HNE Eberswalde
Eberswalde University for Sustainable Development
University of Applied Sciences
Faculty of Wood Engineering

Assessment of the load-bearing capacity of a historic glued laminated timber structure

Influence of chemically-aggressive media on the load-bearing capacity of timber members

Research Workshop
„Contextualizing Early Glulam – The Change in Timber Technology in the 19th & early 20th century"
24./25. January 2019 – ETH Zurich – Department of Architecture

Wood corrosion
Definition, causes and forms of appearance

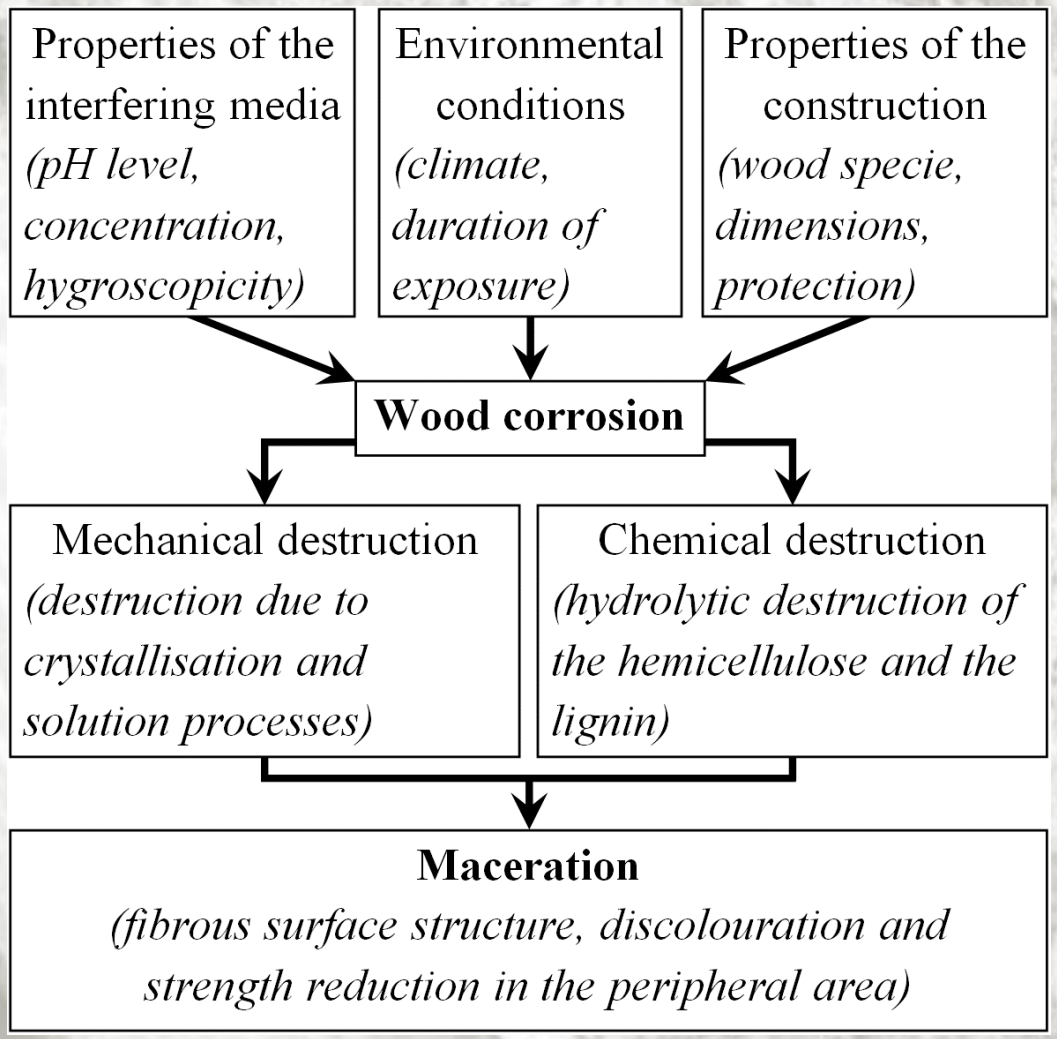
Definition :

- **Alteration of the wood structure** beginning from the outer surface due to **chemical & physical reactions** in interaction with environmental condition

Causes:

