



DESIGN OF CONNECTIONS FOR MASS TIMBER STRUCTURES

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October 28, 2024
 Next-Generation Wood Construction HQP Seminar XIV

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EDUCATION

- 2000 **PhD in Forestry and Forest Products**
Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
- 1983 **Dipl. Eng. in Civil Engineering with Honours**
Vyatka State University, Kirov, Russia, USSR



COMMITTEE MEMBERSHIPS

- **Executive committee member**, Technical Committee A257 *Engineering Design in Wood (CSA O86)*, CSA Group
- **Chair**, Subcommittee on Connections, Technical Committee A257 *Engineering Design in Wood (CSA O86)*, CSA Group
- **Voting member**, Technical Committee A370 *Solid and Engineered Wood Products*, CSA Group
- **Vice-Chair**, Committee D07 *Wood Construction*, ASTM International
- **Voting member**, Committee E06 *Performance of Buildings*, ASTM International
- **Vice-Chair**, ANSI/APA PRG 320 Standard Committee on *Cross-laminated timber (CLT)*
- **Chair**, Canadian Mirror Committee on ISO/TC 218 *Timber*, Canadian National Committee on the ISO
- **Member**, Canadian Mirror Committee on ISO/TC 165 *Timber Structures*, Canadian National Committee on the ISO
- **Liaison**, ISO/TC 59 *Buildings and Civil Engineering Works/SC2 Terminology and Harmonization of Languages*
- **Member**, RILEM TC TPT on *Test methods for a reliable characterization of resistance, stiffness and deformation properties of timber joints*
- **Associate member**, International Scientific Committee on the Analysis and Restoration of Structures of Architectural Heritage (ISCARSAH), International Committee on Monuments and Sites (ICOMOS)
- **Member**, Coordinating Council, *World Conference on Timber Engineering (WCTE)*

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CONTENT

- A little bit of history
- General requirements to timber connections
- Dowel-type fasteners
- Self-tapping screws (STS)
- Hydrogen embrittlement
- Bonded-in (glued-in) rods
- Ongoing research
- Summary and outlook
- Some exotic stuff for dessert ? (if time permits)

October 28, 2024
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THE OLDEST BUILDING MATERIAL



Hwangnyongsa
Gyeongju, S. Korea
7th century



Hōryū-ji pagoda
Nara, Japan
7th century



Sakyamuni pagoda
Shanxi, China
11th century



Gol Stave Church
Oslo, Norway
12th century

Photos: A. Salenikovich © 2010-2024

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BUILT TO LAST...



Vasa
Sweden
1627

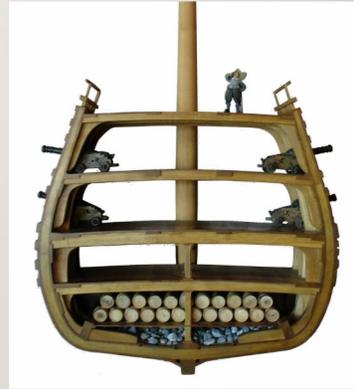


Photo: A. Salenikovich © 2015

Image: Wikipedia

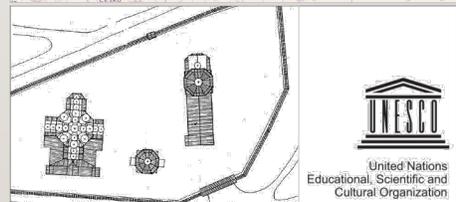
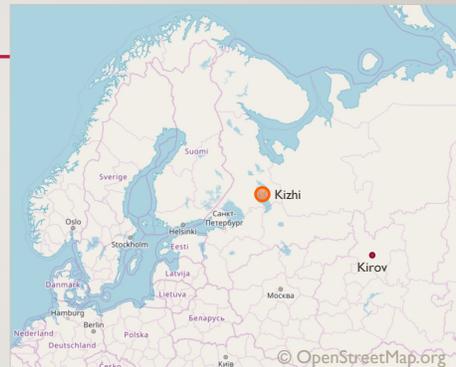
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KIZHI POGOST (1714)



Photo: A. Salenikovich © 2006



World Heritage Site #544 (since 1989)

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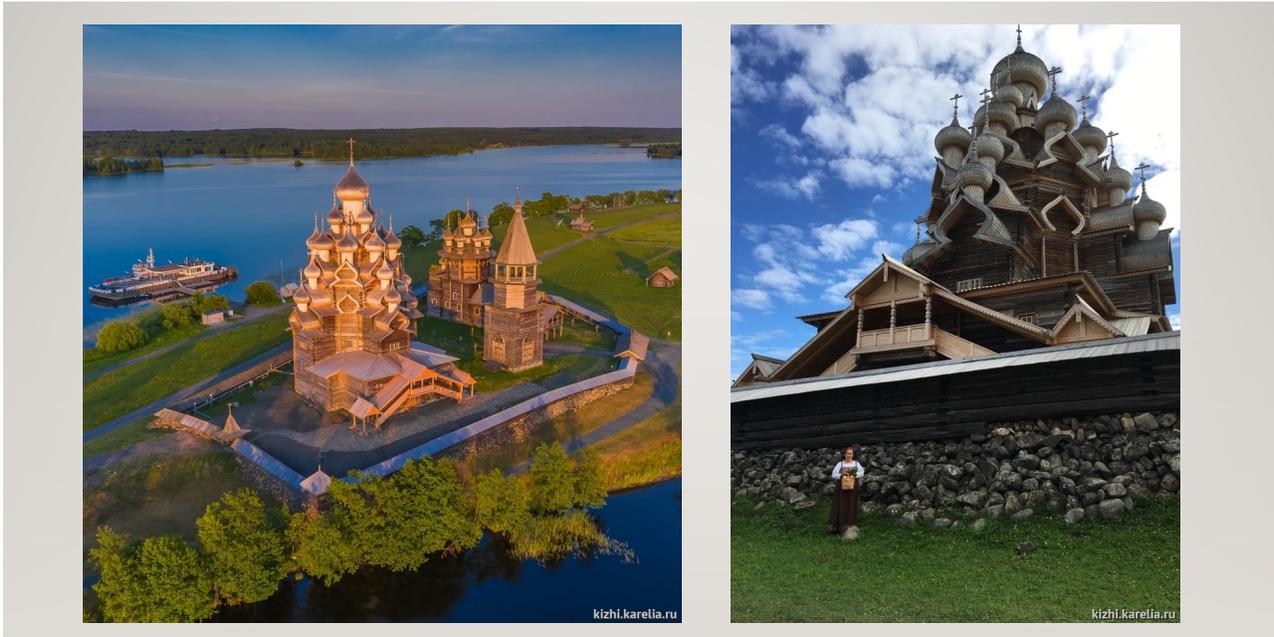
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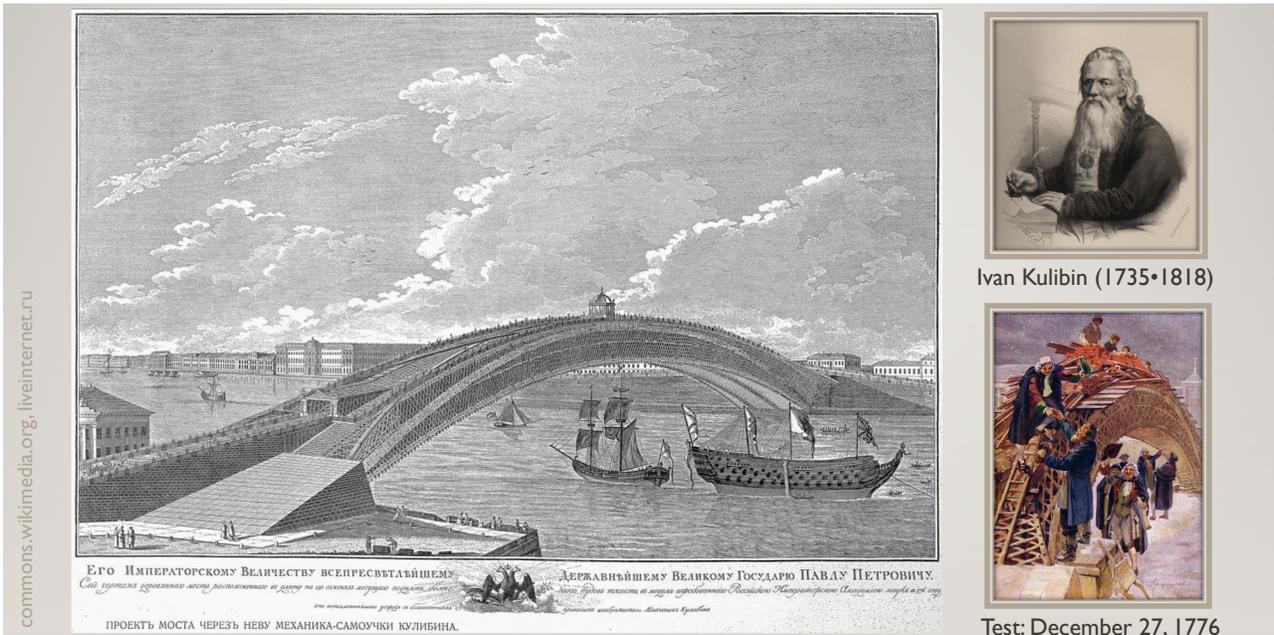
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After the restoration • 2020

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Ivan Kulibin (1735•1818)

Test: December 27, 1776

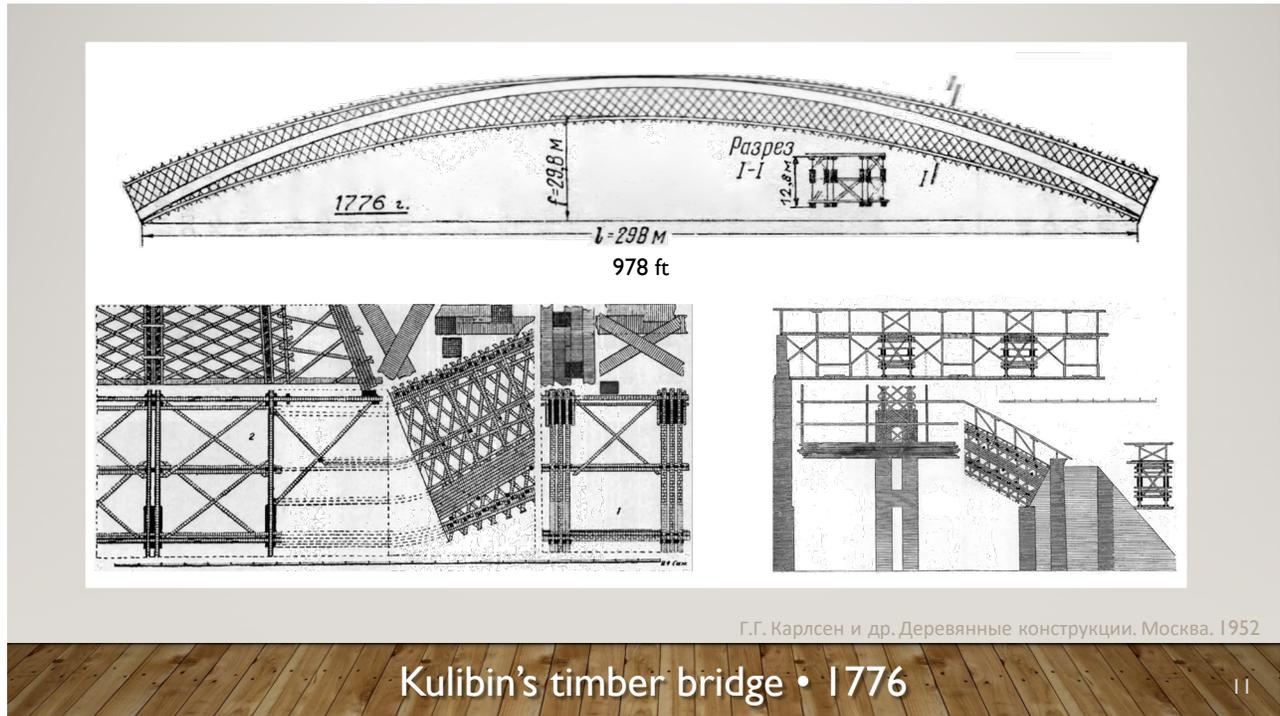
commons.wikimedia.org, liveinternet.net.ru

ЕГО ИМПЕРАТОРСКОМУ ВЕЛИЧЕСТВУ ВСЕПРЕСВЯТАЙШИМУ
 Св. великаго государя императора Павла Петровича и супруги на их великия государя императрицы
 ЕЕ ИМПЕРАТОРСКОМУ ВЕЛИЧЕСТВУ ВСЕПРЕСВЯТАЙШЕЙ
 ЕЕ ИМПЕРАТОРСКОМУ ВЕЛИЧЕСТВУ ИМПЕРАТРИЦЫ МАРИИ ФЕДОВНЫ
 Державнейшему Великому Государю Павлу Петровичу.
 Проектирование и устройство моста через Неву
 Проектъ моста черезъ неву механика-самоучки Кулибина.

