Optimization of Sandwich Panels

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Institute of Steel Construction and Material Mechanics

Optimization of geometry and core material of sandwich panels with metallic faces

Introduction

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- **Study**
- 1998 - 2003 — Studies of Civil Engineering at the Opole University of Technology (Poland)
- 2001 - 2002 — Exchange Programme for Students at the University of Applied Sciences Mainz (Germany)
  First contact with Sandwich Technology
- 2003 - 2005 — Studies of Civil Engineering at University of Applied Sciences Mainz
- **Professional activities**
- 2002 - 2003 — Work Experience in Engineering Office
- 2005 - 2008 — Research Assistant at the Institute for Sandwich Technology Mainz
- since Sept. 2008 — Research Assistant and Doctoral Thesis at the Technische Universität Darmstadt (Germany)

Content

- Background
- Aim of the optimization
- Theoretical optimization of mechanical properties
  - Optimization of core material
  - Optimization of metallic faces
- First tests of sandwich panels with lightly profiled faces

Optimization of Sandwich Panels… Why?

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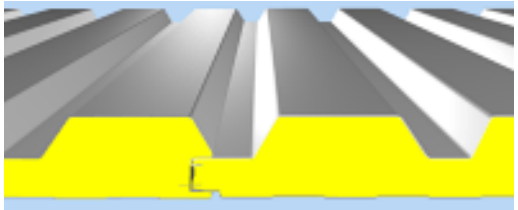

- Possibility to save money and resources
- Lack of investigations into optimization of sandwich panels
- Possibility to get sandwich panels with better load bearing capacity
    - Previous experience and observations during the mechanical tests
    - Capability of the producers to create sandwich panels with defined properties

Research Project *SandTweak*

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FH MAINZ
UNIVERSITY OF APPLIED SCIENCES

iS-mainz

Institut für SANDWICHTECHNIK

Institut für Stahlbau und Werkstoffmechanik

External source

Bundesministerium für Bildung und Forschung

Realization September 2006 – September 2009

Project partners *SandTweak*

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iFSW
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FISCHER PROFIL
ELEMENTE FÜRS BAUEN
Ein Unternehmen von Corus Building Systems

ROMA
DAMM-SYSTEME

BAYER
Bayer

BASF
The Chemical Company

ThyssenKrupp Steel

ROCKWOOL

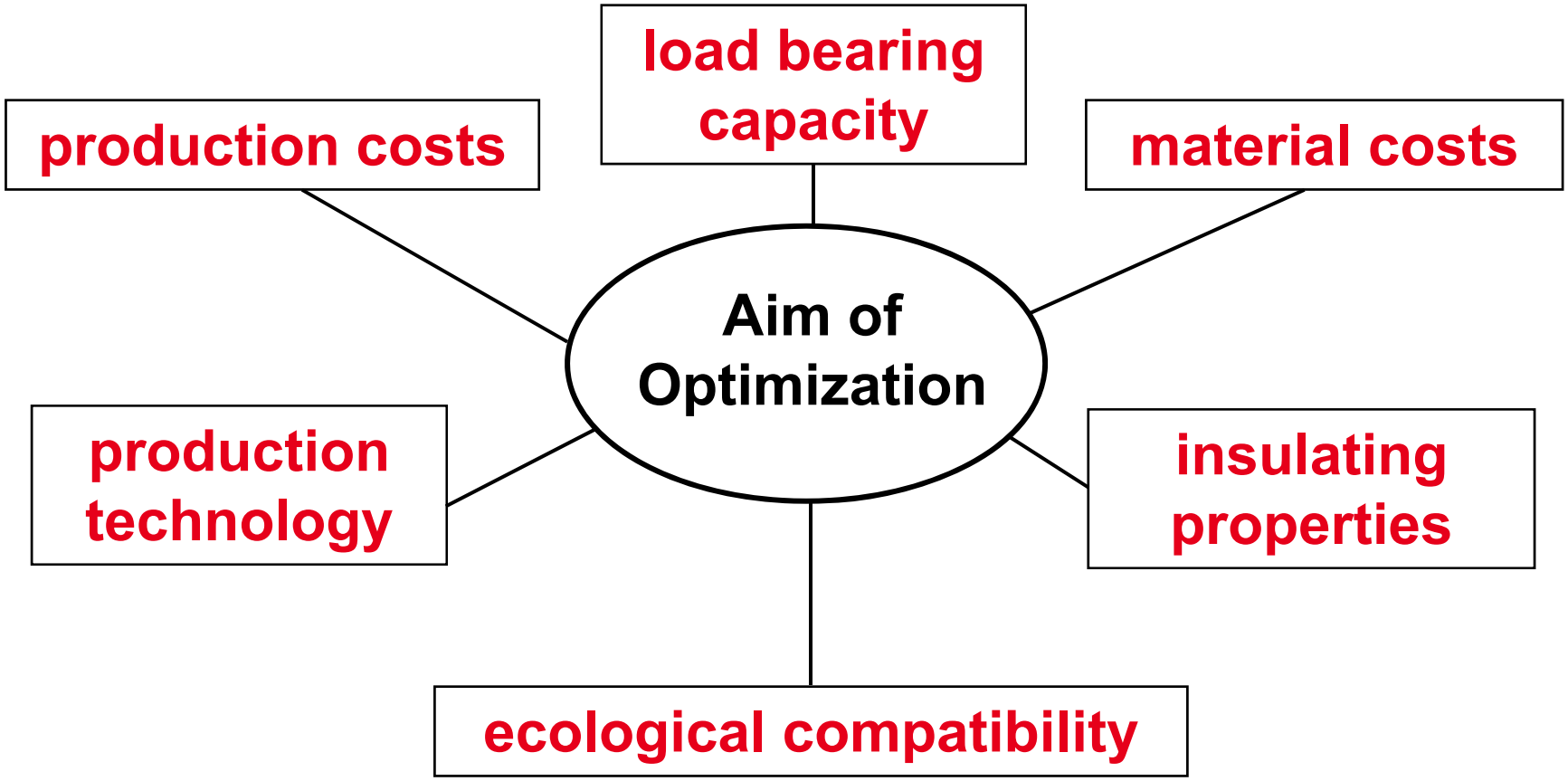
Trimo

SHS
Siempelkamp Handling Systeme

Elastogran

ECP

Aim of the Optimization of Sandwich Panels



Aim of the Optimization of Sandwich Panels

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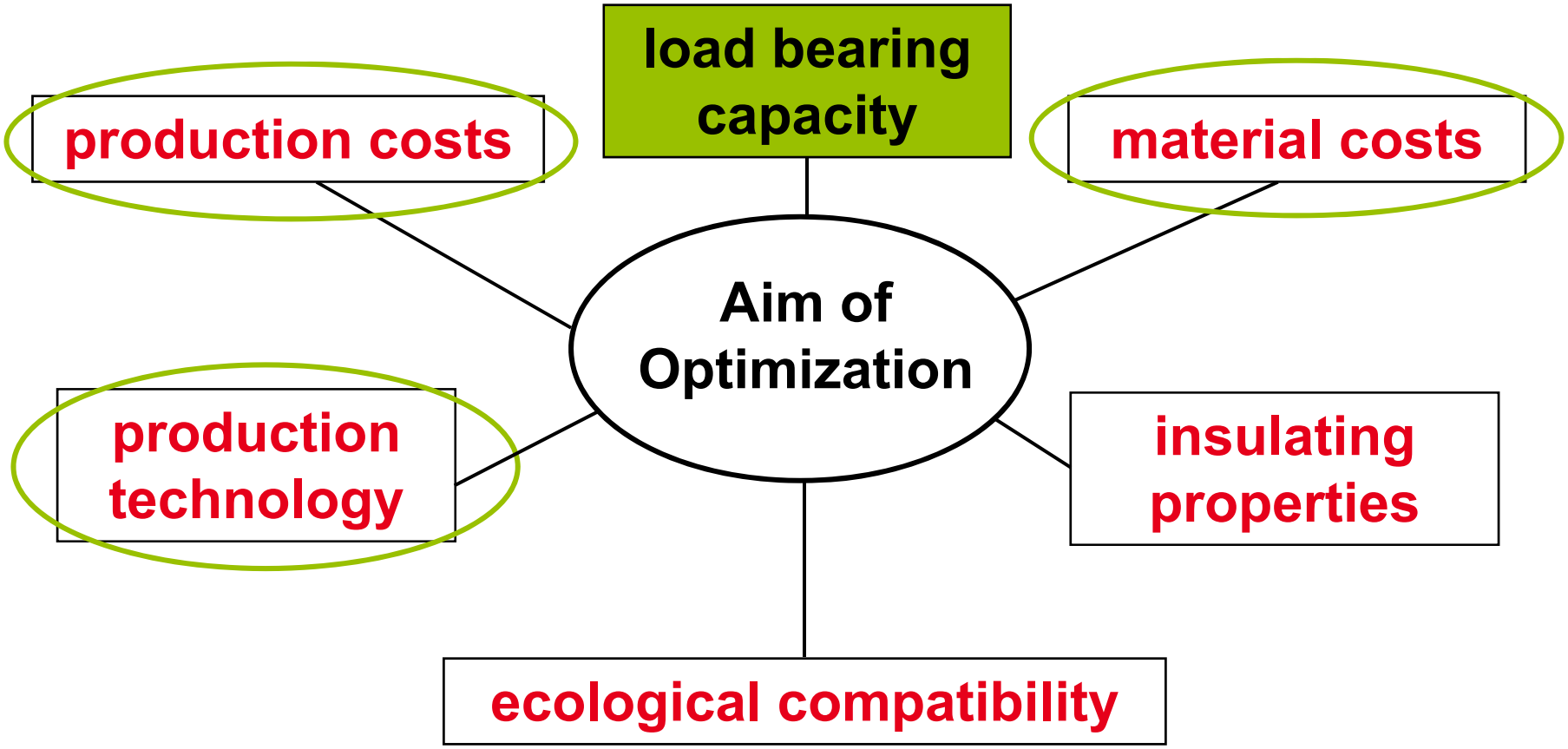