- Creation of a **corrosion system** consisting of:
  - timber structure
  - attack conditions (temperature, relative humidity, wood moisture)
  - attacking media (chemically-aggressive media)
- Absorption & deposition of **chemically-aggressive media**:
  - stored material
  - smoke & exhaust fumes
  - wood preservatives & fire retardants

Wood corrosion
Definition, causes and forms of appearance



shematic depiction of the wood corrosion

Wood corrosion
Definition, causes and forms of appearance

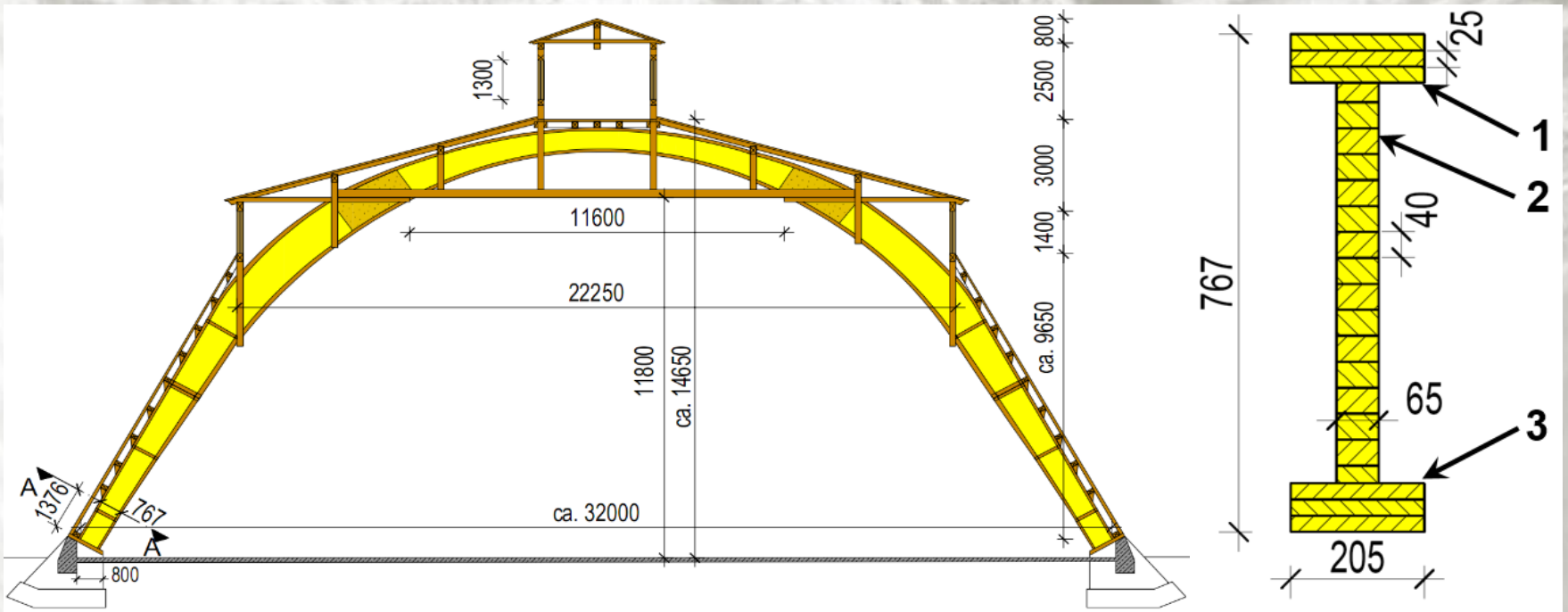
typical appearance of the wood corrosion – left: fibreous surface structure; right: Oberflächenstruktur; rechts: shedding of the superficial wood structure as fibre bundles or wood strips