Kulibin's timber bridge • 1776

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WITHOUT METAL FASTENERS...



timemilitary.files.wordpress.com

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FIRE !!!



- Alexandria 286 B.C.
- London 1666
- Hamburg 1842
- St-Louis 1849
- Chicago 1871
- Boston 1872
- San Francisco 1906
- New York 1911
- ...

Chicago History Museum

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FIRE !!!



Alexandria 286 B.C.
London 1666
Hamburg 1842
St-Louis 1849
Chicago 1871
Boston 1872
San Francisco 1906
New York 1911
...
Paris, 19 April 2019

Image from Wikipedia

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FIRE... AND CONNECTIONS !!!



Photo: A. Salenikovich © 2024

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MOISTURE... AND CONNECTIONS !!!



2012



2021



2022



2022

KEEP WOOD DRY BY ALL MEANS !!!

Photo: A. Salenikovich © 2012-2022

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CONNECTIONS... AND.. CONNECTIONS !!!



70 m (230-ft) span stadium (Montreal)

Photo: A. Salenikovich © 2009



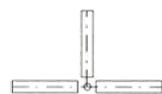
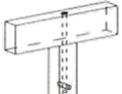
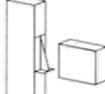
90 m (295-ft) span aquapark (Moscow, RF)

Turkovsky et al. (2013)

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GEOMETRY AND TYPE OF FORCE

TYPE D'EFFORT				
GÉOMÉTRIE				
<p>Adequate connections are to... transfer axial forces, moments, and shear forces from one structural element to another, with acceptable deflections and rotations, and adequate safety at a reasonable cost.</p>				
				

Natterer et al. « CONSTRUCTION EN BOIS » 2004
 Madsen « BEHAVIOUR OF TIMBER CONNECTIONS » 2001

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REQUIREMENTS FOR CONNECTIONS

- Strength
- Stiffness
- Failure mode (ductility)
- Reversed loading
- Loads transferred through contact
- Simplicity of design
- Ease of manufacturing
- Construction friendly
- Appearance
- Minimum field welding
- Corrosive environment
- Fire resistance
- Minimized site fabrication
- Costs

Madsen « BEHAVIOUR OF TIMBER CONNECTIONS » 2001

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SPECIFIC PROPERTIES OF WOOD

- **Anatomy** (density, anisotropy, growth characteristics, variability)
- **Hygroscopicity** (moisture content, shrinkage and swelling, warping, cracking, strength loss)
- **Viscoelasticity** (mechanisorptive creep, duration of load effects)
- **Durability** (resistance to rot, insects, fungi, chemical treatment, protective construction)
- **Heat resistance** (fire resistance of wood, adhesives and binders)

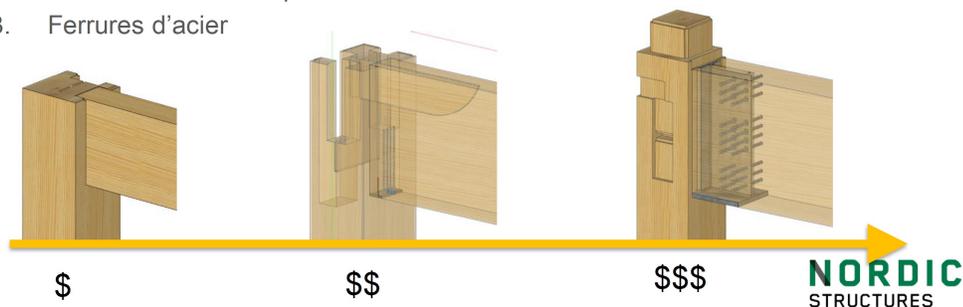
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DESIGN PRINCIPLES FOR CONNECTIONS

3 principes de connections dans la construction en bois massif contemporaine :

1. Bois-bois
2. Connecteurs métalliques
3. Ferrures d'acier



Keven Durand, ing., Nordic Structures (2023)

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DESIGN PRINCIPLES FOR CONNECTIONS

CRITERIA	WOOD-WOOD	METAL FASTENERS	METAL CONNECTORS
Cost reduction	+++	++	+
Speed of installation	+++	++	+
Structural performance	+++	++	+
Availability	++	-	+
Resistance	++	++	+++
Architectural aspects	+++	++	++ or --

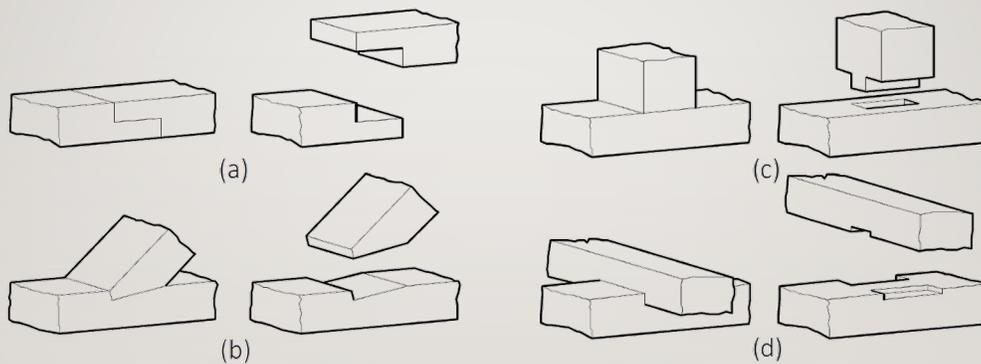
NORDIC
STRUCTURES

Keven Durand, ing., Nordic Structures (2023)

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CONTACT JOINTS (CARPENTRY JOINTS)



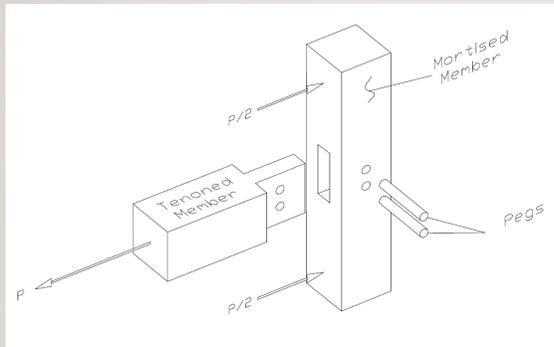
(a) half-lap joint, (b) step joint, (c) mortise and tenon joint, (d) cogged joint

STEP 1995 Article C12

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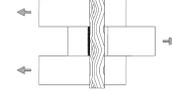
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PEGGED CONNECTIONS



(a) Mortise and tenon joint
(b) Yield limit equations

$$I_m \quad Z = \frac{D l_m F_{em}}{R_d}$$



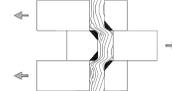
$$I_s \quad Z = \frac{2 D l_s F_{es}}{R_d}$$



$$III_s \quad Z = \frac{2 k_3 D l_s F_{em}}{(2 + R_e) R_d}$$



$$V \quad Z = \frac{\pi D^2 F_{vy}}{2 R_d}$$

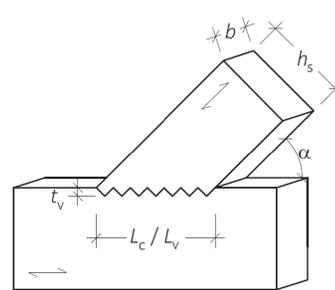


Standard for Design of Timber Frame Structures TFEC 1-10 (2010)

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MULTIPLE STEP JOINT



$$F_{c,90,R} = \frac{A_c \cdot f_{c,90} \cdot k_{c,90}}{\sin \alpha}$$

$$F_{v,R} = \frac{A_v \cdot f_v}{\cos \alpha}$$

$$A_c = b \cdot (L_c + 2 \cdot 30 \text{ mm}) \quad L_c = \frac{h_s}{\sin \alpha}$$

$$A_v = b \cdot L_v \quad L_v = \frac{h_s}{\sin \alpha}$$

Blass H.J. and Enders-Comberg M. 2012 Fachwerkträger für den industriellen Holzbau. KIT Scientific Publishing. <https://publikationen.bibliothek.kit.edu/1000028217>

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DOWEL-TYPE CONNECTIONS



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DOWEL-TYPE CONNECTIONS

	ASSEMBLAGES BOIS-BOIS	ASSEMBLAGES BOIS-ACIER
CLOUS ou VIS	<p>appui élastique dans les deux pièces à assembler</p>	<p>encastrement partiel dans les tôles métalliques</p>
BROCHES ou BOULONS	<p>élançement important : sections cisillées mal définies</p>	<p>élançement réduit : sections cisillées mieux définies</p>

Natterer et al. « CONSTRUCTION EN BOIS » 2004

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DOWEL-TYPE FASTENERS



CAN/CSA O86-2024

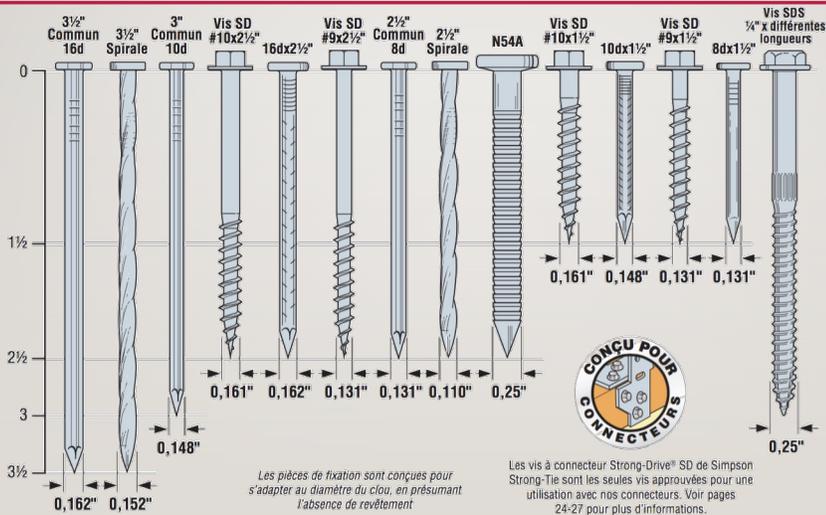
- 12.4 Bolts and dowels
- 12.5 Drift pins
- 12.6 Lag screws
- 12.7 Timber rivets
- 12.9 Nails and spikes
- 12.11 Wood screws
- 12.12 Self-tapping screws

Photo: A. Salenikovich © 2004

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DOWEL-TYPE FASTENERS



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TIMBER RIVETS IN GLULAM

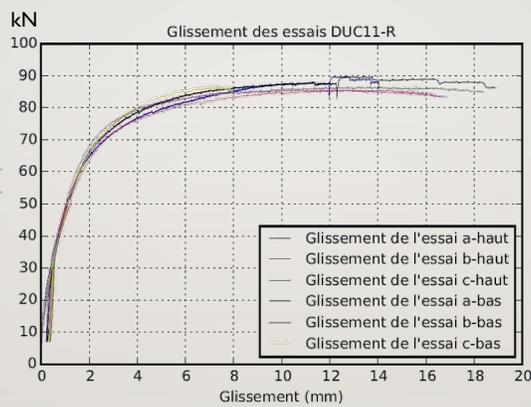


Photos: A. Salenikovich © 2004

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TIMBER RIVETS IN GLULAM



Ductile failure mode

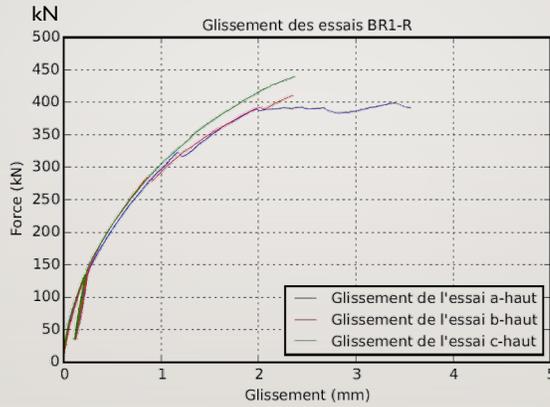


J. Choquette (2016) Évaluation d'une nouvelle méthode de calcul des assemblages de bois. MSc thésis

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TIMBER RIVETS IN GLULAM



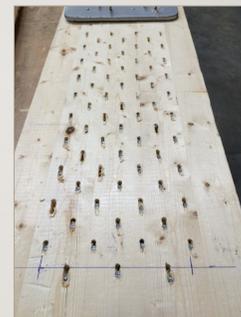
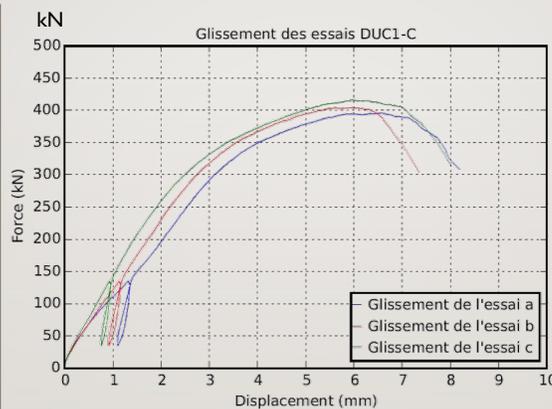
Plug shear