Main Works

- Investigation into Mechanical Properties of Sandwich Panels
  - Optimization of Core Material - theoretical
  - Optimization of Metal Faces - theoretical, experimental
  - Optimization of Complete Sandwich Panel - in progress

Optimization of Core Materials

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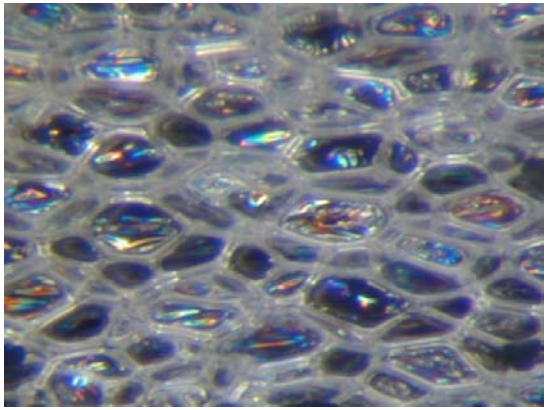
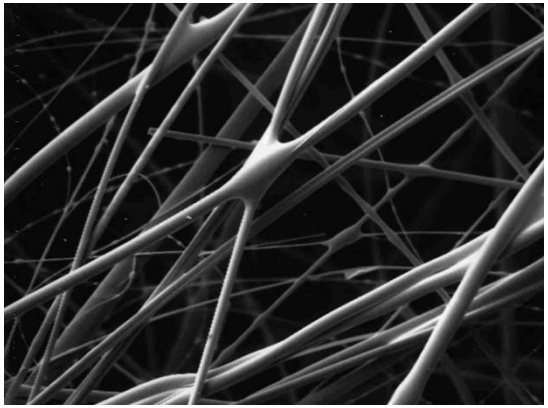
Three most commonly used core materials of sandwich panels

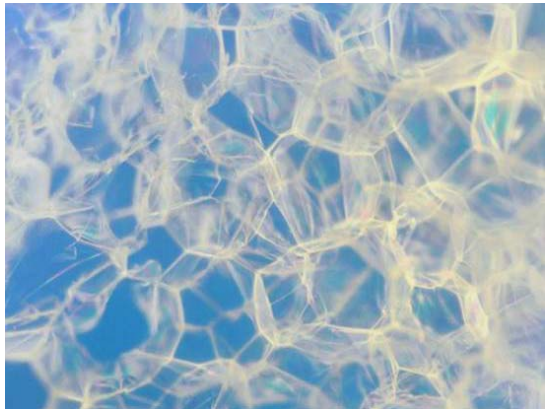
PUR



MW



PS



G_C = ? f_{Cv} = ? E_{Cc} = ? f_{Cc} = ? E_{Ct} = ? f_{Ct} = ?

Which strength and modulus values are needed to get an optimal core material?

Optimization of Metal Faces

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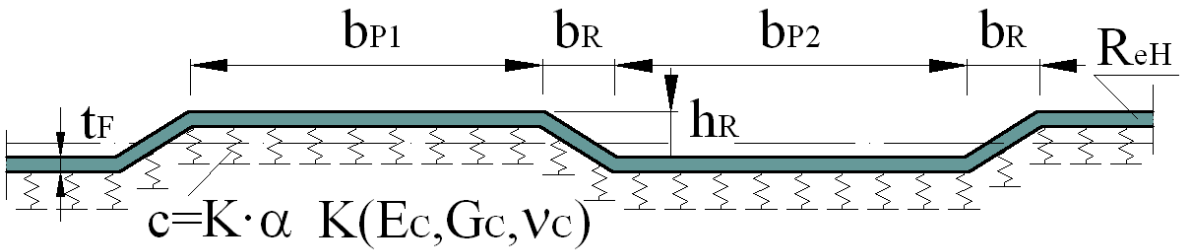
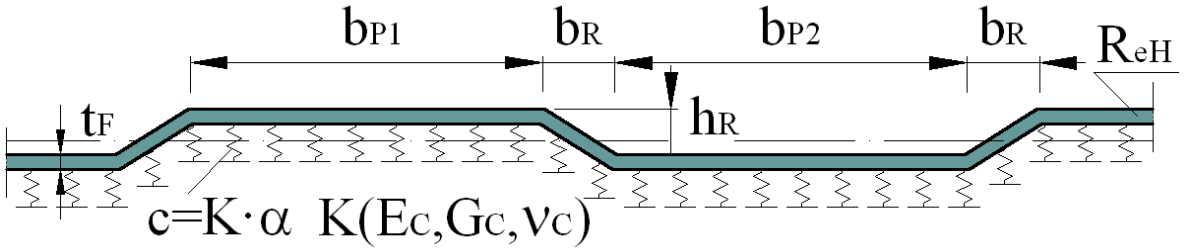
Different forms, geometries and thicknesses of metallic faces

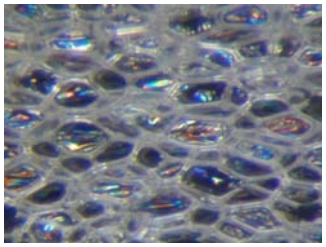
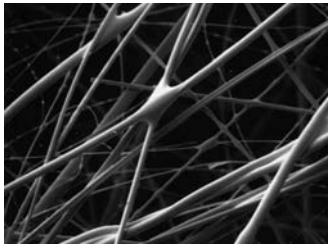
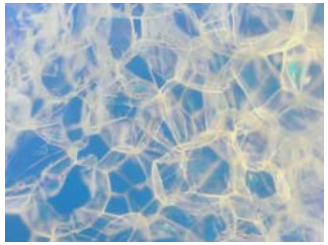


b_{P1} = ? b_{P2} = ? b_R = ? h_R = ? t_f = ? R_{eH} = ?

Which combination of dimensions and yield strength of metal face are needed to get an optimal face geometry?

Optimization of Complete Sandwich Panel



Which combination of the mechanical properties of the core and geometry of the faces

- **leads to high load bearing capacity (maximal spans)?**
- **is possible to manufacture?**
- **uses the material most economically?**

Investigations into Mechanical Properties

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Complicated calculations

Investigations into Mechanical Properties

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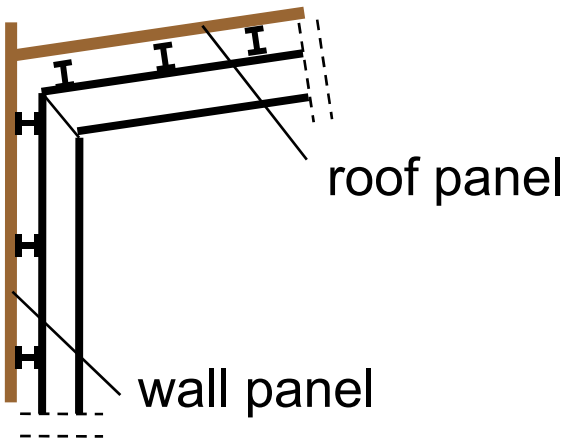
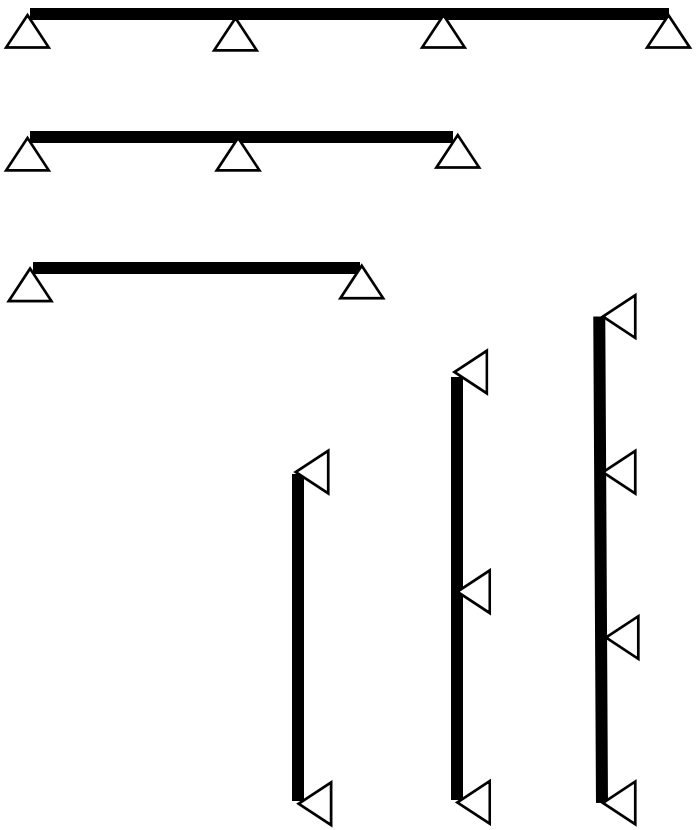
Complicated calculations