Object despriction
glulam timber structure of a warehouse

top: external view; bottom: internal view

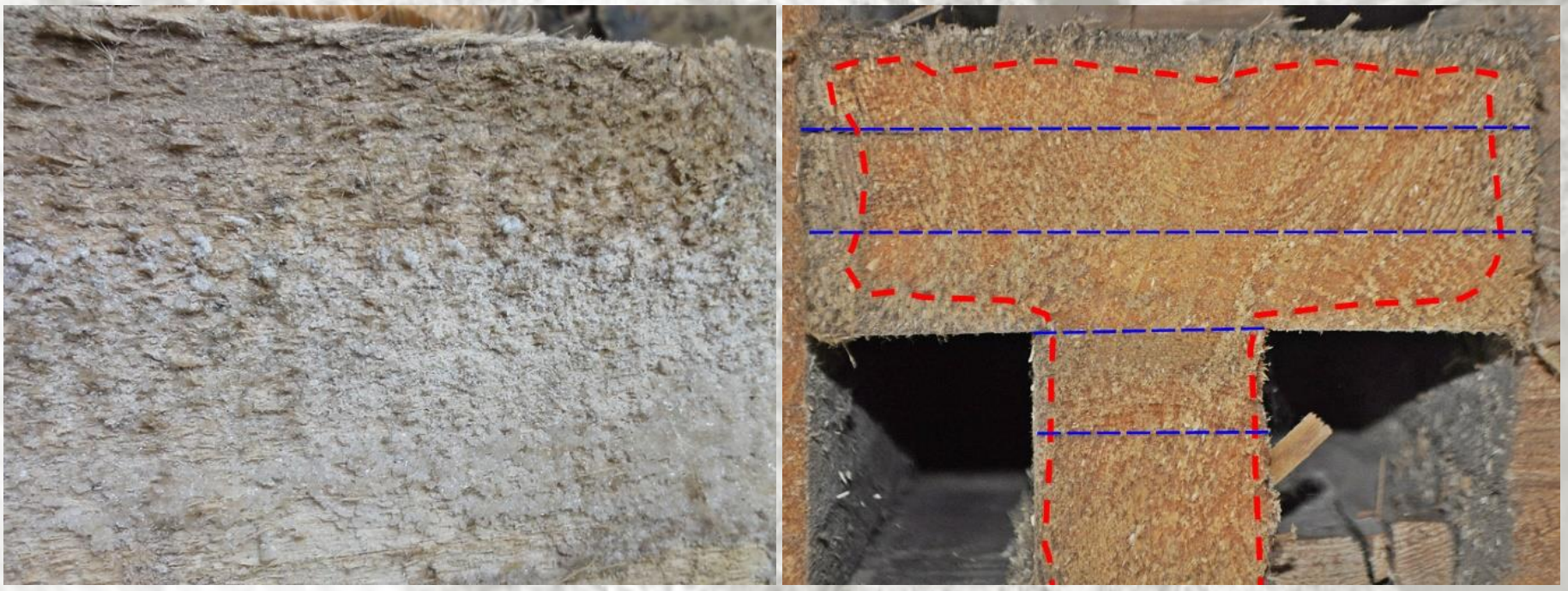
- errected 1912 by the Otto Hetzer AG, Weimar
- used approx. 80 years as warehouse for fertilisers
- demolished in April 2010
- Parabolic trusses – HETZER construction method (spruce wood)
- Span width: 32m; height: 14,5m
- greyish-brown discolouration
- fibreous surface structure
- shedding of superficial structure
- Heavy corrosion on the connectors and steel members