J. Choquette (2016) Évaluation d'une nouvelle méthode de calcul des assemblages de bois. MSc thésis

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RING-SHANK NAILS IN GLULAM



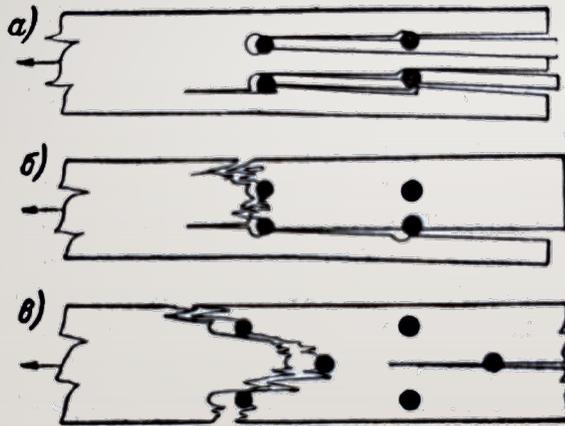
Nail head shear off

J. Choquette (2016) Évaluation d'une nouvelle méthode de calcul des assemblages de bois. MSc thésis

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BRITTLE FAILURE MODES



CAN/CSA O86-2009

12.4 Bolts and dowels

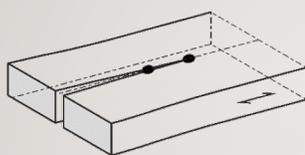
- a) Row shear
- b) Group tear-out
- c) Net tension

Г.Г. Карлсен и др. Деревянные конструкции. Москва. 1952

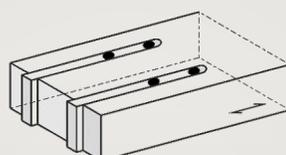
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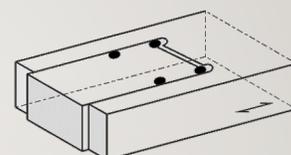
BRITTLE FAILURE MODES



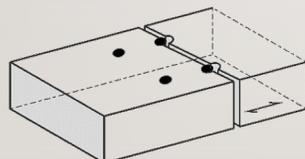
a) Splitting



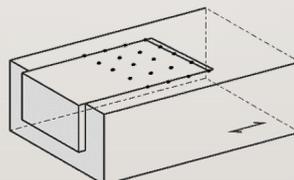
b) Row shear



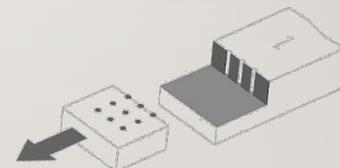
c) Block shear Group tear-out



d) Net tension



e) Plug shear



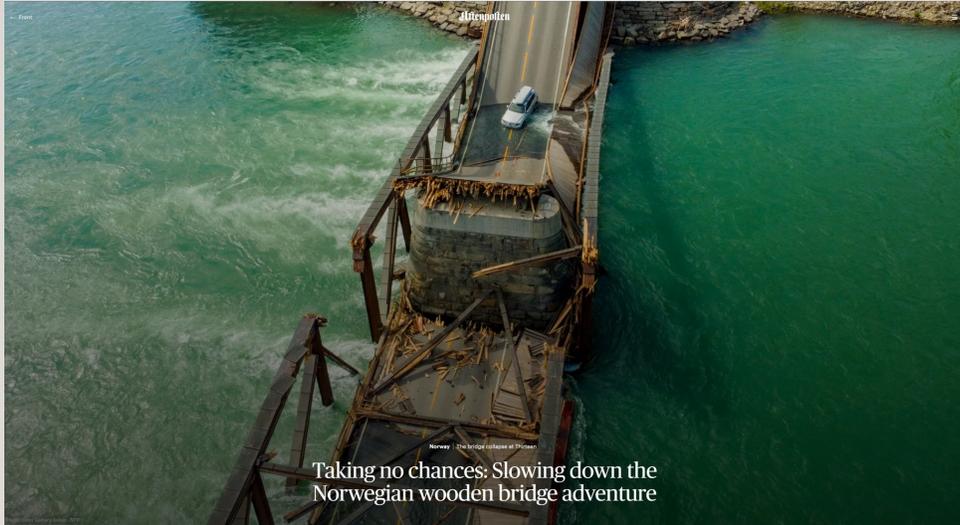
e) Step shear

prEN 1995-1-1:2024. Eurocode 5 - Design of timber structures - Part 1-1: General rules and rules for buildings

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BRITTLE FAILURE



Taking no chances: Slowing down the Norwegian wooden bridge adventure

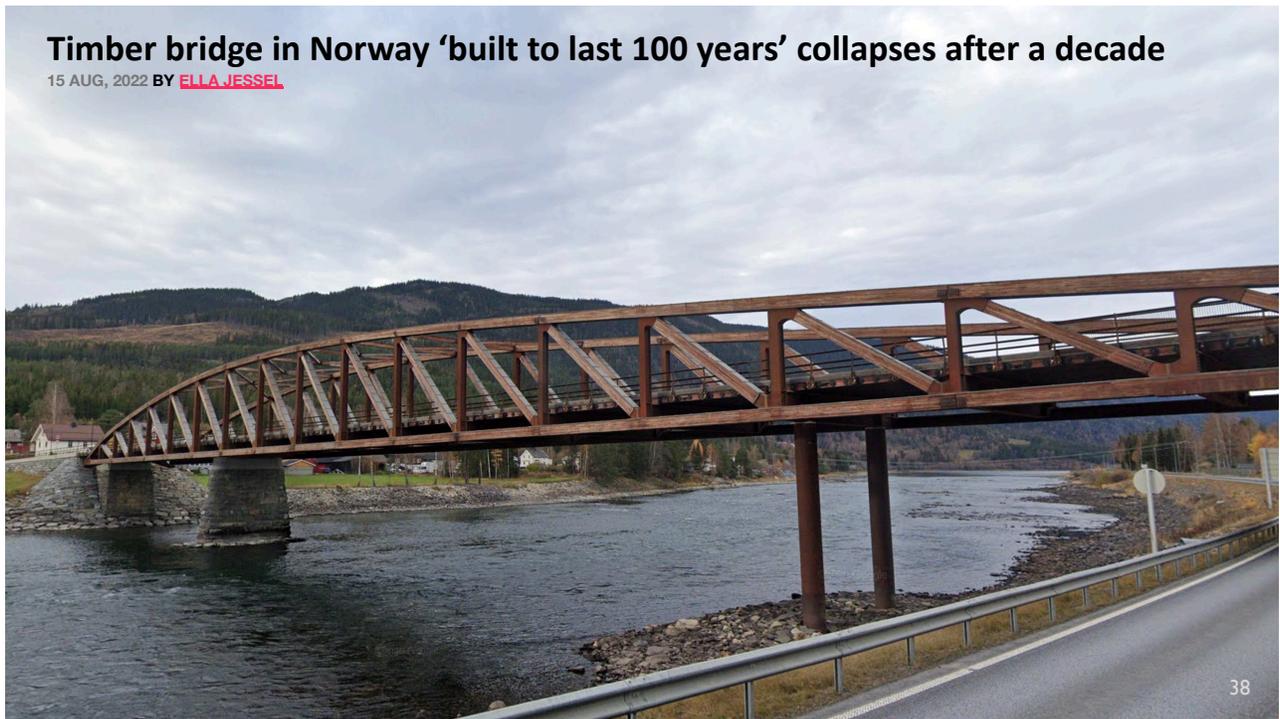
Taking no chances: Slowing down the Norwegian wooden bridge adventure (aftenposten.no)

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Timber bridge in Norway 'built to last 100 years' collapses after a decade

15 AUG, 2022 BY [ELLA JESSEL](#)

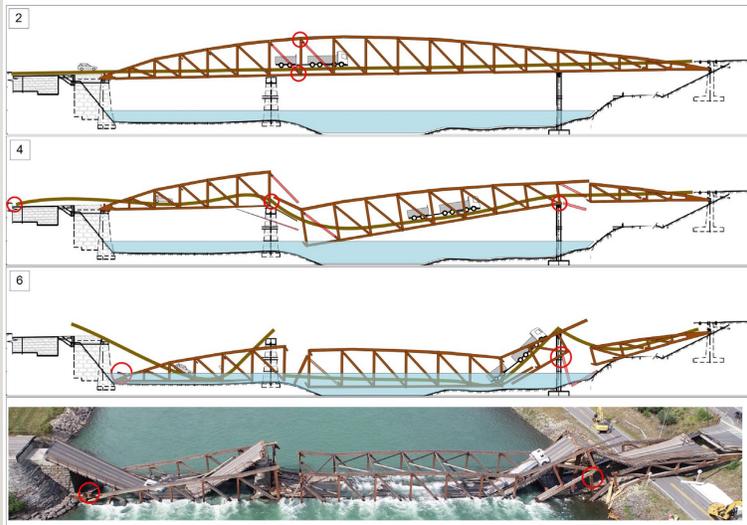


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THE TRETEN BRIDGE COLLAPSE How could it happen?

Visualization of the stages of progressive collapse



Kjell Arne Malo (IHF 2023)

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THE TRETten BRIDGE COLLAPSE How could it happen?



Block (shear) pull-out failure joint 14B in diagonal 6B

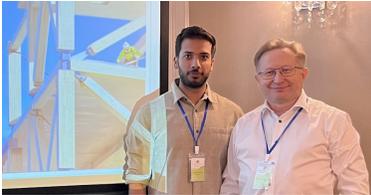
The fatigue is caused by too high stress concentrations in the head tensile area resulting from narrow dowel groups.