- different statical systems





Investigations into Mechanical Properties

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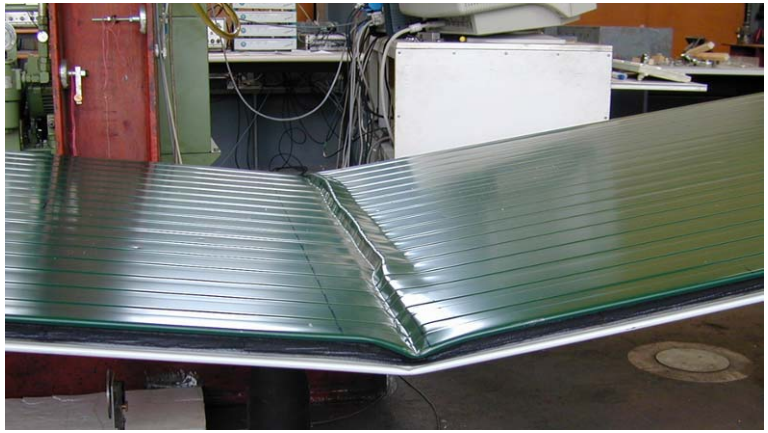
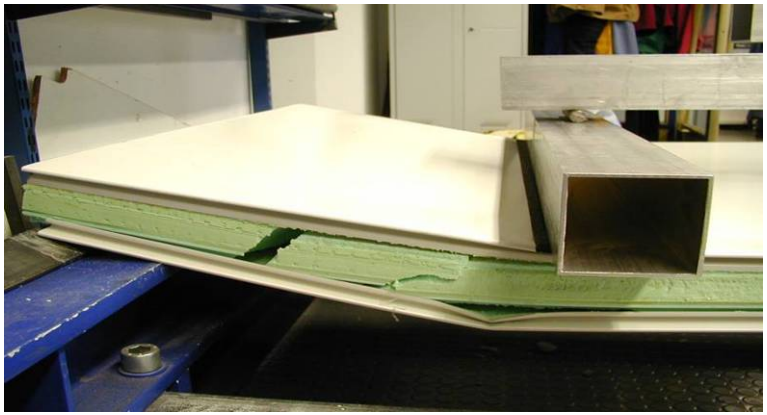
Complicated calculations

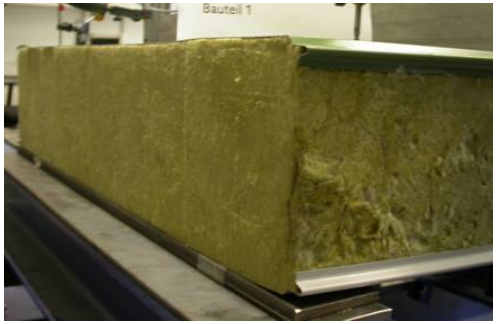
- different statical systems
- different possible failure modes



Wrinkling of metal face (σ_w)



Shear failure of the core (f_{Cv})



Compressive failure of the core (f_{Cc})

Investigations into Mechanical Properties

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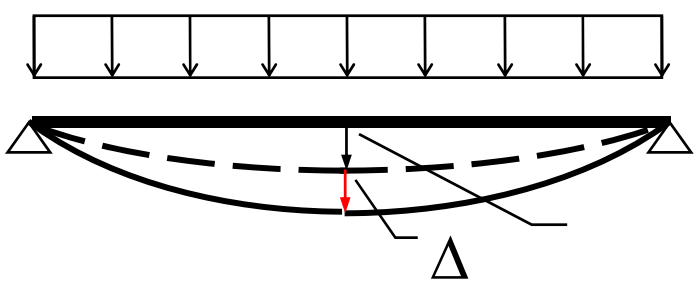
Complicated calculations

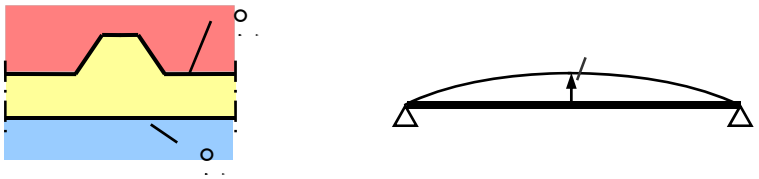
- different statical systems
- different possible failure modes
- special loads and load cases

- Creeping of the core

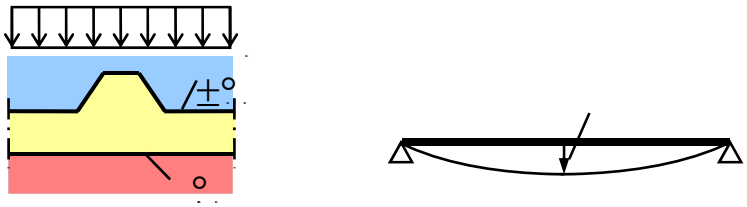


- Temperature differences

Summer load ΔT_{Summer}



Winter load ΔT_{Winter}



Investigations into Mechanical Properties

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Complicated calculations

- different statical systems
- different possible failure modes
- special loads and load cases

Optimization of Core Materials – 1st Step

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Optimization of core material for panel with given geometry

any existing panel

with given geometry

G_C = ?

f_{Cv} = ?

E_C = ?

f_{Cc} = ?

f_{Ct} = ?

→ **OPTIMUM**

concerning design

Optimization of Core Materials – 1st Step

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Optimization of core material for panel with given geometry

Searching for:

Mechanical properties from certain sets:

$G_C \in \langle G_{C1}; G_{C2} \rangle$

$E_C \in \langle E_{C1}; E_{C1} \rangle$

$f_{Cv} \in \langle f_{Cv1}; f_{Cv2} \rangle$

$f_{Cc} \in \langle f_{Cc1}; f_{Cc2} \rangle$

Aiming at →

Requirements:

1. High load bearing capacity
2. High utilization factor of mechanical properties

$f_{Cv} \rightarrow 100\ \%$

$f_{Cc} \rightarrow 100\ \%$

$\sigma_w = f(G_C, E_C) \rightarrow 100\ \%$

$w = f(G_C) \rightarrow 100\ \%$

→ **OPTIMUM concerning design**

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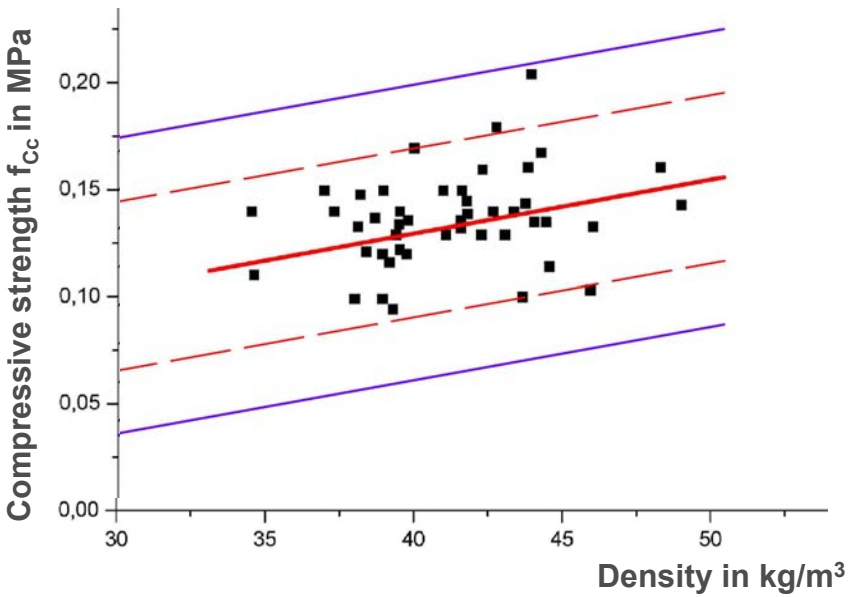
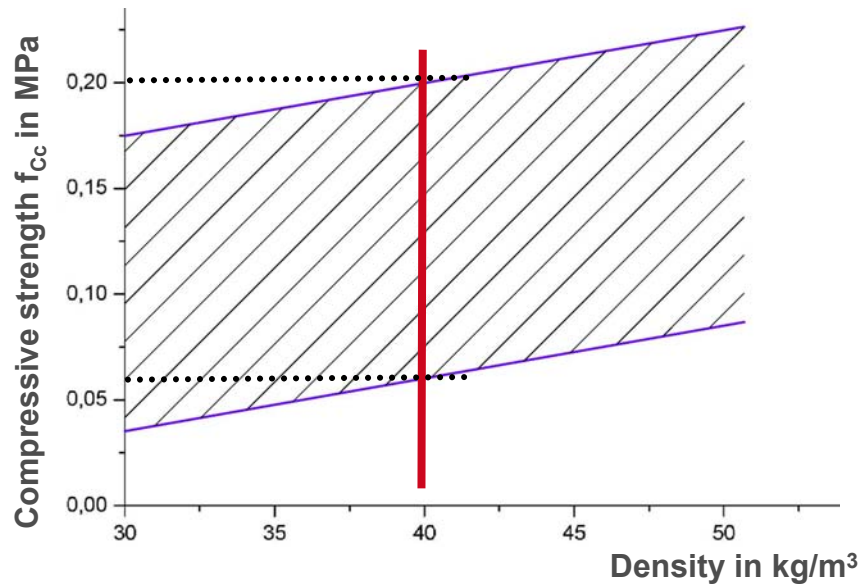
Optimization of Core Materials – 1st Step