Object despriction
glulam timber structure of a warehouse



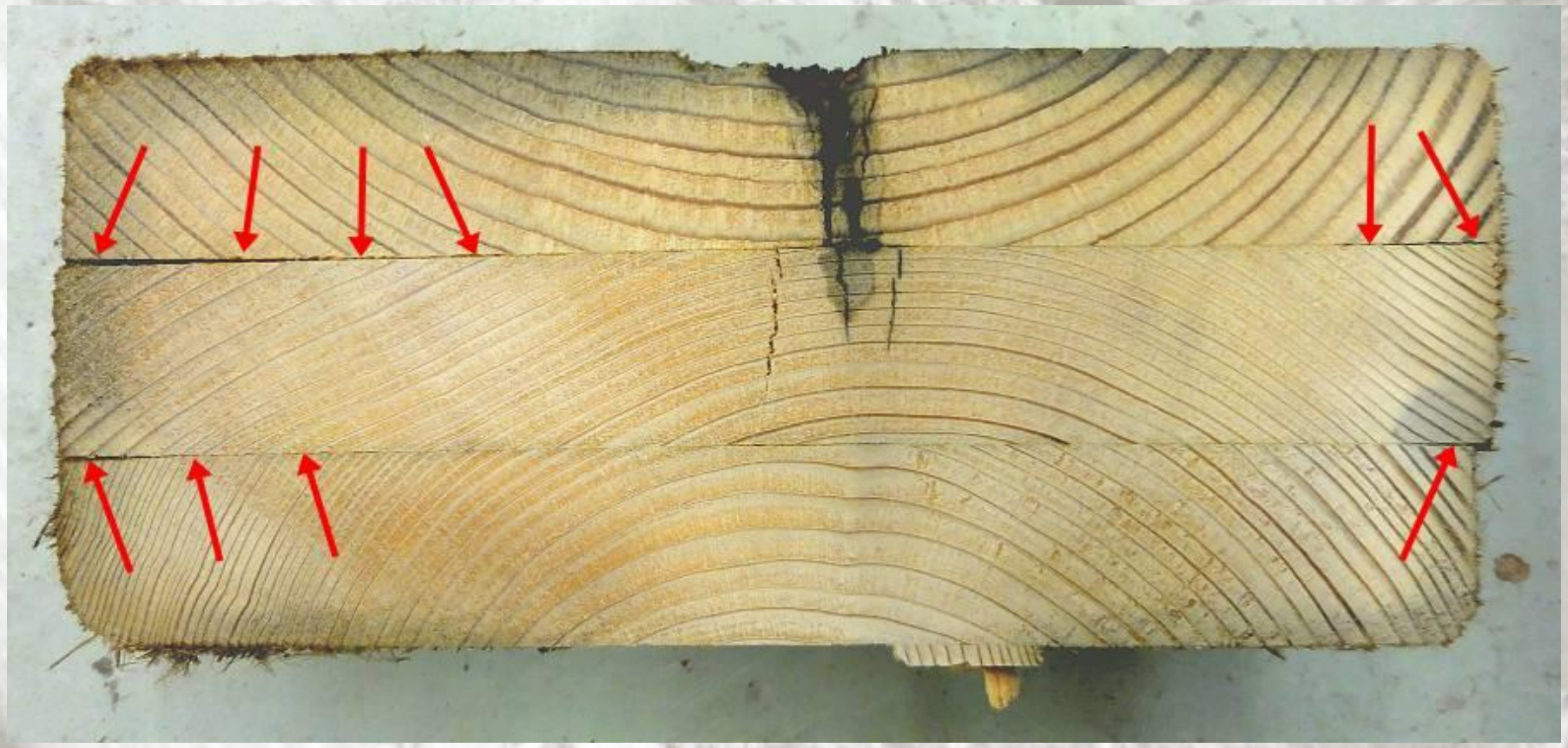
Grafic depiction of the load-bearing structure:
left: parabolic glulam timber trusses; right: cross section A-A (1 … top chord; 2 … web; 3 … bottom chord)

Object despriction
glulam timber structure of a warehouse



Clearly visible marks of corrosion
left: fibrous surface structure and greyish discolouration as well as salt deposits; right: discolouration of the superficial structure (red dashed lines: discolouration border; blue dashed lines: glue joints);

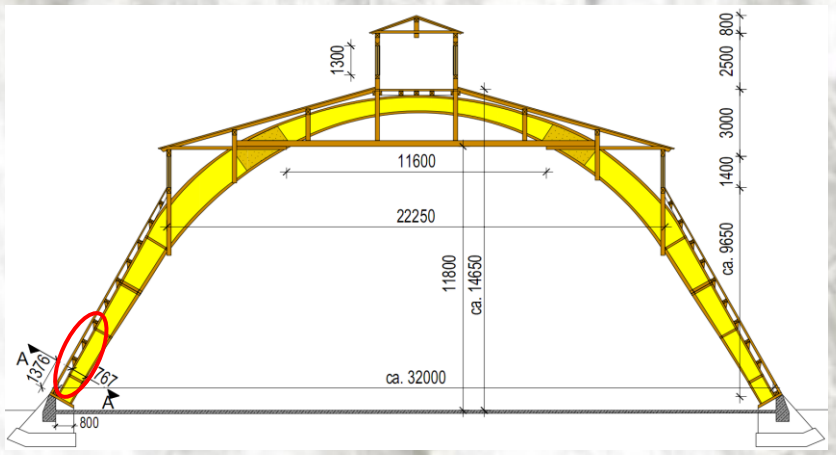
Object despriction
glulam timber structure of a warehouse