Kjell Arne Malo (IHF 2023)

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STATIC AND CYCLIC TESTS ON DOWEL CONNECTIONS WITH SINGLE AND DOUBLE KNIFE PLATES

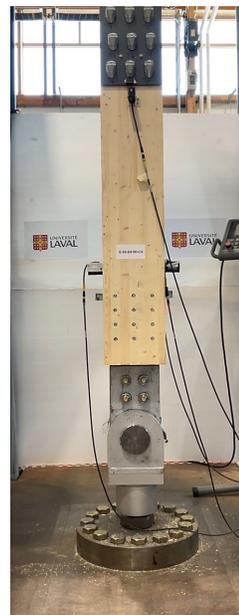
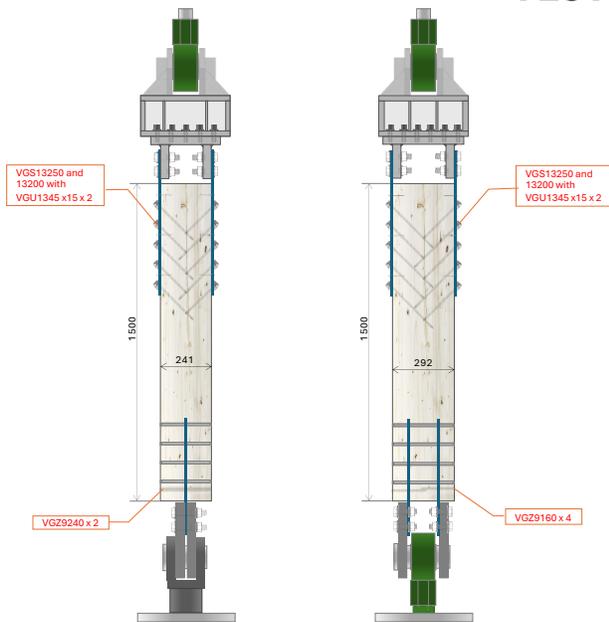


PhD Candidate: Kiavash Gholamizoj
 Supervisor: Alexander Salenikovich
 Co-supervisors: Ying-Hei Chui, Peyman Homami
 Industry advisor: Marjan Popovski



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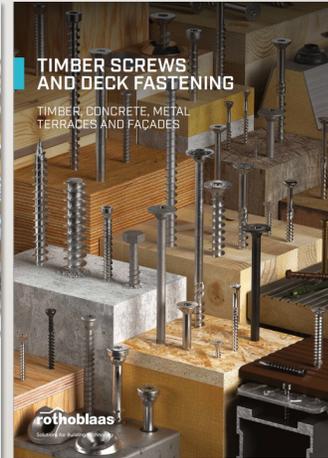
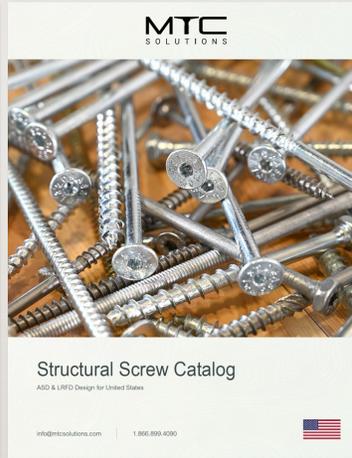
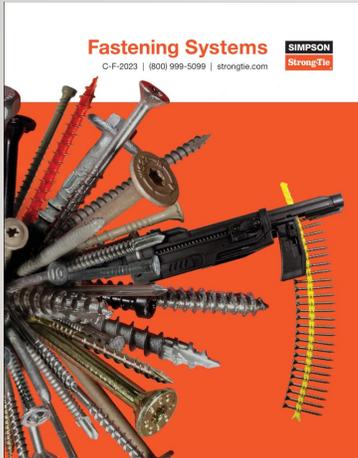
TEST SETUP



Single knife plate: 1/2" (12.7 mm) 350w, NordicLam+ 215x241 Double knife plates 3/8" (9.5 mm) 350w, NordicLam+ 215x292 Dowels: Ø1/2" 300w Screws: VGS13250 / VGS13300

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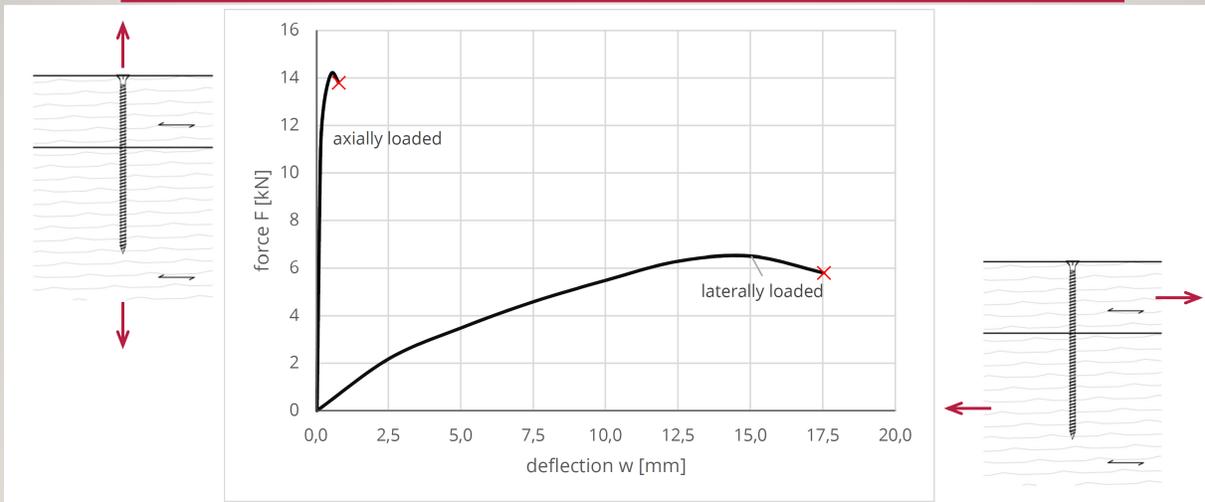
SELF-TAPPING SCREWS



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CONNECTIONS WITH SCREWS

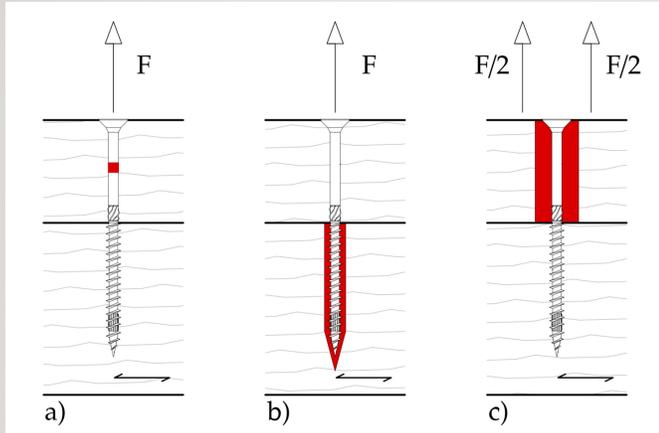


Wallner-Novak & Scheibenreiter « TECHNICAL SCREW MANUAL » 2019

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AXIALLY LOADED SCREWS



Failure modes:

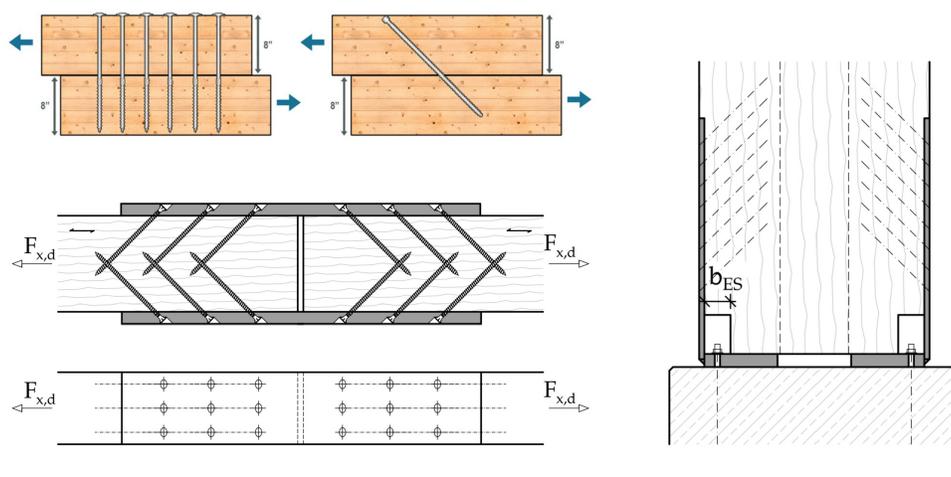
- a) Steel tensile capacity, F_{tens}
- b) Withdrawal failure, F_{ax}
- c) Head pull-through, F_{head}

Wallner-Novak & Scheibenreiter « TECHNICAL SCREW MANUAL » 2019

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INCLINED SCREWS

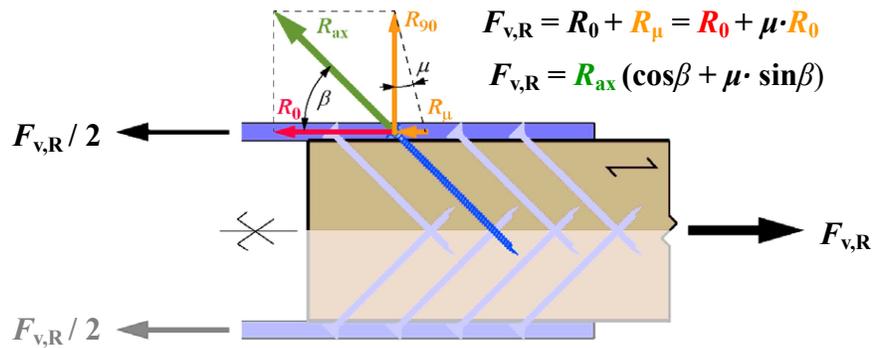


MTC Solutions (2021); Wallner-Novak & Scheibenreiter « TECHNICAL SCREW MANUAL » 2019

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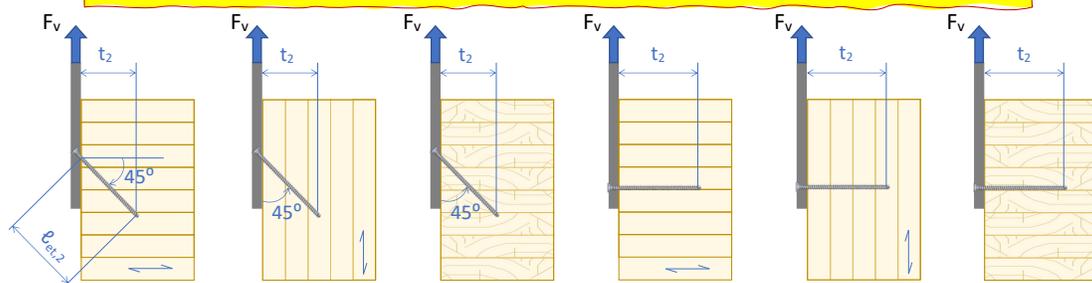
INCLINED SCREWS



Truss-model for calculation of the capacity of steel-to-timer joints

H. Krenn, G. Schickhofer (2009) Joints with Inclined Screws and Steel Plates as Outer Members. CIB-W18 Paper 42-7-2

CAN/CSA O86-2024. Clause 12.12.4.2 Installation angles of self-tapping screws



	"Joist" 45°	"Column" 45°	"Header" 45°	"Joist" 90°	"Column" 90°	"Header" 90°
α	45°	45°	90°	0°	90°	90°
β	45°	45°	45°	90°	90°	90°
θ	90°	0°	90°	90°	0°	90°

α = angle between the fastener axis and the grain, °

β = angle between the fastener axis and the shear plane of a connection, °

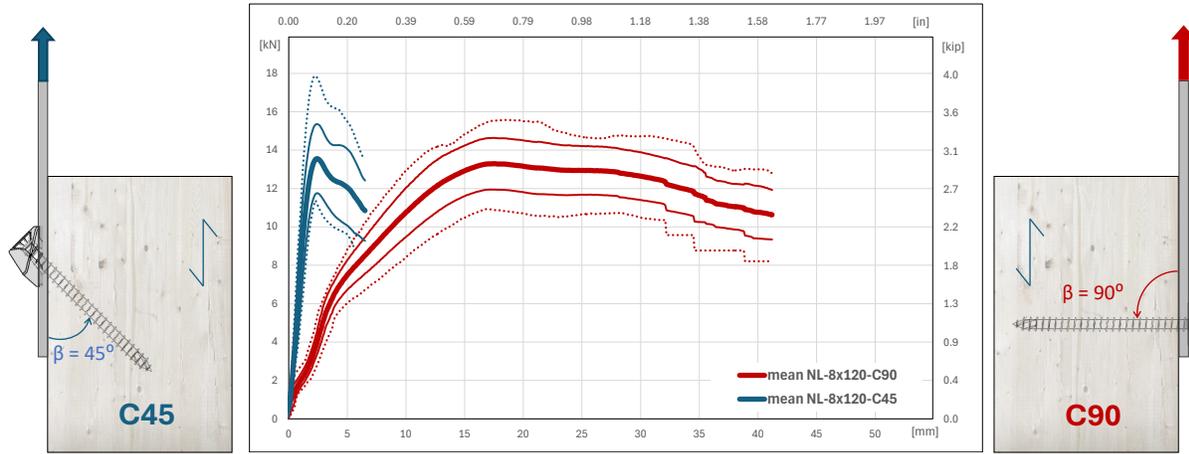
θ = angle between the direction of applied lateral load and the grain direction of wood member, °

θ = angle of bearing relative to the grain, ° [Clause 12.4.4.3.3.1]

t_2 = bearing length of screw in member 2 normal to the load direction in accordance with Clause 12.4.2.1, mm

