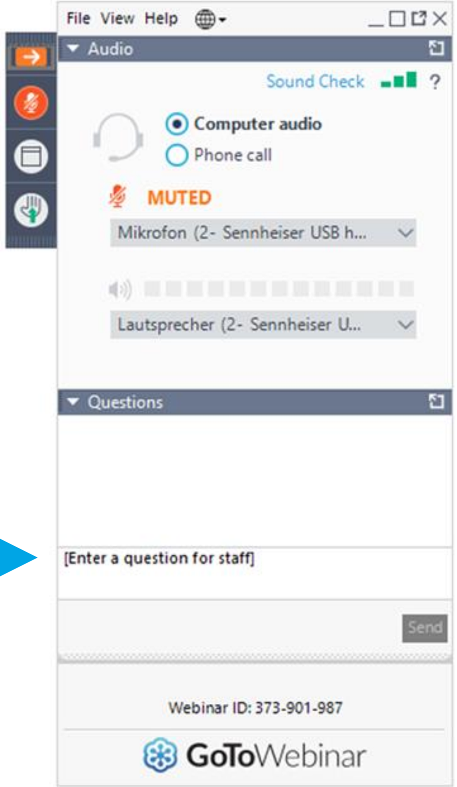

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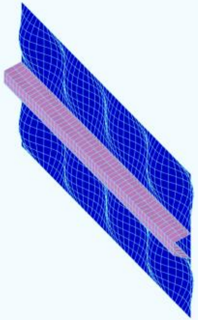
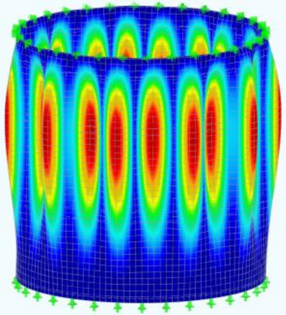
CONTENT

01 **Plate buckling design according to EN 1993-1-5 in PLATE-BUCKLING**

02 **Shell buckling design utilizing the global MNA and LBA calculation according to EN 1993-1-6 with RFEM**





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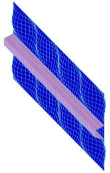


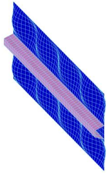
Plate Buckling Analyses of Steel Plates According to EN1993-1-5

Method of effective cross-sections
([1], Sec. 4-7)

Reduced stress method
([1], Sec. 10)

Analyses using Finite Element Method
([1], Annex C)

PLATE-BUCKLING
Plate buckling analysis with or without stiffeners



Example: Buckling Analysis of a Stiffened Plate with PLATE-BUCKLING (Reduced Stress Method)