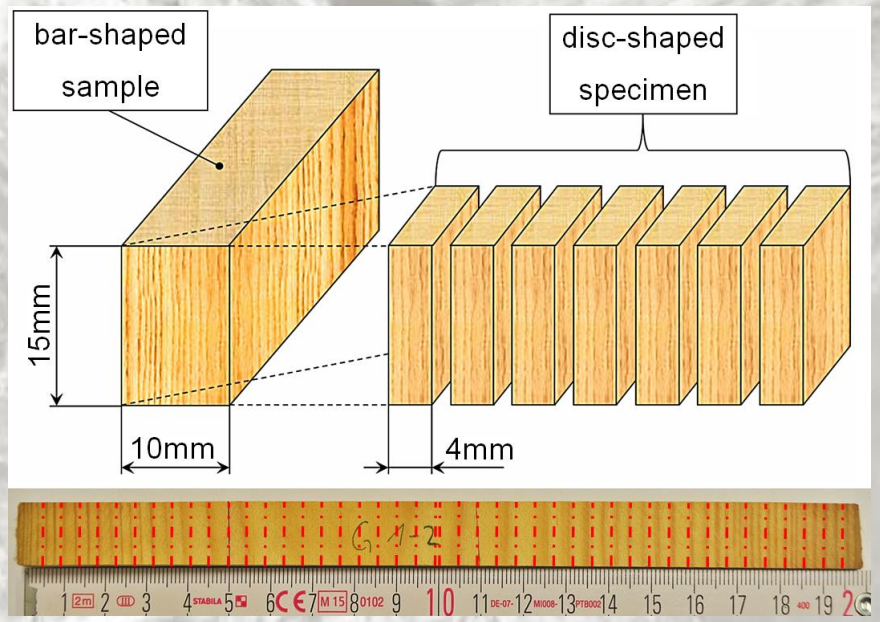


Loose glue joints in the periphery of the chord‘s cross section

Materials studies

study on the extent of the corrossion layer



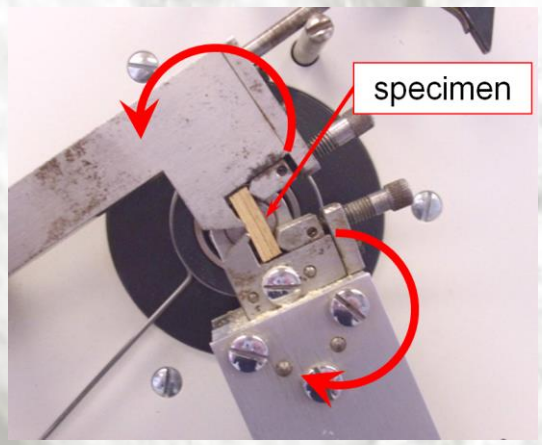


Sample series „chord“: 30 samples with 44 specimen → 1320 specimen

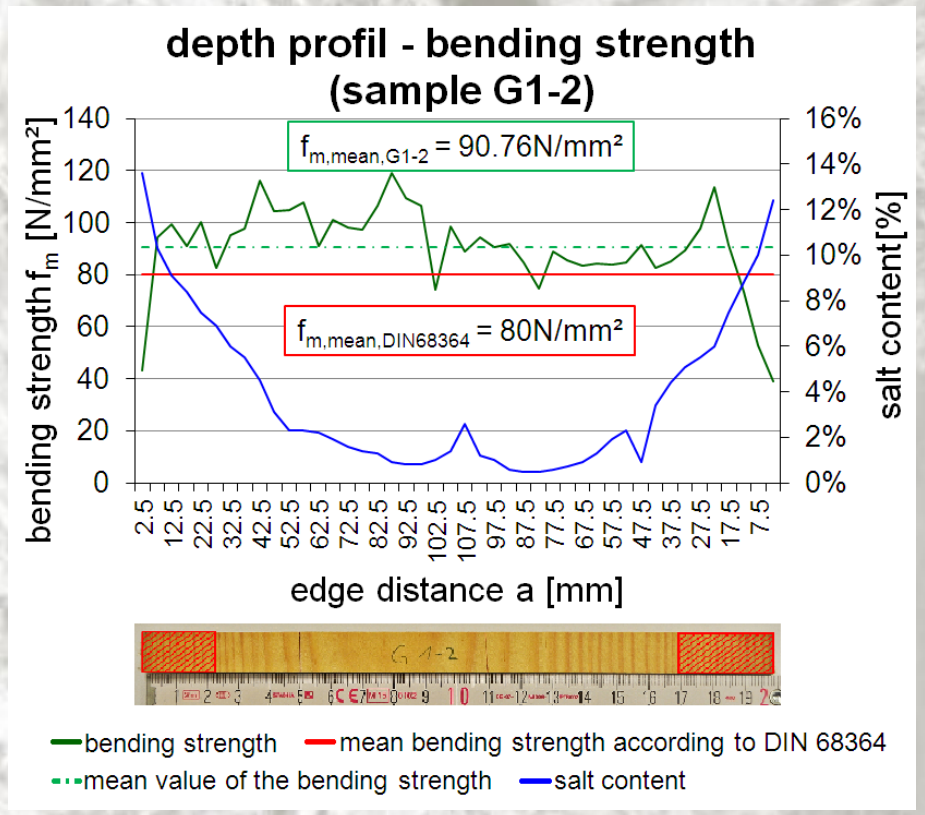
Sample series „web“: 30 P samples with 14 specimen → 420 specimen