$l_{et,2}$ = effective thread length penetration (see Clause 12.12.6.2), mm

STIFFNESS, RESISTANCE AND DUCTILITY OF CONNECTIONS WITH SCREWS



Wood	Nordic Lam 137x394
Screw	SDCF22434

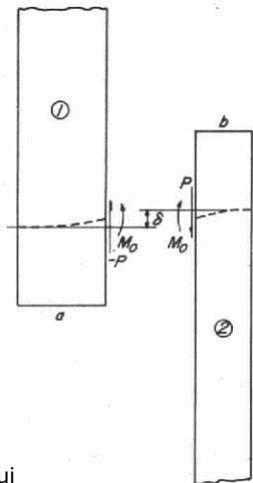
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STIFFNESS OF TIMBER CONNECTIONS - RESEARCH METHOD



Tao Gui,
PhD student



Winkler

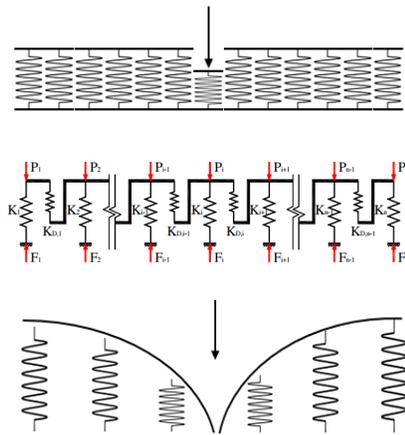
$$R_i = K_i s_i$$

Multiple-spring

$$K_{D,i} = \frac{kGA}{L}$$

Half-space

$$\delta_{ij} = \frac{(1 - \nu^2)R}{\pi E_0 r_{ij}}$$



Supervisor: Y. H. Chui
Co-supervisor: A. Salenikovich



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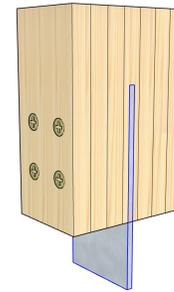
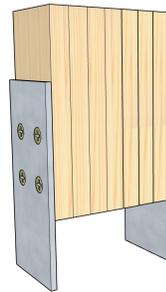
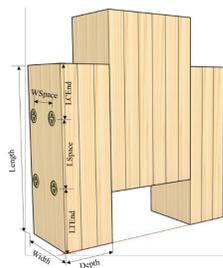


Tao Gui,
PhD student

STIFFNESS OF TIMBER CONNECTIONS – EXPERIMENTAL PLAN

Connection Tests:

- Fasteners: 8 mm STS and 12.7 mm steel dowels
- Timber: Glulam and CLT
- Joint configurations: Number of fasteners, inclined angle for STS
- Loading protocol: Monotonic until failure



UNIVERSITY OF ALBERTA



NSERC CRSNG

NSERC Industrial Research Chair in Engineered Wood & Building Systems

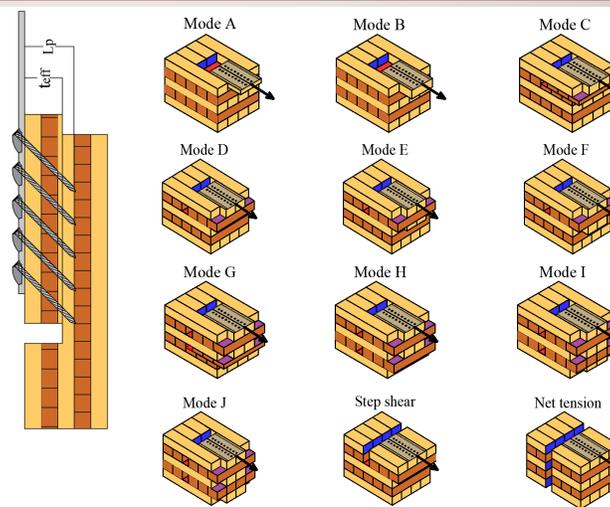


Amir Einipour
MASc student

BRITTLE FAILURE OF CROSS-LAMINATED TIMBER IN CONNECTIONS WITH SELF-TAPPING SCREWS



Supervisor: T. Tannert
Co-supervisors: J. Zhou, A. Salenikovich





FIRE PERFORMANCE OF MODERN CONNECTIONS



Christian Dagenais, ing., PhD

Metal components behave differently from timber in fire conditions:

Conductivity / charring

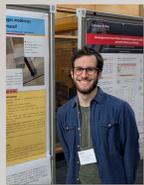
Loss of strength and stiffness

Need to expand database and knowledge to reduce conservatism for fire design related to modern connections exposed to fire up to 2-hrs

Need to develop design provisions based on engineering principles vs. prescriptive



October 28, 2024
Next-Generation Wood Construction HQP Seminar XIV



FIRE PERFORMANCE OF MODERN CONNECTIONS



Luc Girompaire
PhD candidate

Supervisor: C. Dagenais
Co-supervisor: A. Salenikovich

Ongoing multi-year projects at FPInnovations / U. Laval

Char penetration at joints

Effect of gap size between members

Firestopping of joints

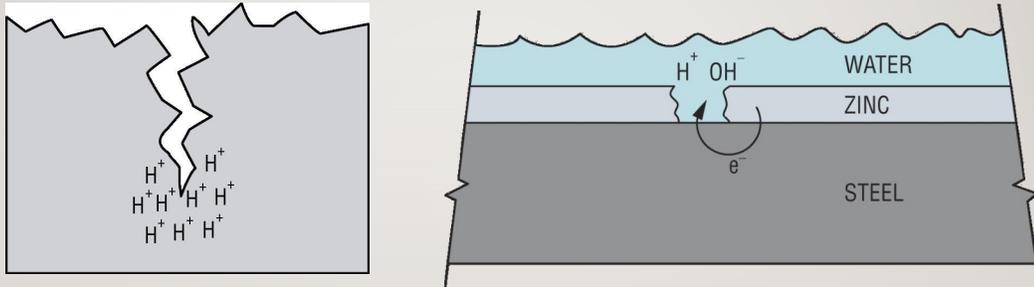
Thermal cover protection

Failure modes in fire vs. ambient conditions



October 28, 2024
Next-Generation Wood Construction HQP Seminar XIV

HYDROGEN EMBRITTLEMENT



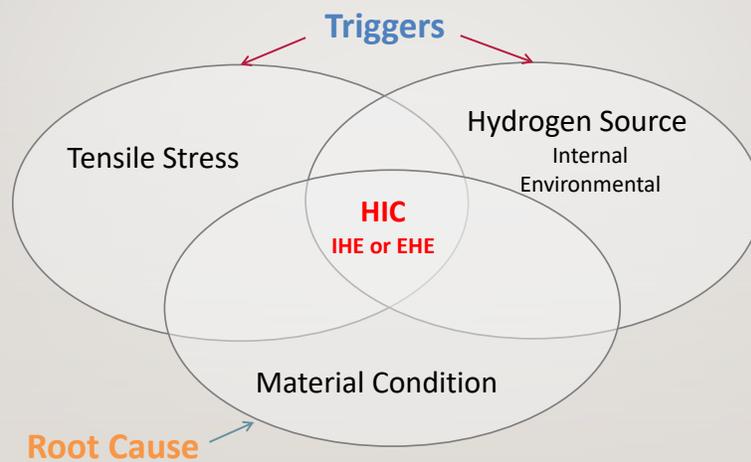
permanent loss of ductility in a metal or alloy caused by hydrogen in combination with stress, either externally applied or internal residual stress

<https://seblog.strongtie.com/2015/10/hydrogen-embrittlement-in-high-strength-steels/>
 S. Brahimi. 2014. Fundamentals of hydrogen embrittlement in steel fasteners

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HYDROGEN EMBRITTLEMENT



S. Brahimi. 2014. Fundamentals of hydrogen embrittlement in steel fasteners
 ISO 4042:2022. Fasteners — Electroplated coating systems

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CAN/CSA O86-2024

Core hardness of screws

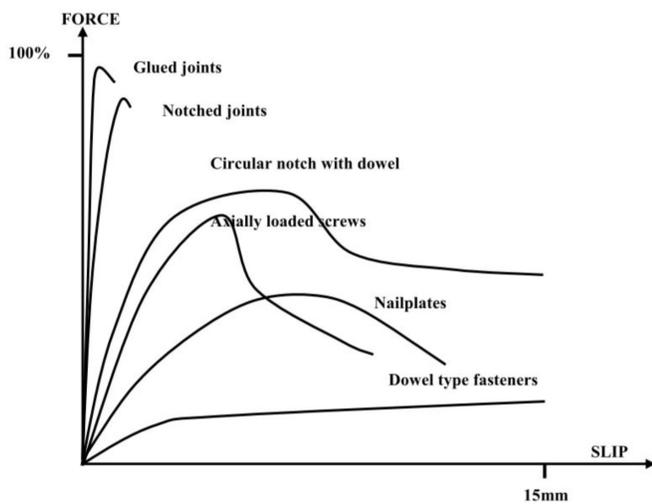
≤ 36 HRC (360 HV)	$36 < \text{HRC} \leq 38$ (390 HV)	$38 < \text{HRC}$ (390 HV)
Pre-qualified (not sensitive to HE)	Shall be tested for internal HE	HE sensitive !
Wet use permitted	Dry use ONLY	Not allowed!!!

See Table 12.1 and Clause 17.6.4

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RIGID JOINTS



A.M.P.G. Dias (2005) Mechanical behaviour of timber-concrete joints

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RIGID JOINTS



HSK (TiComTek)



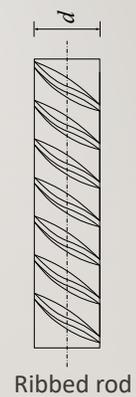
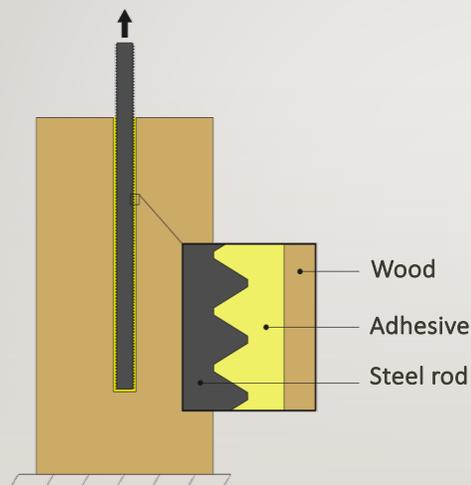
Glued-in (bonded-in) rods

Resix® system www.simonin.com

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GLUED-IN ROD (GIR) BONDED-IN ROD (BIR)



Raphaël Bouchard (2019)

EN 17334:2021

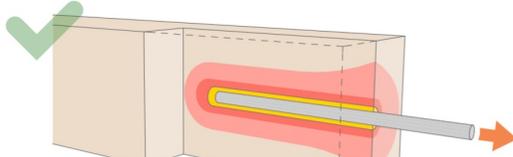
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BONDED-IN RODS VS. TRADITIONAL FASTENERS

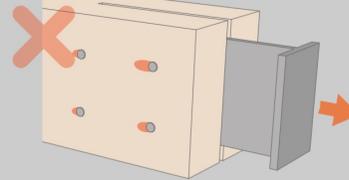
- Load transfer

Assemblage Résix
Sollicitation en traction ou compression



Absence totale de jeu, reprise d'efforts instantanée, aucune flèche induite

Assemblage traditionnel
Sollicitation en traction et/ou compression



Jeu d'assemblage obligatoire par construction
Glissement d'assemblage
Flèche supplémentaire induite

Resix® system www.simonin.com

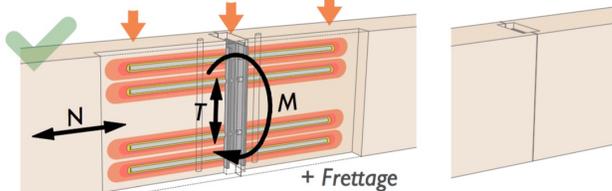
61

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BONDED-IN RODS VS. TRADITIONAL FASTENERS

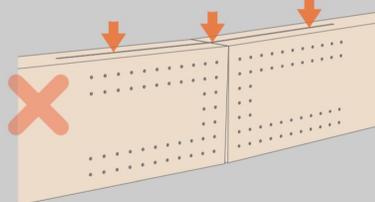
- Moment-resistance

Assemblage Résix
Reprise de moment d'encastrement



Efforts repartis dans toutes les tiges, uniformément et instantanément (Moment, efforts normaux et cisaillement).