Data

Material: S 355

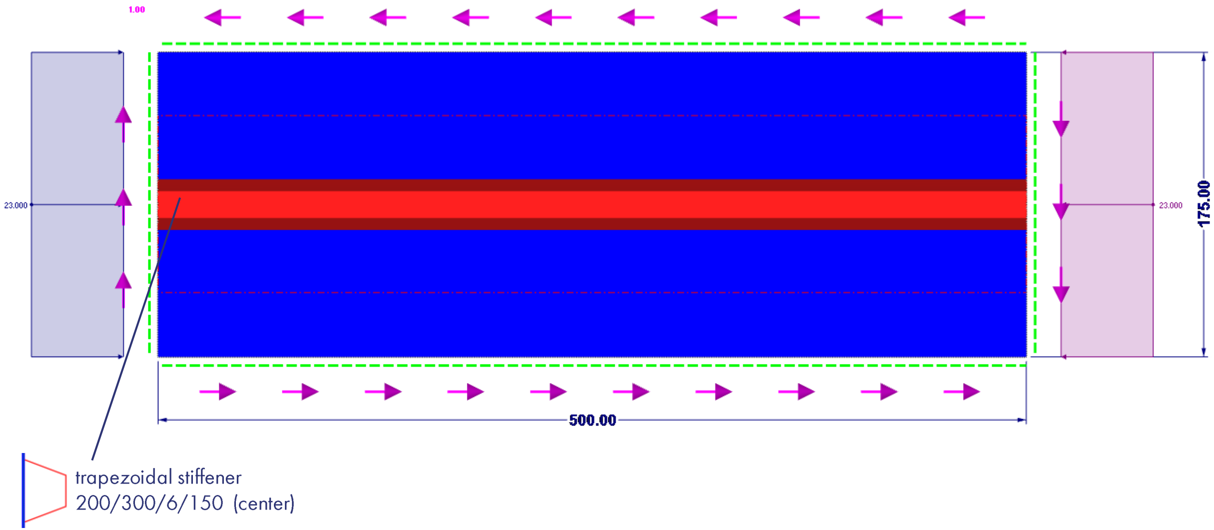
Plate thickness: t = 14 mm

Stresses

$\sigma_1 = \sigma_2 = 23.0\ kN/cm^2$

$\tau = 1.0\ kN/cm^2$

System



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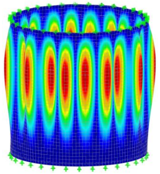


Plate Buckling Analyses of Steel Shell Structures acc. to EN1993-1-6

Stress-based plate buckling analysis

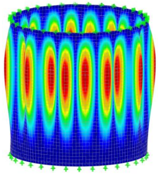
- Simple application for expert engineers
- Low requirements for computer technology (often hand calculation formulas used)
- Economic results difficult to achieve for load situations significantly differing from conventional buckling shapes

Plate buckling design by global numerical MNA/LBA analysis

- More background knowledge for shell stability required
- Higher requirements for computer technology (materially nonlinear analysis (MNA), linear elastic bifurcation analysis (LBA))
- Computer technology using FE analysis consequently applied

Plate buckling design by global numerical GMNIA analysis

- Excellent background knowledge for shell stability required (e.g. correct application of imperfections (pre-forming) is complex)
- Considerable requirements for computer technology
- Difficult application in real design situations



Example: Plate Buckling Design by Global Numerical MNA/LBA Analysis acc. to [3]

Technical data

Liquid: γ = 10 kN/m³

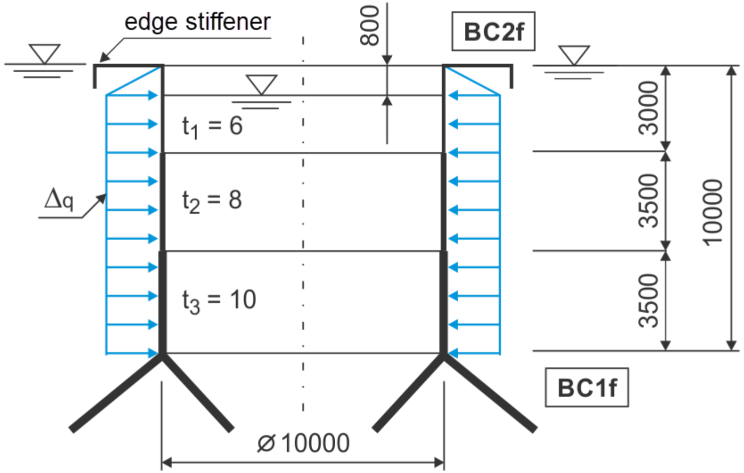
Material: S 235

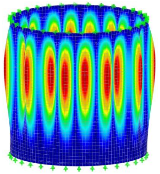
Manufacturer quality: class A

Load (1.0 x differential pressure)

Δq_d = 8.0 kN/m²

System





Analysis

Elastic critical buckling resistance ratio

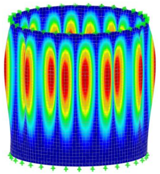
r_{Rcr} = 1.507 (FE eigenvalue analysis (LBA) in RFEM)

Plastic reference resistance ratio ([2], Eq. 8.24)

$$r_{Rpl} = t \cdot f_{yk} \;/\sqrt{n^2_{x,Ed} - n_{x,Ed}n_{\theta,Ed} + n^2_{\theta,Ed} + 3n^2_{x\theta,Ed}}$$

The lowest value of plastic resistance ratio so calculated should be taken as the estimate of the plastic reference resistance ratio r_{Rpl}.