Materials studies

study on the extent of the corrossion layer



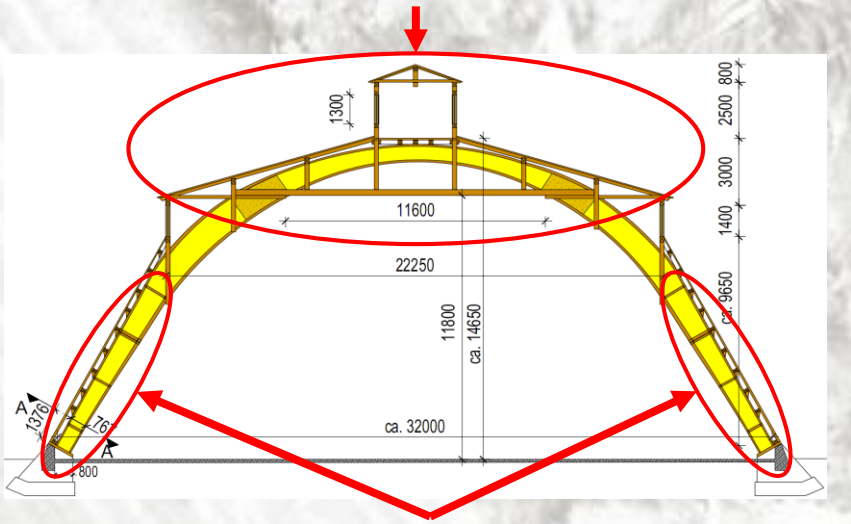
Determination of the bending strength (Dynstat-method)