Assemblage traditionnel
Reprise de moment d'encastrement



Déformation par glissement d'assemblage

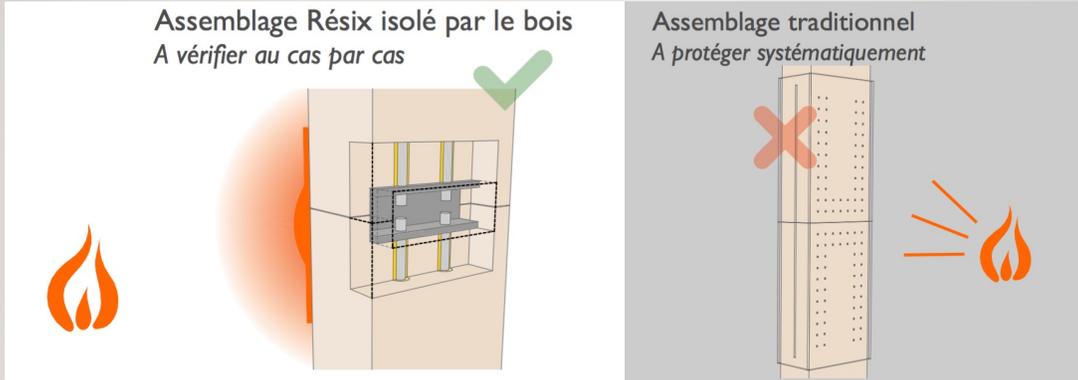
Resix® system www.simonin.com

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BONDED-IN RODS VS. TRADITIONAL FASTENERS

- Fire resistance



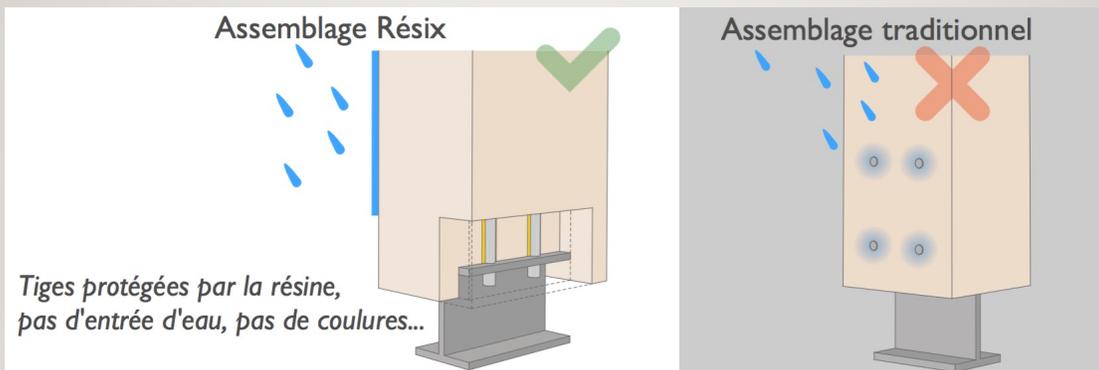
Resix® system www.simonin.com

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BONDED-IN RODS VS. TRADITIONAL FASTENERS

- Weather protection

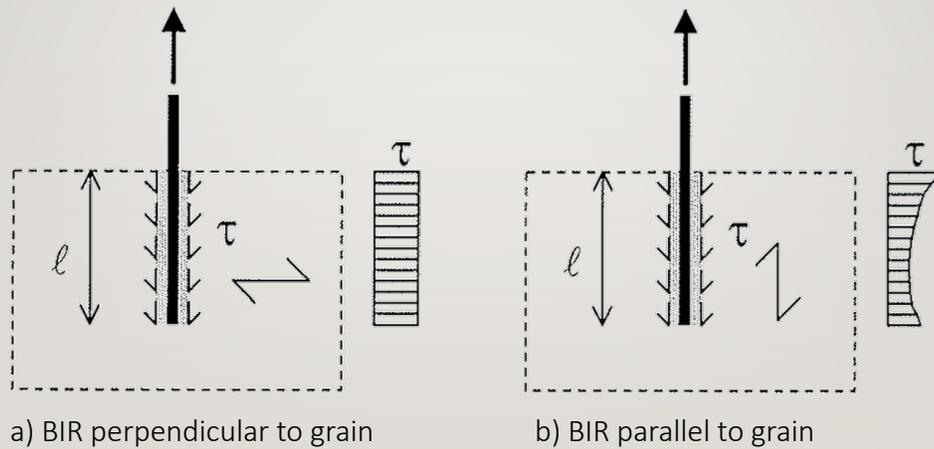


Resix® system www.simonin.com

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STRESS DISTRIBUTION ALONG THE BIR

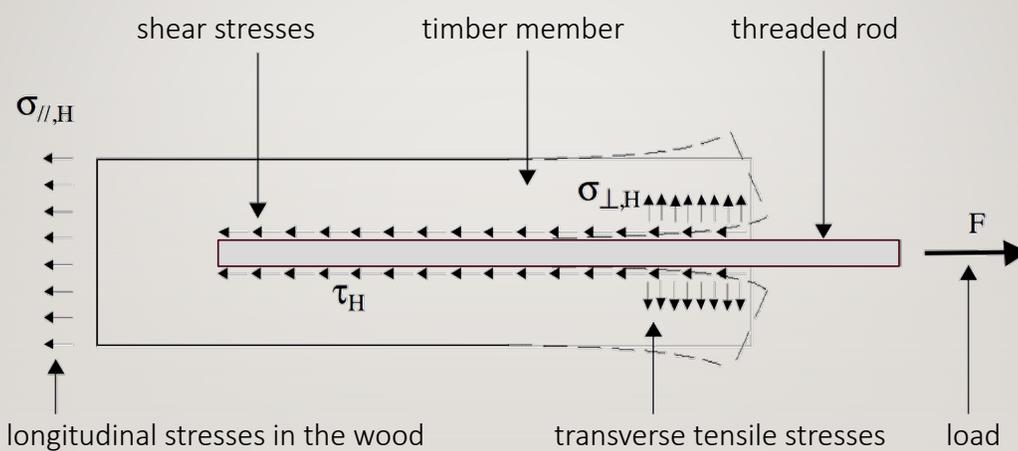


Bernasconi (2001) CIB-W18 Paper 34-7-6

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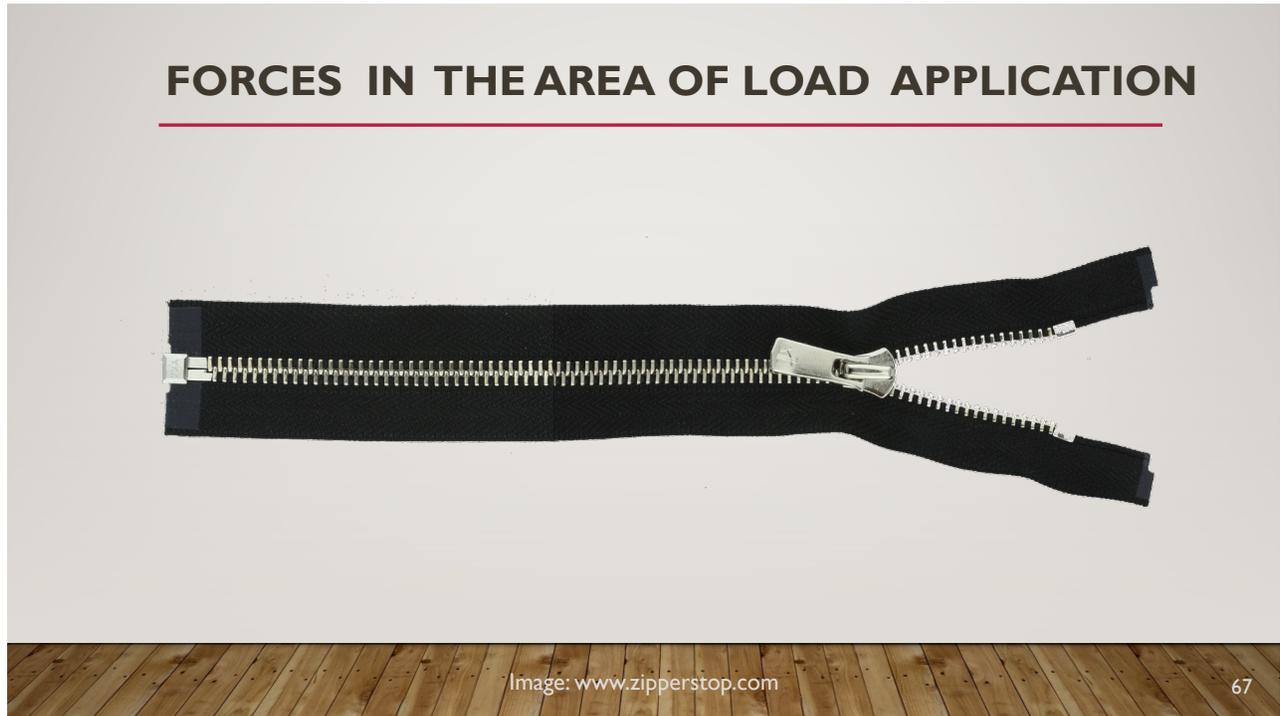
FORCES IN THE AREA OF LOAD APPLICATION



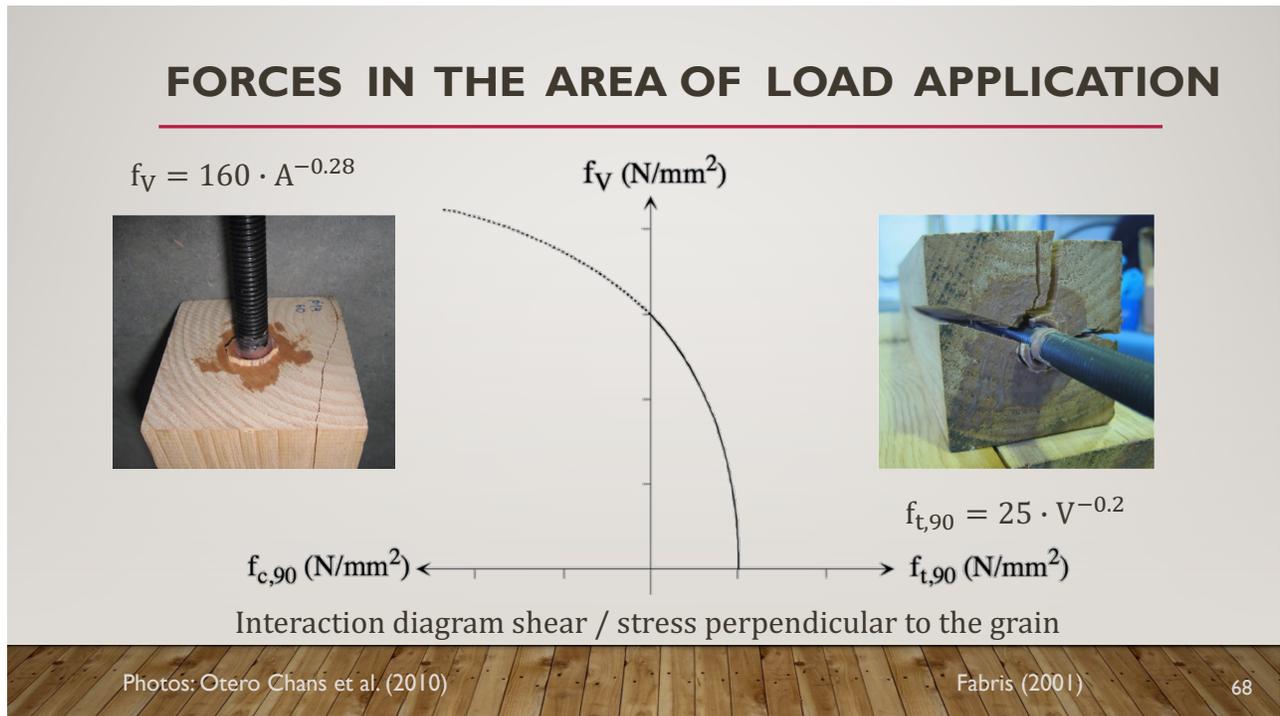
Fabris (2001) «Verbesserung der Zugeigenschaften von Bauholz parallel zur Faser mittels Verbund mit profilierten Stahlstangen» Dissertation ETH Nr. 14050

66

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67



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FAILURE MODES OF BIR (GIR)

- a) tensile failure of the rod
- b) compression (buckling) failure of the rod
- c) failure of the adhesive within the glue line or in the bondline with the rod and/or timber
- d) shear failure of the wood adjacent to the bondline
- e) splitting of the wood starting from the bonded-in rods
- f) plug shear failure of the wood in a joint with several bonded-in rods
- g) net tension failure of the wood at the end of the rod