NOTE: A safe estimate of r_{Rpl} can usually be obtained by applying expression (8.24) in turn at the three points in the shell where each of the three buckling-relevant membrane stress resultants attains its highest value, and using the lowest of these three estimates as the relevant value for r_{Rpl}. [2]



Analysis

$r_{Rpl} = 35.6$ (materially non-linear analysis (MNA in RFEM)

Overall relative slenderness ([2], Eq. 8.25)

$$\bar{\lambda}_{ov} = \sqrt{r_{Rpl}/r_{Rcr}}$$

$$\bar{\lambda}_{ov} = \sqrt{35.6/1.507}$$

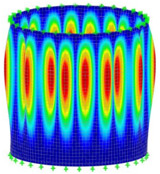
$$\bar{\lambda}_{ov} = 4.86$$

Circumferential elastic imperfection reduction factor ([2], Tab. D.5)

$$\alpha_{ov} = \alpha_{\theta} = 0.75$$

Plastic range factor ([2], D.26)

$$\beta = 0.60$$



Analysis

Plastic limit relative slenderness ([2], Eq. 8.16)

$$\bar{\lambda}_p = \sqrt{\alpha/(1-\beta)}$$

$$\bar{\lambda}_p = \sqrt{0.75/0.40)}$$

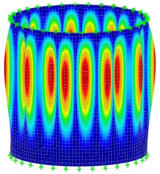
$\bar{\lambda}_p = 1.37 << 4.86$ → pure elastic plate buckling

Buckling reduction factor ([2], Eq. 8.15)

$$\chi_{ov} = {}^{\alpha}/_{\bar{\lambda}^2}$$

$$\chi_{ov} = {}^{0.75}/_{4.86^2}$$

$$\chi_{ov} = 0.0318$$



Analysis

Characteristic buckling resistance ratio ([2], Eq. 8.26)

$$r_{Rk} = \chi_{ov} \cdot r_{Rpl}$$

$$r_{Rk} = 0.0318 \cdot 35.6$$

$$r_{Rk} = 1.132$$

Design buckling resistance ratio ([2], Eq. 8.27)

$$r_{Rd} = {}^{r_{Rk}}/_{\gamma_{M1}}$$

$$r_{Rd} = {}^{1.132}/_{1.1}$$

$r_{Rd} = 1.03 > 1$ → design fulfilled

→ Another example available in Knowledge Base

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Bibliography

[1] Eurocode 3: Design of steel structures – Part 1-5: General rules – Plated structural elements; EN 1993-1-5:2006 (E)

[2] Eurocode 3: Design of steel structures – Part 1-6: Strength and stability of shell structures, EN 1993-1-6:2007 (E)

[3] Schmidt H.: Beulsicherheitsnachweise für Schalen nach dem neuen Eurocode EN 1993-1-6 – Ein Überblick mit Beispielen aus der Anwendungspraxis, Referat beim 27. Stahlbau-Seminar in Neu-Ulm und Wien, 2005

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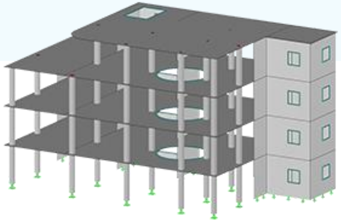

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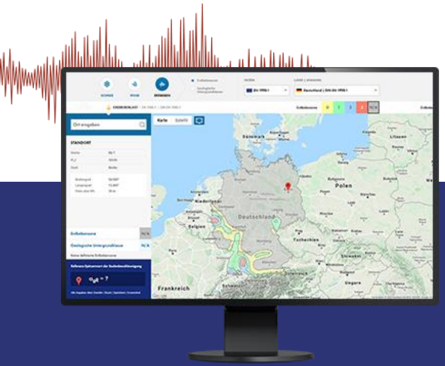