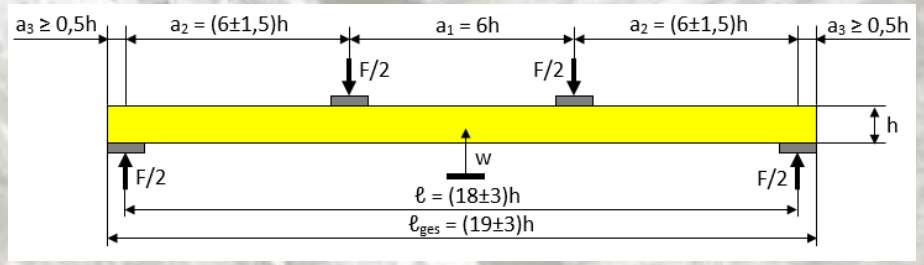
Materials studies

study on the load-bearing capacity of the timber members

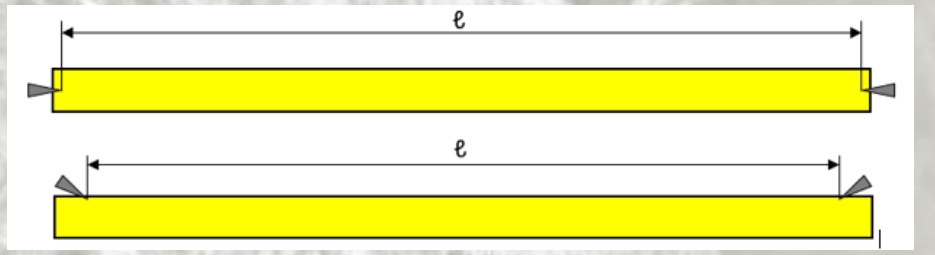
Sample series „VH“



Sample series „BSH“



Bending test acc. EN 408



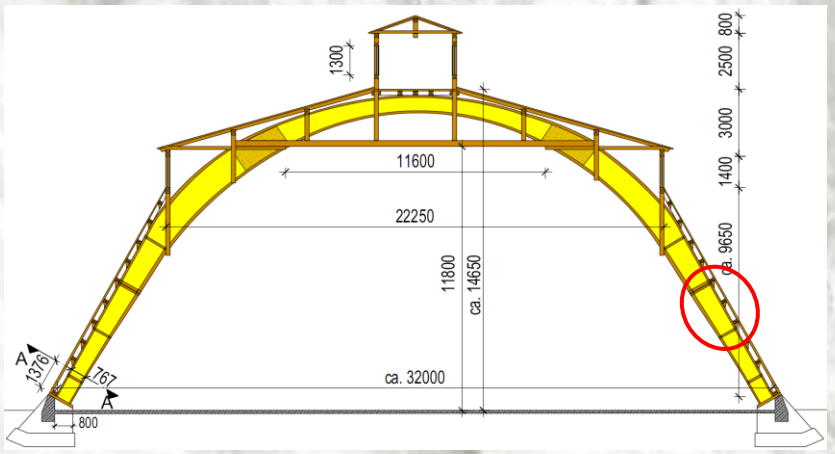
Ultrasonic time of flight measurement

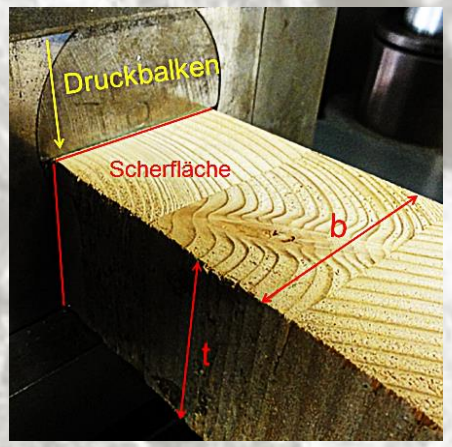
Sample series „VH“: 40 specimen from the roof structure

Sample series „BSH“: 40 specimen from the glulam trusses

Materials studies

study on the strength of the Casein glue joints





Shear test acc. EN 392

Samples: 314 glue joints extracted from the chords and webs of two Truss fragments

Determination of the fiber fracture ratio

Results
study on the extent of the corrossion layer

- **Increased density due to salt deposition**, especially in the peripherical cross section

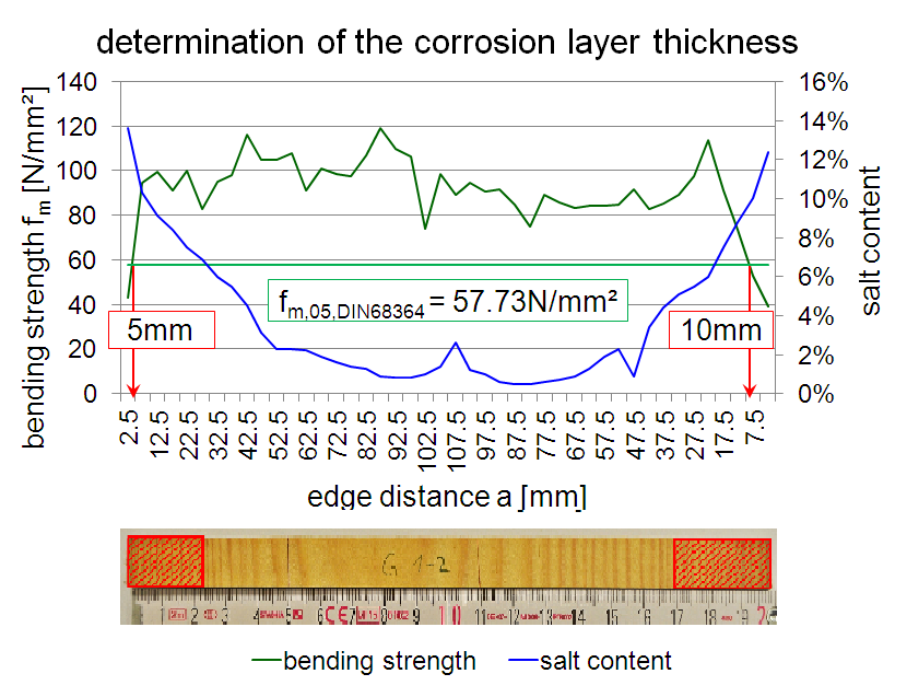
- **Significant reduction of the bending strength due to wood corrosion** in the peripherical cross section