PUR

$G_C \in \langle 1{,}9;\ 5{,}5 \rangle$

$E_{Cc} \in \langle 1{,}0;\ 5{,}0 \rangle$

$f_{Cc} \in \langle 0{,}06;\ 0{,}20 \rangle$

$f_{Cv} \in \langle 0{,}085;\ 0{,}225 \rangle$

1. Determination of certain sets according to known material properties (possible to manufacture)
2. Determination of new combinations of mechanical properties

→ **new core materials**

Optimization of Core Materials – 1st Step

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Calculations in optimization processes

1. Selection of an **existing sandwich panel** with given face geometry
2. Creation of **"new elements"** with the given face geometry and new core materials
3. Calculations of **span widths** for different statical systems and load cases for **old panel (Point 1)** and **new panels (Point 2)**
4. Comparison of results
5. Determination of the **optimal core material** from the defined sets

Optimization of Core Materials – 1st Step

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Results and conclusion

- Increasing the span width is possible

  but

- *Wrinkling strength* σ_w is most relevant factor for limitation of span width of sandwich panel:

→ Optimization of Metal Faces

Optimization of Metal Faces

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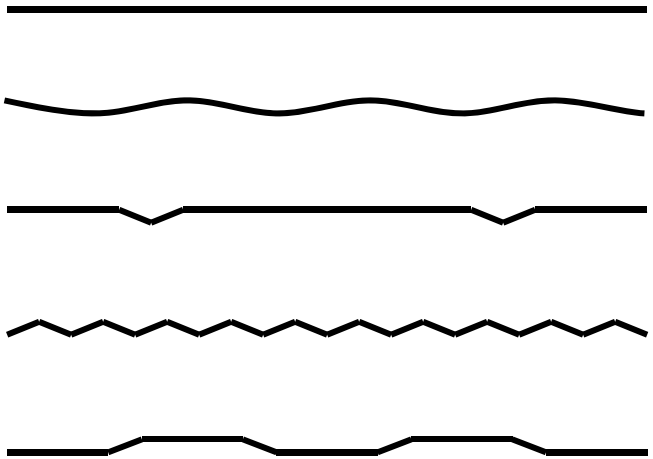
Walls



Flat

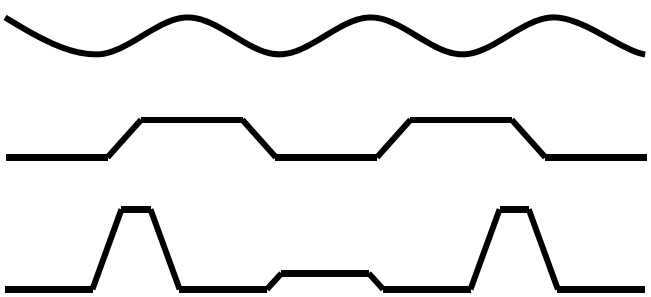
Corrugated profile

Bead profile

Micro-lined profile

Ribbed profile

Roofs



Corrugated profile

Ribbed profile

Trapezoidal profile

Optimization of lightly profiled Metal Faces

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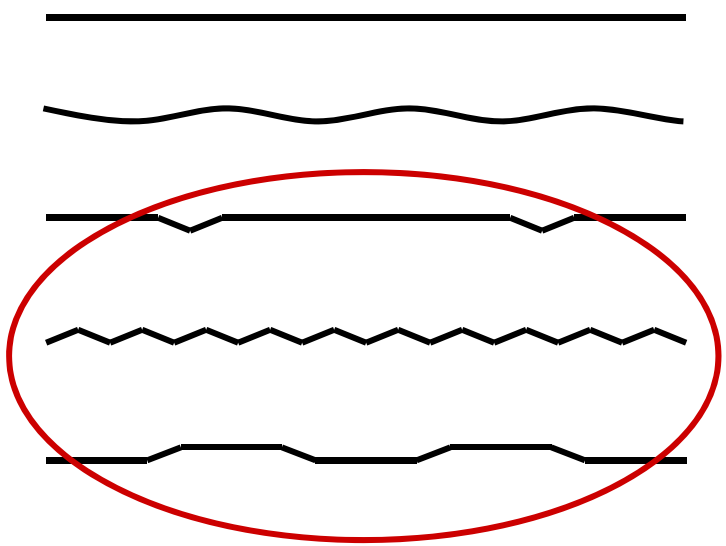
Walls



Flat

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Bead profile

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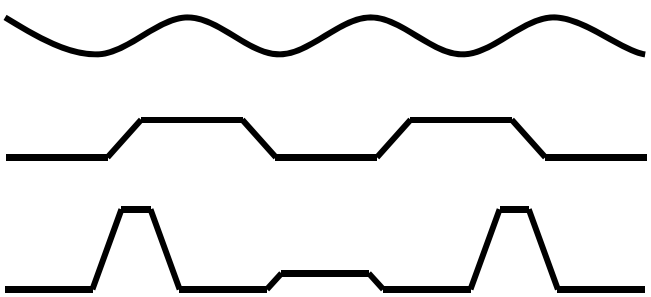

Corrugated profile

Ribbed profile

Trapezoidal profile

Optimization of lightly profiled Metal Faces

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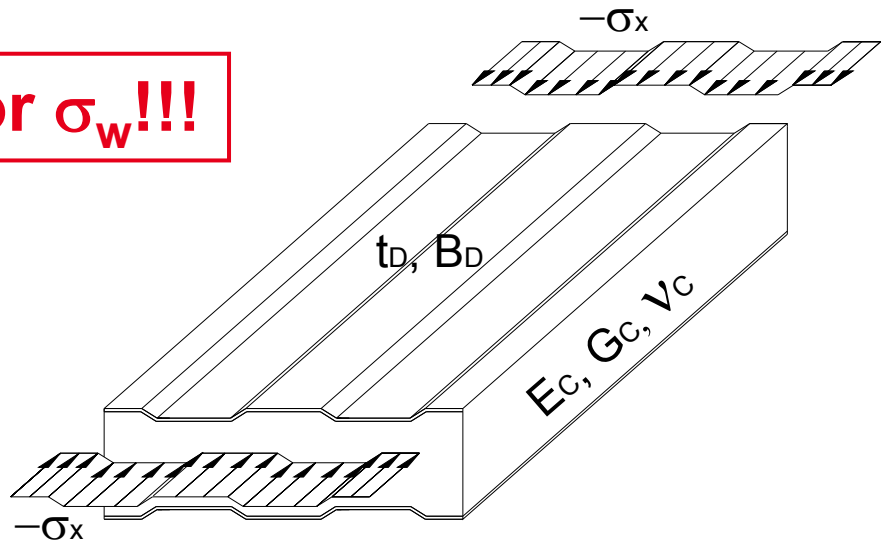
Walls

Ribbed wall profile

New analytical model for σ_w!!!



Evaluation of wrinkling strength σ_w with consideration of

- **buckling theory**
- **elastic bedding on the core**

Optimization of lightly profiled Metal Faces

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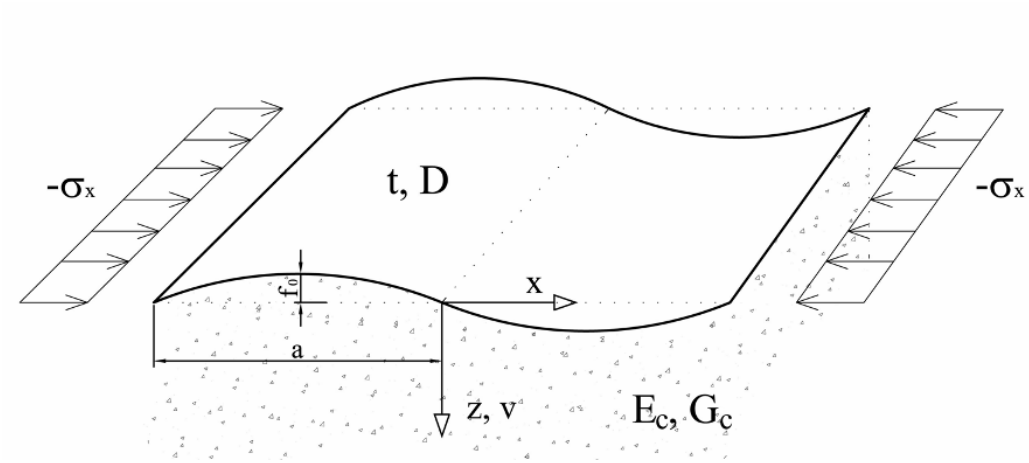
Analytical model for assessment of the ideal wrinkling strength

- Analytical model based upon existing theory for flat faces

$$\sigma_{w,flat} = a \cdot \sqrt[3]{E_C \cdot G_C \cdot E_F}$$



Optimization of lightly profiled Metal Faces

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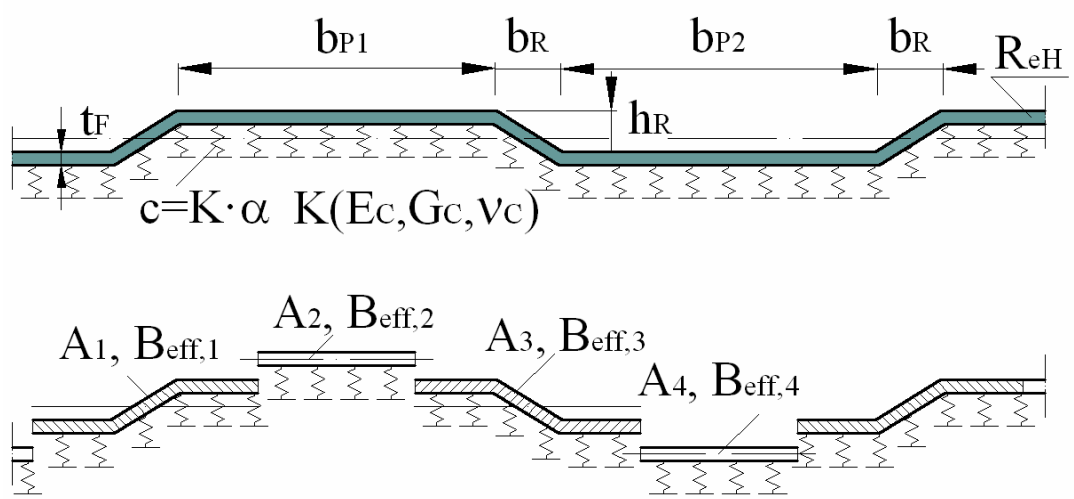
Analytical model for assessment of the ideal wrinkling strength