R. Jockwer, P. Palma, A.S. Rebouças, A. Salenikovich, WCCTE 2023
Development of comprehensive testing procedures for high-performance bonded-in rods

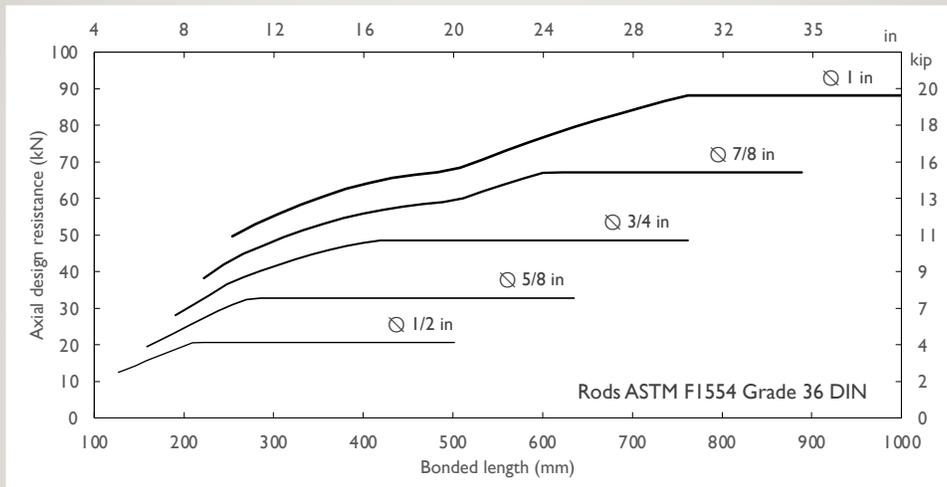
69

DESIGN PRINCIPLES

Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

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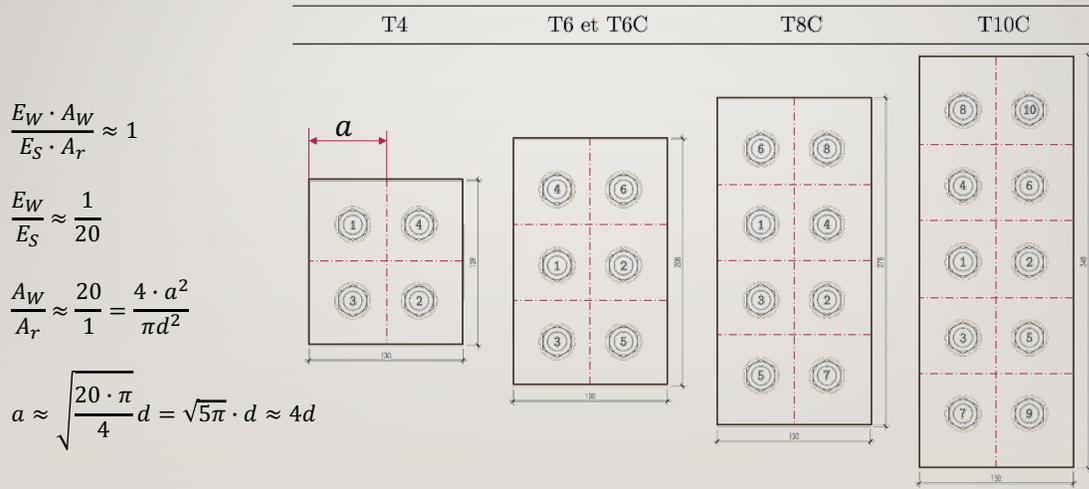
DESIGN RESISTANCE OF BIR



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EFFICIENT BIR CONNECTION DESIGN

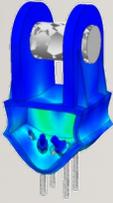


Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

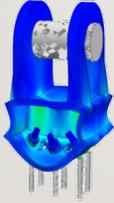
72

72

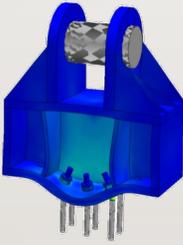
IS THERE A GROUP EFFECT ???



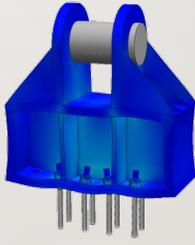
T4



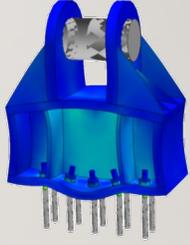
T6



T6C



T8C



T10CR

Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis 73

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LET'S FIND OUT !!!



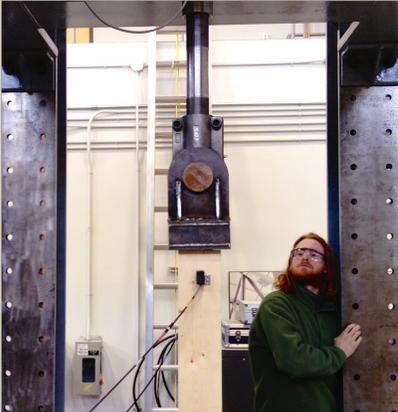
(a) MCS SERVO : 450 kN
(Séries T4 et T6)



(b) Riehle : 850 kN
(Séries T6C et T8C)



(c) MTS : 1005 kN
(Série T10CR)

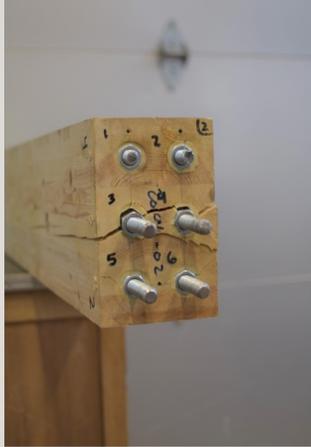


Raphaël Bouchard (photo:A. Salenikovich)

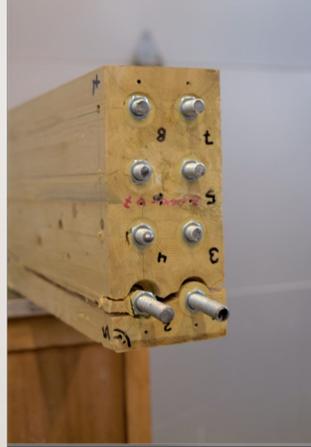
Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis 74

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TEST RESULTS 2019 : FAILURE MODES



(a) Spécimen T6C-02



(b) Spécimen T8C-07



(c) Spécimen T6C-05

Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

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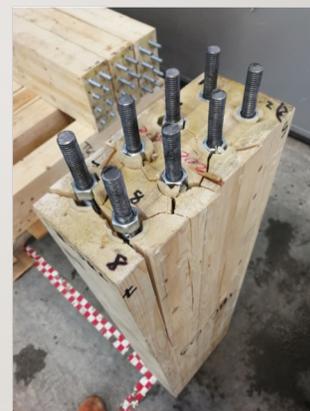
TEST RESULTS 2019 : FAILURE MODES



(a) Specimen T6C-7



(b) Specimen T8C-2



(c) Specimen T8C-3

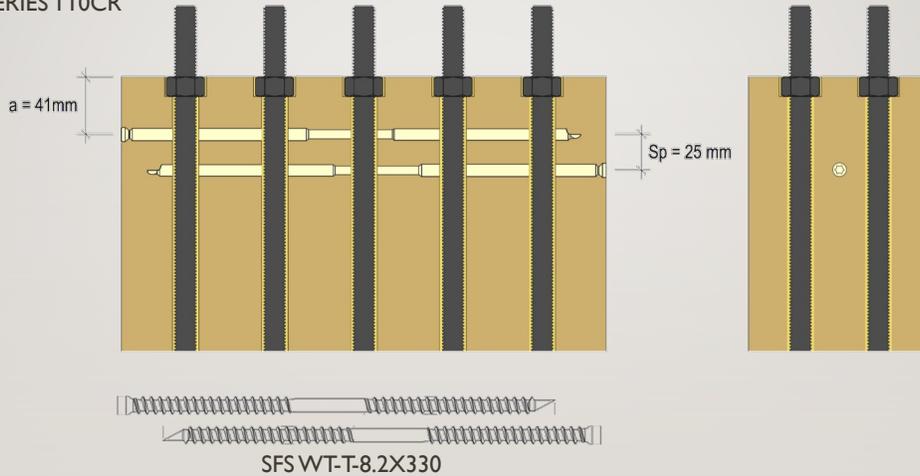
Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

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TRANSVERSE REINFORCEMENT

SERIES T10CR

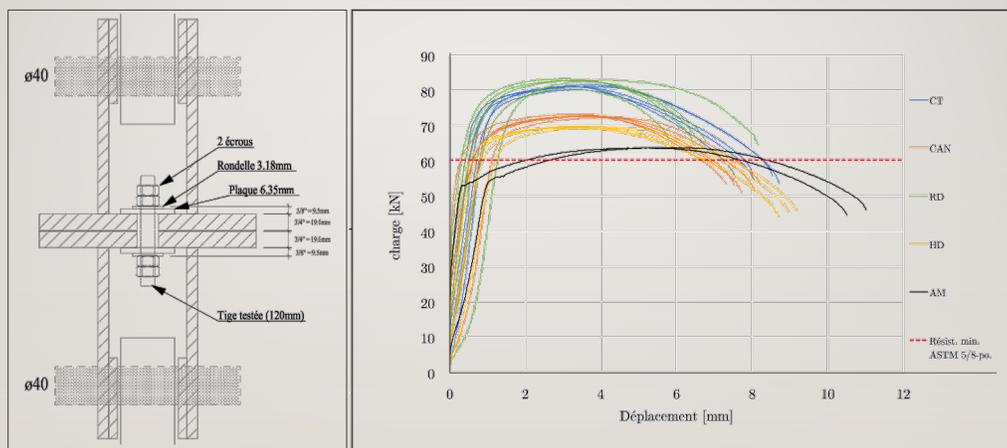


Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

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HOW STRONG THE INDIVIDUAL RODS ARE ?

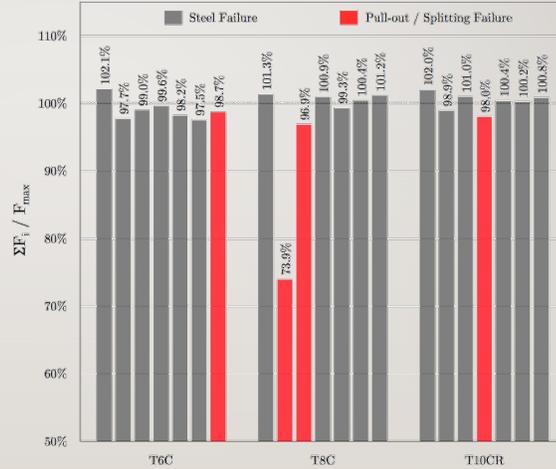


Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

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HOW STRONG THE INDIVIDUAL RODS ARE ?

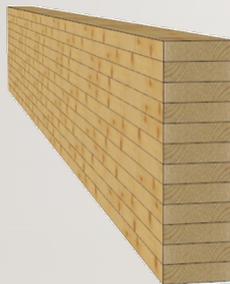


Raphaël Bouchard (2019) Système d'assemblage métallique pour les poutres en bois lamellé-collé. MSc thésis

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ENGINEERED WOOD PRODUCTS (EWP)



a) Glued-laminated timber (GL)



b) Cross-laminated timber (CLT)

A. Salenikovich, et al. WCTE 2021. A study of the structural performance of glued-in rods in CLT.

80

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GLUED JOINTS IN CLT



<https://alexschreyer.net/photography/john-w-oliver-design-building-2017>

81

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BiR IN CLT

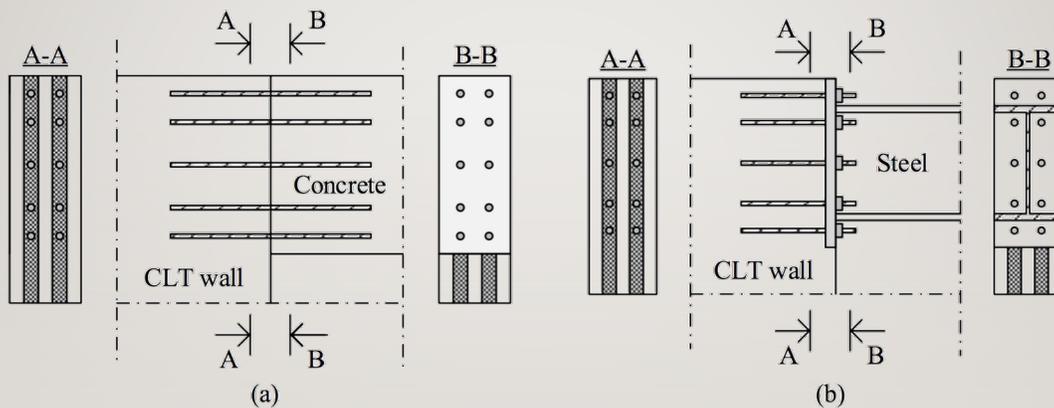


Fig. 1.17 Illustration of vertical joint in a hybrid system. (a) Joint between a CLT wall and a steel beam with glued-in threaded rods and (b) Joint between a CLT wall and a concrete beam with glued-in deformed rods.