- **Salt content** (mainly Potassium-, Sodium- and Magnesiumchloride) **in the peripherical cross section up to 10-13%**, in the core section 1-5%
-

Results

study on the load-bearing capacity of the timber members

Determination of the corrosion layer‘s thickness on the basis of the bending strength depth profile according to the relevant literature



Thickness of corrosion layer:

chords: approx. 13,5 mm

web: approx. 11,0 mm

Results

study on the load-bearing capacity of the timber members

Mode of failure:

Bending tensile/ compressive on solid and glulam timber

Additional shear fracture on glulam timber

Results

study on the load-bearing capacity of the timber members

Evaluation of the load-bearing capacity:

Solid timber

signifikant reduction of the bending strength, stiffness apparently not reduced

Comparison of the characteristic values of the investigated solid timber with the characteristic values of the strength classes C18, C24, C27 and C30 according EN 338:2010

	VH	**C18**	**C24**	**C27**	**C30**
density ρ_k [kg/m³]	379,6	320	350	370	380
Bending strength $f_{m,k}$ [N/mm²]	19,2	18	24	27	30
Modulus of elasticity $E_{0,mean}$ [N/mm²]	11903	9000	11000	11500	12000
(95% of the modulus of elasticity)		(8550)	(10450)	(10925)	(11400)

Results

study on the load-bearing capacity of the timber members

Evaluation of the load-bearing capacity :

Glulam timber

signifikant reduction of the bending strength and the stiffness, no classification according EN 14080 possible

Comparison of the characteristic values of the investigated glulam timber with the characteristic values of homogeneous glulam of the strength classes GL 20h, Gl22h and GL24h according EN 14080:2013

	BSH	**GL 20h**	**GL 22h**	**GL 24h**
density ρ_k [kg/m³]	377,6	340	**370**	370
Bending strength $f_{m,k}$ [N/mm²]	19,1	20	22	27
Modulus of elasticity $E_{0,mean}$ [N/mm²]	6519,6	8400	11000	11500

Results
study on the load-bearing capacity of the timber members

Results of the ultrasonic time-of-flight measurements:

- Correlation between density and ultrasonic speed relatively weak (r = 0,097…0,037) → equals correlation of new, unaffected timber

- Correlation between bending strength/stiffness and ultrasonic speed was moderate (r = 0,323…0,441) → influence of the damaged superficial structure is not covered by the measurements

- Evaluation of the strength and stiffness of the unaffected core section is possible by ultrasonic mean, the density should be determined by other means (e.g. core samples)

Results
study on the strength of the Casein glue joints

Partially significant damages of the glue joints due to the influence of the salts as well as moisturisation/drying

Results
study on the strength of the Casein glue joints

- Mean shear strength of 4,3 N/mm² (chords) and 4,9 N/mm² (webs)
- Mean fiber fracture ratio: 59%
- Requirements of the nowadays valid standards are not fullfilled → only valid for synthetic resin glues
- Comparison with literature on the strength of casein glue joints shows that the shear strength of the studied materials equals the shear strength of new casein glue joints
- Therefore, the salts influence on the shear strength is only marginal

Conclusion

- Significant deterioration of the material, especially in the pheripherical cross section
- Macroscopic visible deterioration are confimed by the material test
- Comparable objects require a detailed assessment of the load-bearing capacity
  - → exact determimation of the corrossion layer‘s thickness with the Dynstat-Method on core samples
  - → exact determination of the present material properties of the unaffected core section by non- and semi-destructive means – e.g. ultrasonic time-of-flight measurements and core drill samples

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Thank you for your kind attention

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