- Analytical model based upon existing theory for flat faces
- Additionally
  - Consideration of the light-profiling
    - **flat plate strips** and **stiffeners (ribs or crimps)**



Optimization of lightly profiled Metal Faces

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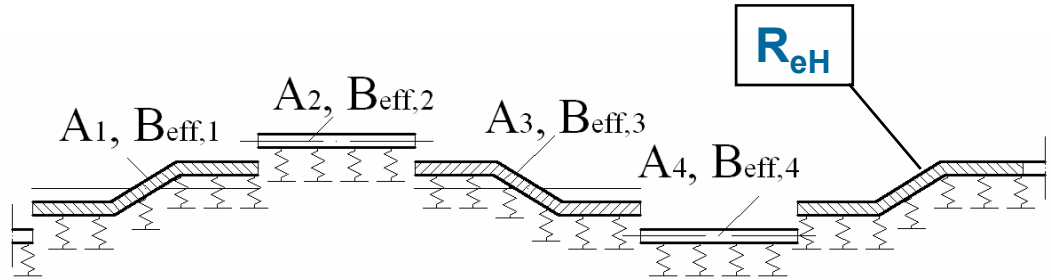
  - Consideration of yield strength of the metal faces R_{eH}



Optimization of lightly profiled Metal Faces

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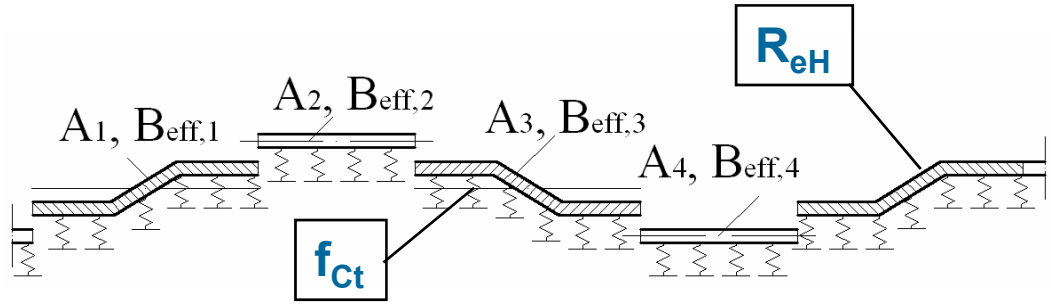
  - Consideration of tensile strength of the core f_{Ct}



Optimization of lightly profiled Metal Faces

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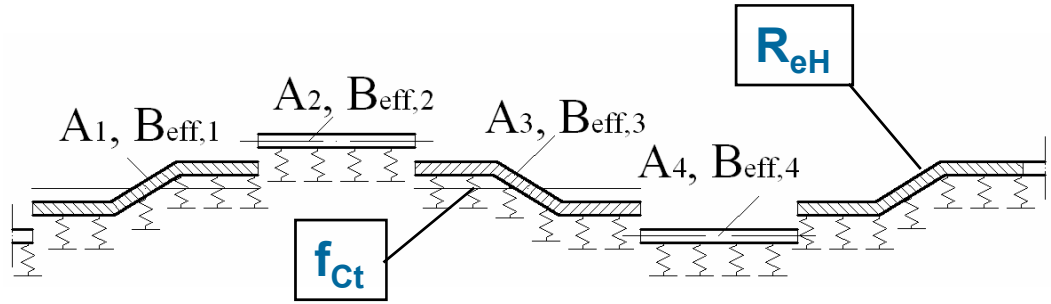

Optimization of lightly profiled Metal Faces

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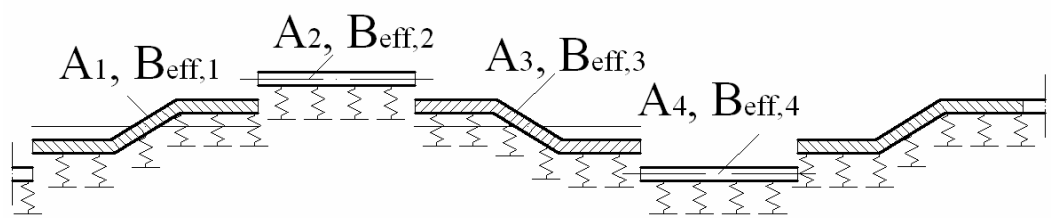
Analytical model for assessment of the ideal wrinkling strength

$$\sigma_{w,ue,f_{Ct}} = \frac{\sigma_{w,ue}}{1 + \frac{\pi}{500} \cdot \sqrt{E_C \cdot G_C} \cdot \frac{1}{f_{Ct}}}$$

$$\sigma_{w,ue} = \frac{\sigma_{w,i} \cdot A_i}{\sum A_i} \quad \text{and} \quad \sigma_{w,i} \leq R_{eH}$$

$$\sigma_{w,i} = \frac{3}{2 \cdot t_F} \cdot \sqrt[3]{2 \cdot B_{eff,i} \cdot K^2}$$



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Optimization of lightly profiled Metal Faces

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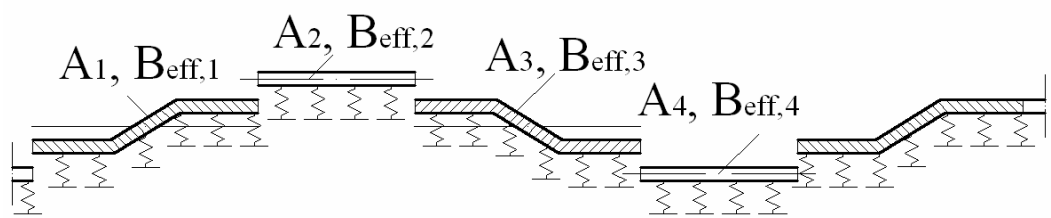
Properties of metal faces



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Optimization of lightly profiled Metal Faces

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Analytical model for assessment of the ideal wrinkling strength

$$\sigma_{w,ue,f_{Ct}} = \frac{\sigma_{w,ue}}{1 + \frac{\pi}{500} \cdot \sqrt{E_C \cdot G_C} \cdot \frac{1}{f_{Ct}}}$$

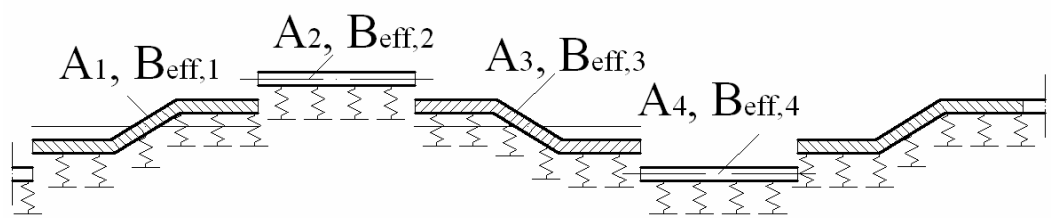
Properties of core material

+

Properties of metal faces

$$\sigma_{w,ue} = \frac{\sigma_{w,i} \cdot A_i}{\sum A_i} \quad \text{and} \quad \sigma_{w,i} \leq R_{eH}$$

$$\sigma_{w,i} = \frac{3}{2 \cdot t_F} \cdot \sqrt[3]{2 \cdot B_{eff,i} \cdot K^2}$$