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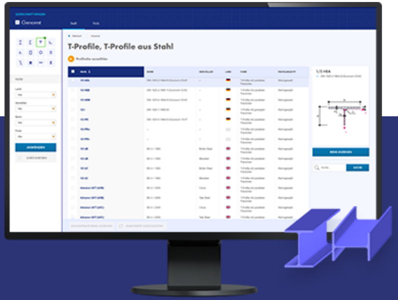

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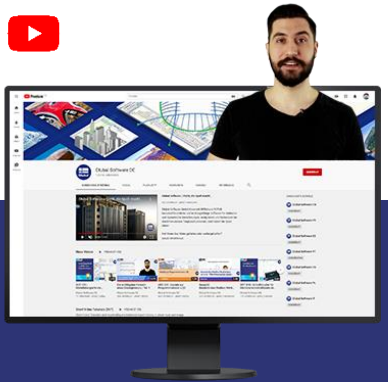

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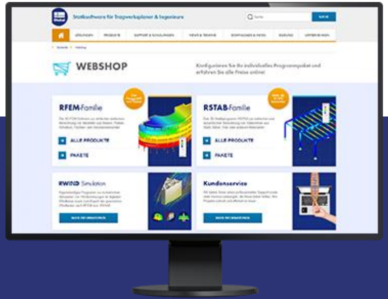

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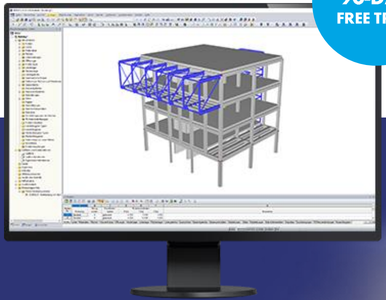

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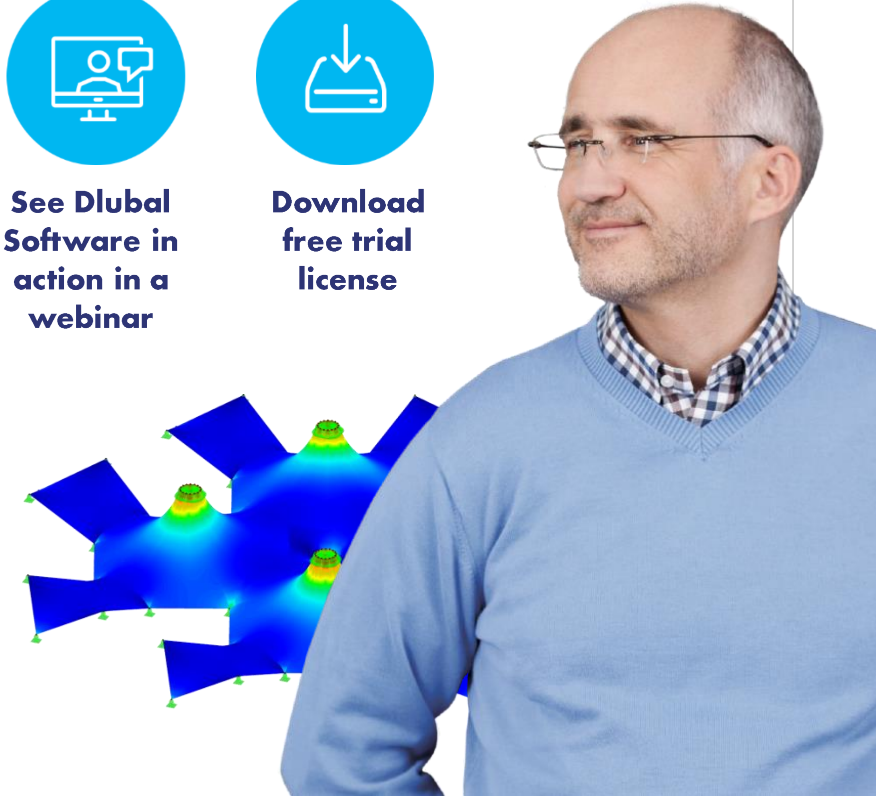

Dlubal Software GmbH
Am Zellweg 2,
93464 Tiefenbach, Germany

Phone: +49 9673 9203-0
E-mail: info@dlubal.com

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