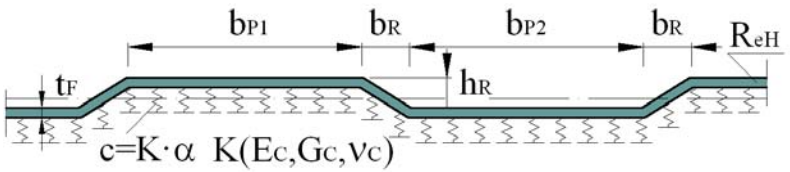
iFSW

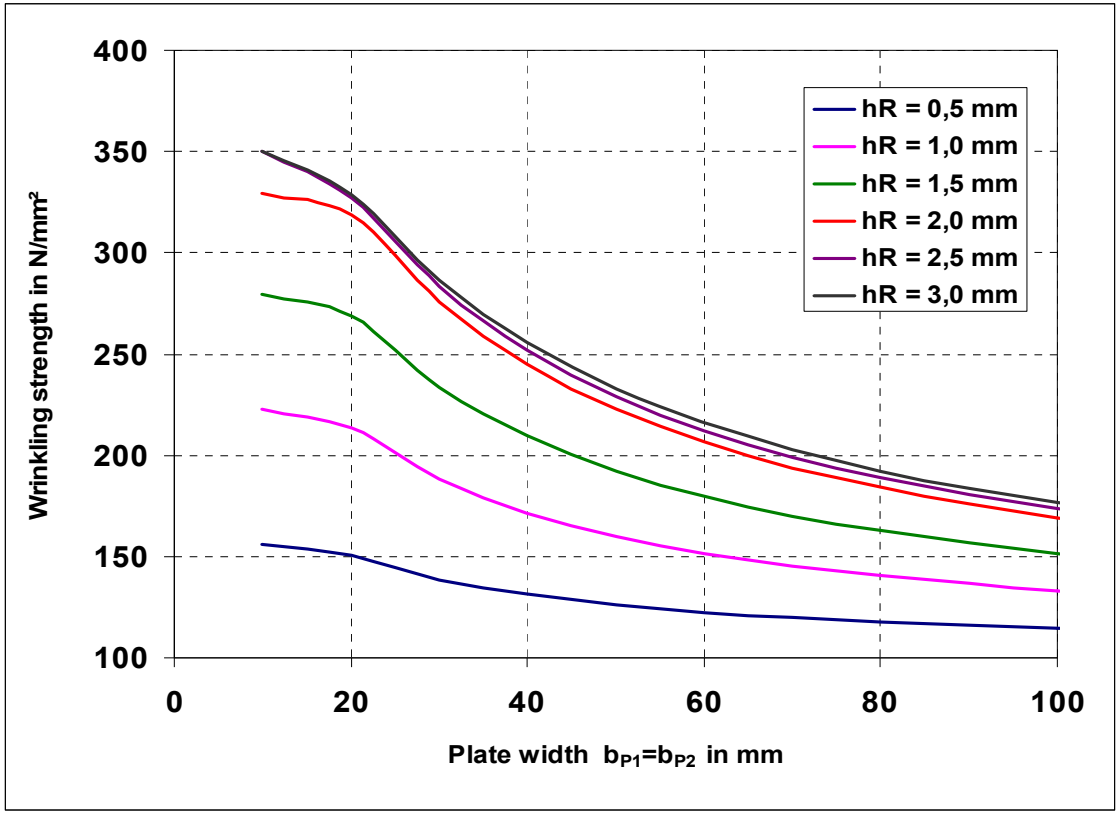
Optimization of lightly profiled Metal Faces

TECHNISCHE UNIVERSITÄT DARMSTADT

$b_{P1} = b_{P2}$

$b_R = 4h_R$





$t_F = 0{,}5$ mm

$R_{eH} = 350$ N/mm²

$E_C = G_C = 3{,}0$ N/mm²

iFSW

Optimization of Metal Faces - First Tests

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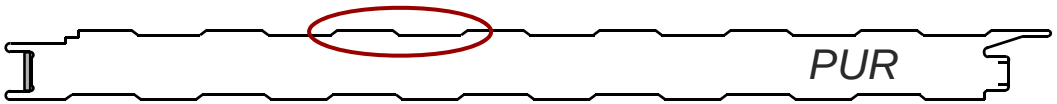
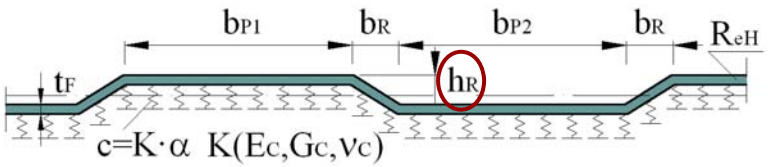
Tested panel faces: Steel ribbed profile, t_F = 0,6 mm



panel thickness: 80 mm

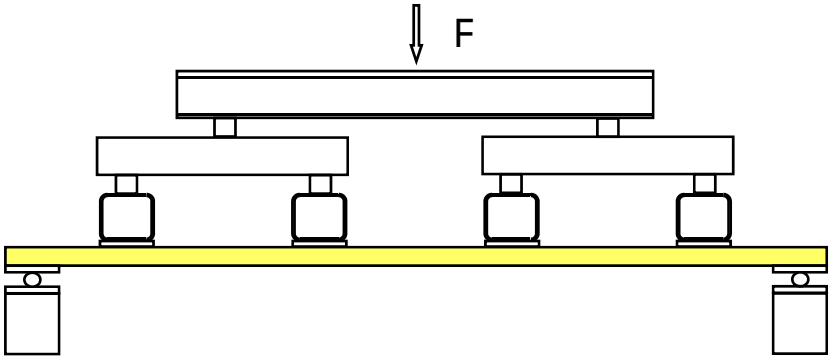


Increasing the rib depth h_R

h_R = 0,60 mm

h_R = 0,90 mm

h_R = 1,30 mm



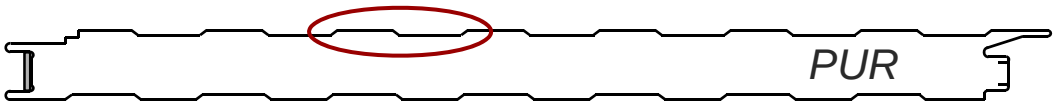
EN 14509 (2006), A.5.

Wrinkling strength σ_w = ?

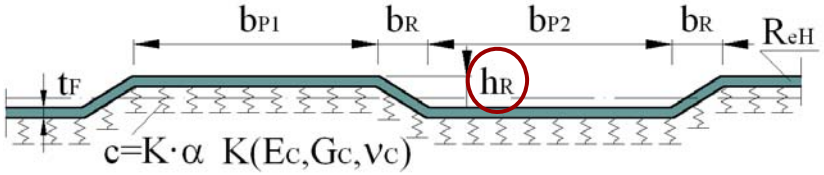
Optimization of Metal Faces - First Tests

TECHNISCHE UNIVERSITÄT DARMSTADT

Tested panel faces: Steel ribbed profile, t_F = 0,6 mm



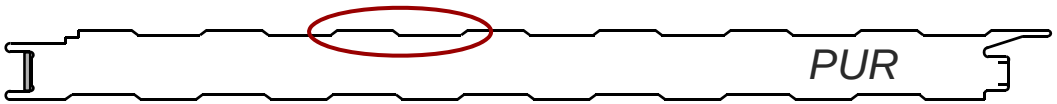
panel thickness: 80 mm

Panel type: Wall ***Face geometry: Ribbed profile***	***Depth of the ribs h_R***	***Wrinkling strength σ_w***	***Increasing of wrinkling strength***
	***0,60 mm***	***170,4 N/mm²***	***-***
	0,90 mm	***188,5 N/mm²***	***10,6 %***
	1,30 mm	***208,2 N/mm²***	***22,2 %***

Optimization of Metal Faces - First Tests

TECHNISCHE UNIVERSITÄT DARMSTADT

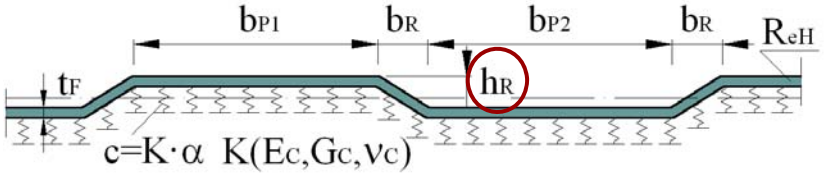
Tested panel faces: Steel ribbed profile, t_F = 0,6 mm

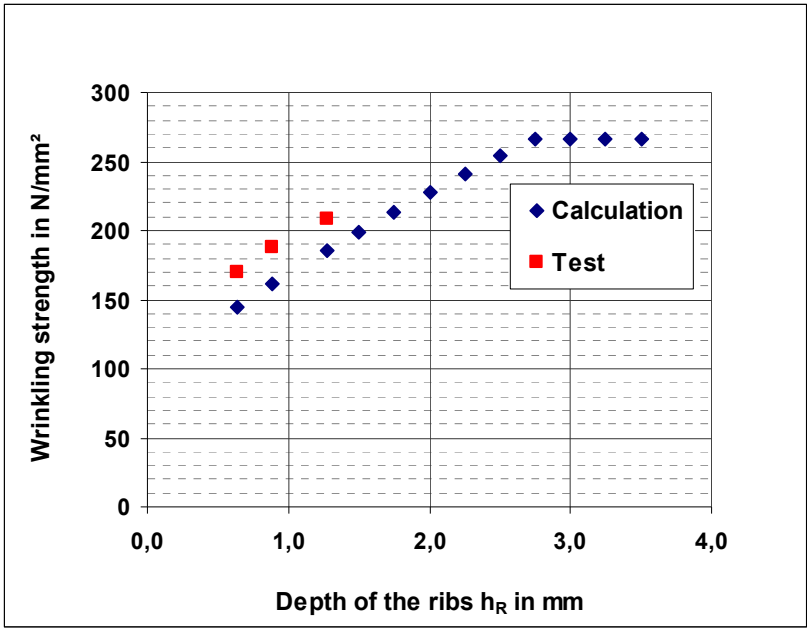


panel thickness: 80 mm

Panel type: Wall

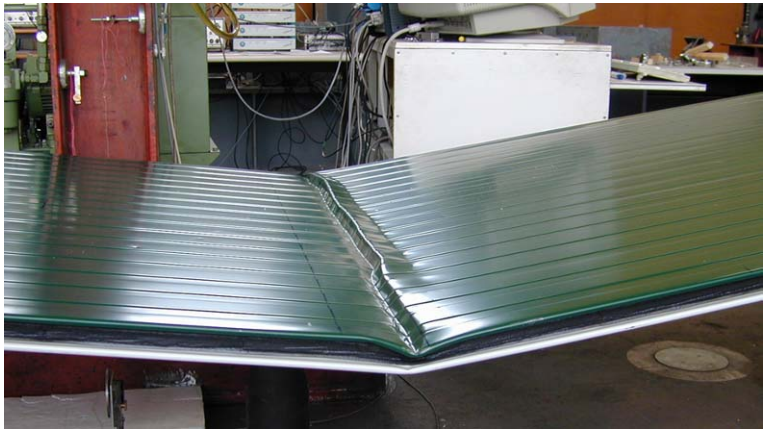
Face geometry: Ribbed profile



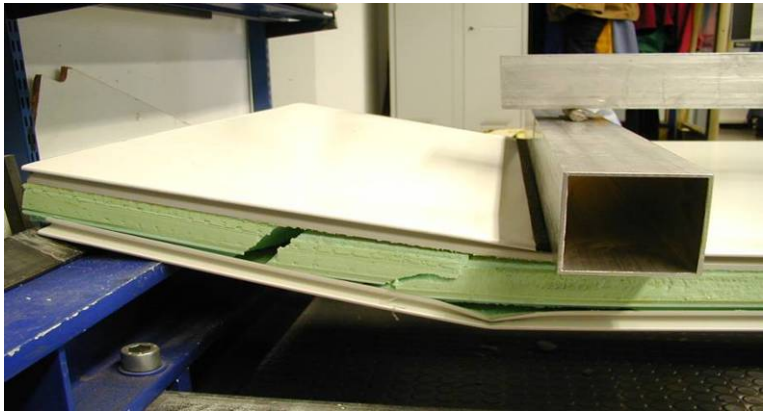


Optimization of Sandwich Panel

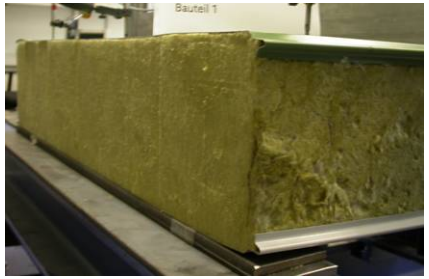
$$\sigma_{w,ue,f_{Ct}} = \frac{\sigma_{w,ue}}{1 + \frac{\pi}{500} \cdot \sqrt{E_C \cdot G_C} \cdot \frac{1}{f_{Ct}}}$$



Wrinkling of metal face (σ_w)



Shear strength of the core (f_{Cv})



Compressive strength of the core (f_{Cc})

Optimization of Sandwich Panel

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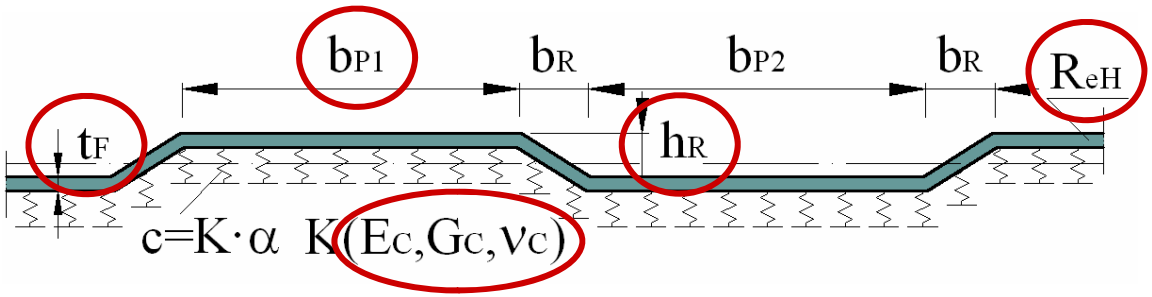
Conclusion:

- Many possibilities for increasing the load bearing capacity
  - increase of the depth of the profiling h_R
  - narrower placing of crimps (narrower plate widths b_P)

  } face geometry
  - selection of optimal yield strength R_{eH} of metal faces

  } face material
  - selection of optimal f_{Ct}; f_{Cc}; f_{Cv} of core material
  - selection of the optimal E_C and G_C of core material

  } core material



Optimization of Sandwich Panel

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Conclusion:

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  - selection of optimal f_{Ct}; f_{Cc}; f_{Cv} of core material
  - selection of the optimal E_C and G_C of core material

  } core material

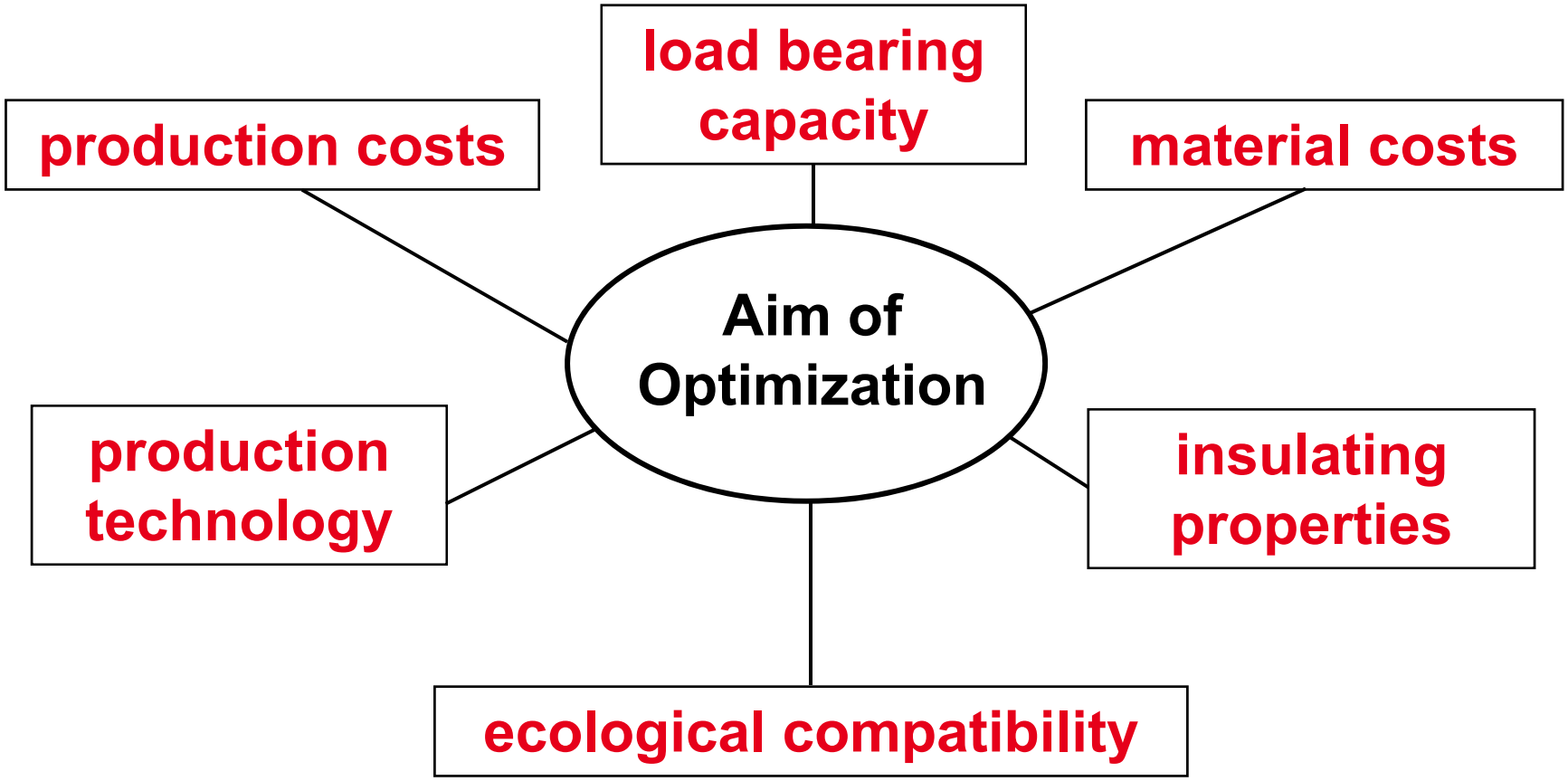
- Additionally
  - thickness of the core
  - thickness of the metal faces

  } material volume

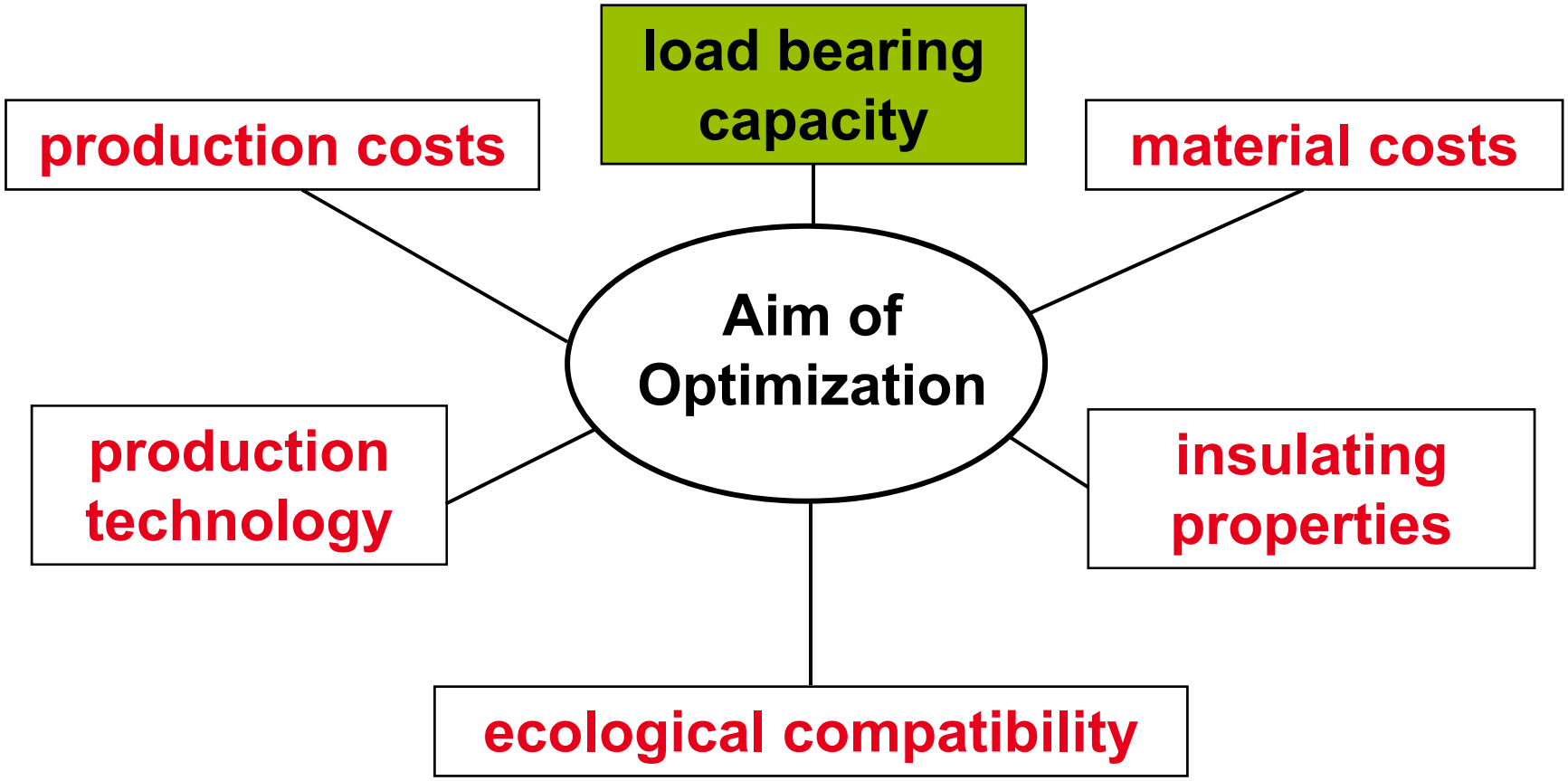
material costs

IFSW

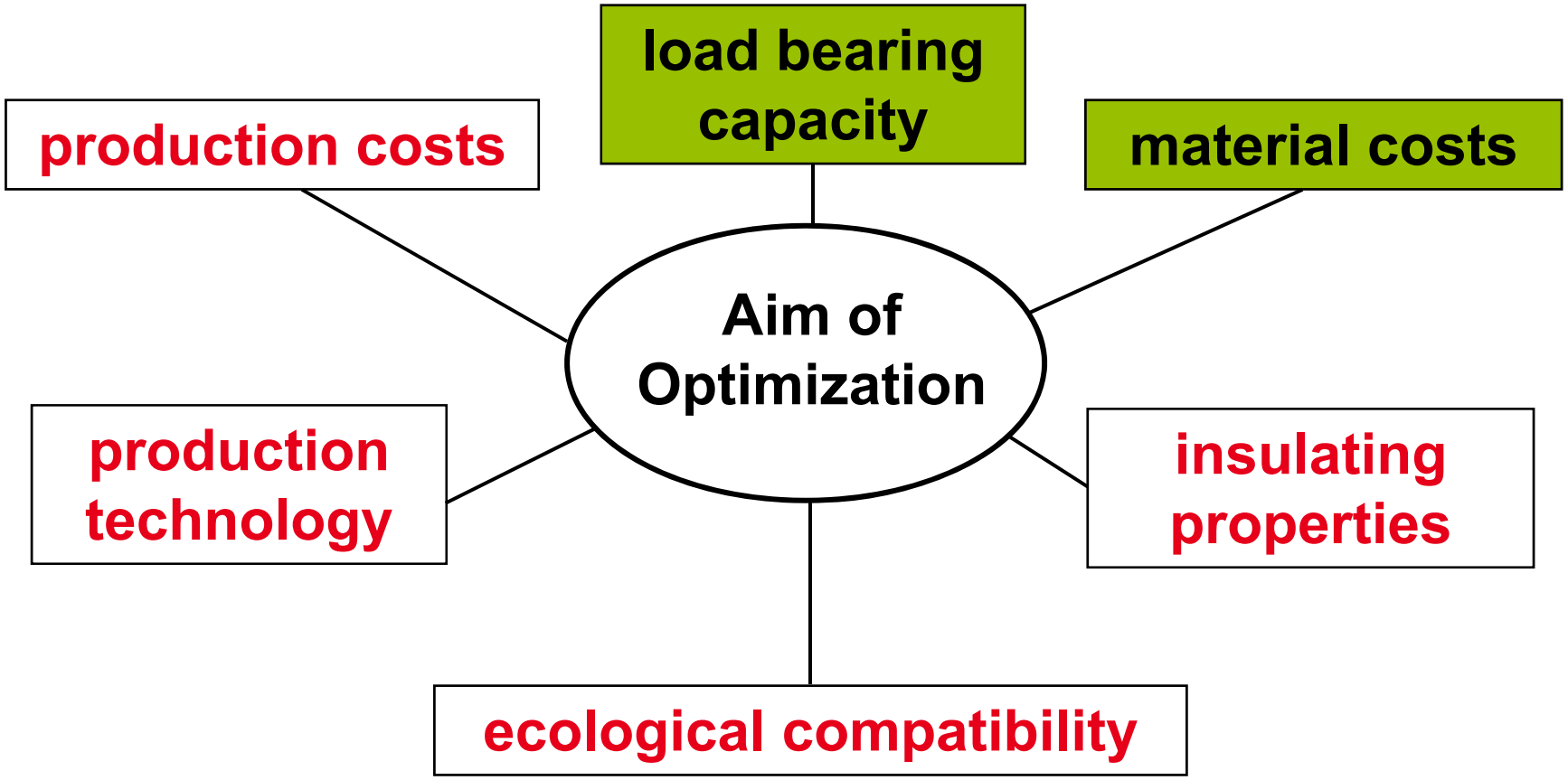
Optimization of Sandwich Panel



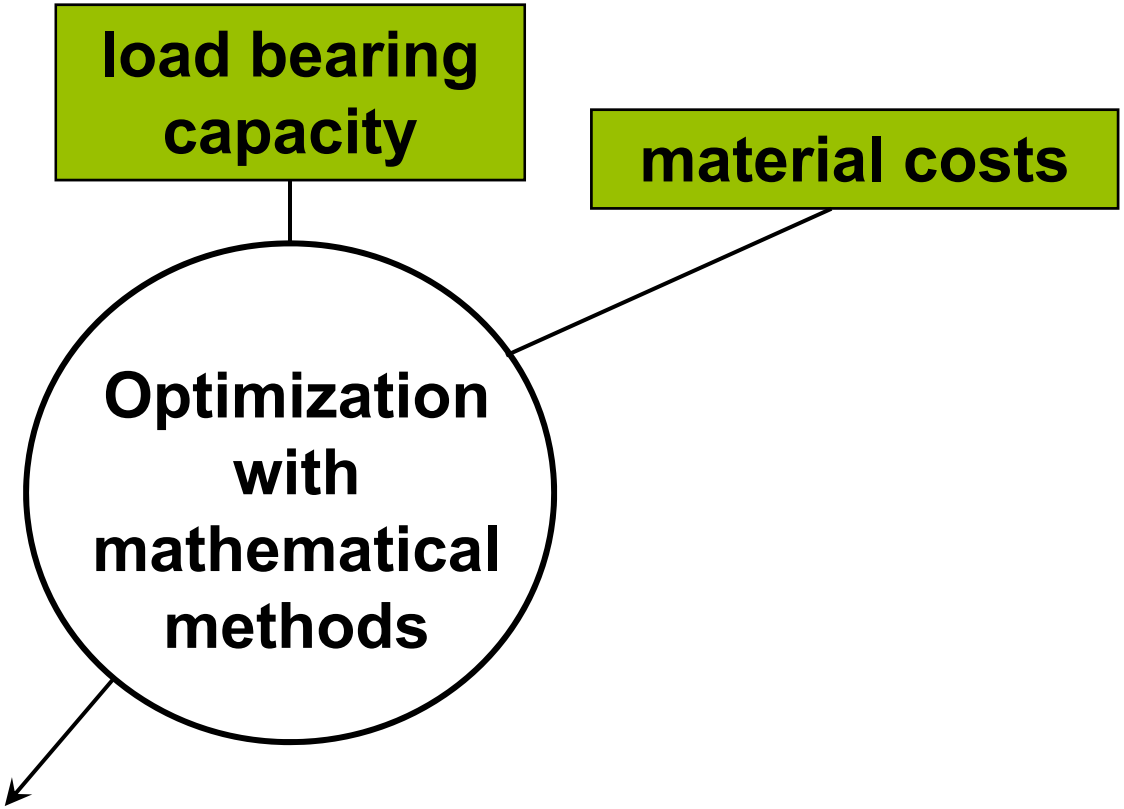
Optimization of Sandwich Panel



Optimization of Sandwich Panel



Optimization of Sandwich Panel



Next step in the Optimization Project

Optimization of Sandwich Panels

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Institute of Steel Construction and Material Mechanics

Thank you very much!

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