Andersen & Højer (2016) Glued-in Rods in Cross Laminated Timber. Aarhus University, Denmark

82

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BIR IN CLT



Tension perp. rupture



Rolling shear rupture



Parallel to grain



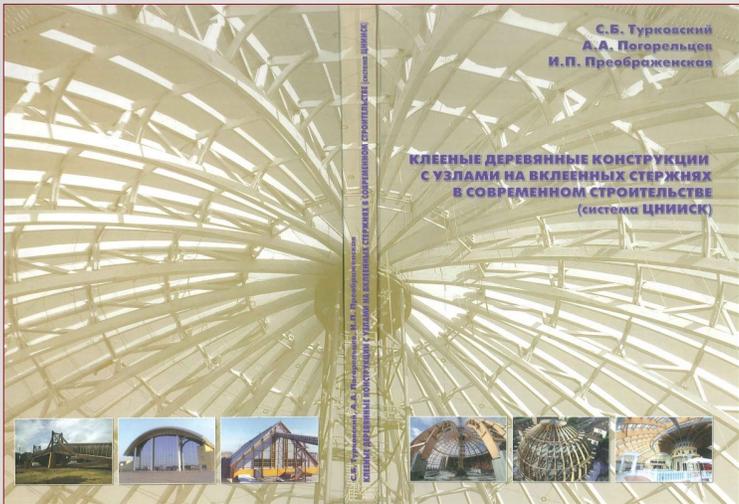
Perpendicular to grain




Azinović et al. (2018) Experimental investigation of the axial strength of glued-in rods in cross laminated timber 83

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GLUED-IN RODS IN THE USSR



S.B. Turkovsky
A.A. Pogoreletsev
I.P. Preobrazhenskaya

GLULAM STRUCTURES WITH JOINTS USING GLUED-IN RODS IN MODERN CONSTRUCTION (TSNIISK system)



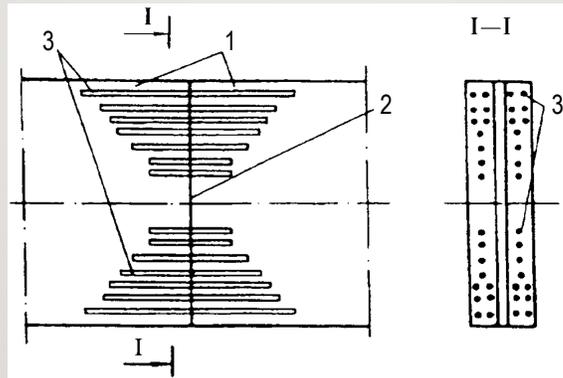
Moscow - 2013

Turkovsky et al. (2013) 84

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RIGID JOINTS WITH GLUED-IN RODS **PARALLEL TO GRAIN**

Initially proposed for bridges in 1970



- 1 glulam members
- 2 butt joint
- 3 glued-in rebar

Not a viable concept for construction joints

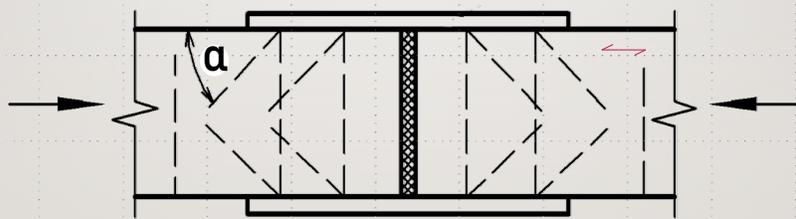
Pospelov and Tumasov (1970)

85

85

RIGID JOINTS WITH INCLINED GLUED-IN RODS

Proposed by S. Turkovsky (TSNIISK) in 1973



$$20^\circ \leq \alpha \leq 90^\circ$$

Turkovsky et al. (2013)

86

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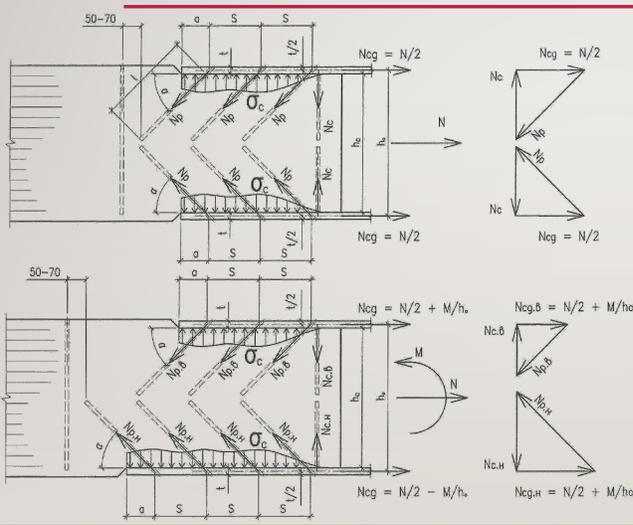
Set of Rules 382.132580.2017

- a) built-up members
- b) shear reinforcement of beams
- c) mounting anchors
- d) reinforcement of supports
- e) hinged joints
- f) symmetric universal rigid joints
- g) joints of members in tension
- h) compressed joints
- k) asymmetrical polygonal members
- i) rigid column base

СП 382.132580.2017: Glulam timber structures with bonded-in rods

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EXAMPLE #1



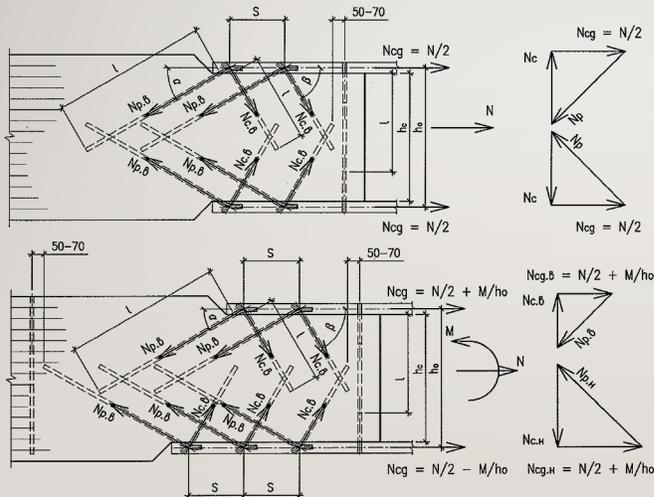


N = 467 kN
Section: 2x140x600
105-kip load capacity
Section 2x5.5x24 in.

Рогорелтсев (2017) РАСЧЁТ РАСТЯНУТЫХ СТЫКОВ КДК НА ВКЛЕЕННЫХ СТЕРЖНЯХ

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EXAMPLE #2



$N = 296$ kip
 $M = 8704$ lbf-ft
 Section: $2 \times 5 \times 35$ in.

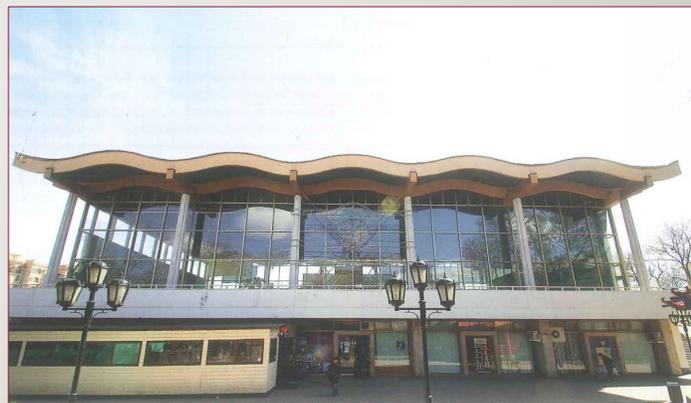
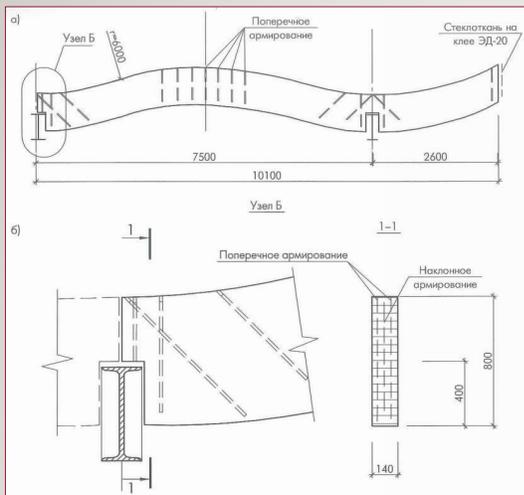
$N = 1318$ kN
 $M = 127$ kN·m
 Section: $2 \times 120 \times 900$

Pogoreltsev (2017) РАСЧЁТ РАСТЯНУТЫХ СТЫКОВ КДК НА ВКЛЕЕННЫХ СТЕРЖНЯХ

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OLYMPIC (1980) SWIMMING POOL



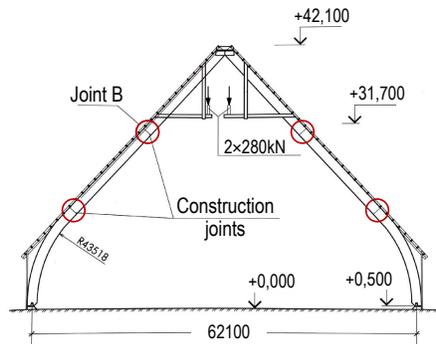
Moscow(1979)

Turkovsky et al. (2013)

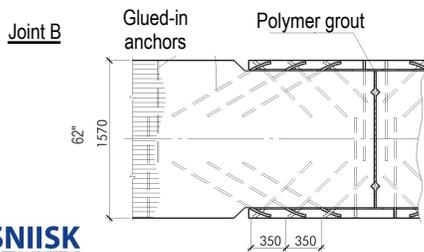
90

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Rigid joints with V-shape glued-in anchors for large-span arches



Saint-Petersburg (2001)
Potassium salt warehouse
63 m span (207 ft)
45 m height (148 ft)
300 m long (984 ft)



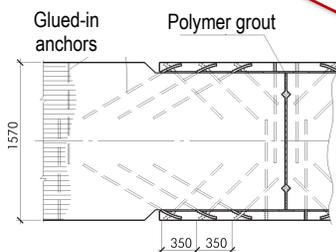
91

Rigid joints with V-shape glued-in anchors for large-span arches



Saint-Petersburg (2001)
Potassium salt warehouse

Arch leg length: 57 m (187 ft)
Section: 420 × 1800 mm (16.5 × 71 in.)
Weight: 30 ton (67.3 kip)



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Examples of structures using TSNIIISK system



Waterpark "Piterland" ▫ St-Petersburg
2009 ▫ 90 m span dome



Waterpark "Akvamir" ▫ Novosibirsk ▫ 2016
95 m span dome



"MTS Live Hall" ▫ St-Petersburg ▫ 2018
45 × 65 m oval dome



Water Sports Arena ▫ Kazan ▫ 2013
66 m trusses



Water Park ▫ Rostov-Don ▫ 2012
36 m span lenticular trusses



MGSU Athletics Arena ▫ Moscow ▫ 2013
30 m dome over 50 m span arches

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Typical 100 m span arches using TSNIIISK system



Krasnoyarsk 2018 ▫ Irkutsk 2020 ▫ Kemerovo 2021

https://upload.wikimedia.org/wikipedia/commons/6/62/ICE_STADIUM_%C2%ABYENISE%C2%BB_-_29th_Winter_Universiade_2019_-_Krasnoyarsk.webm

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EVERYDAY DESIGN CHALLENGES



Abbildung 8: Foto Baustelle, CLT Stützen und Träger, Kerne aus Mauerwerk (CMU Blocks)

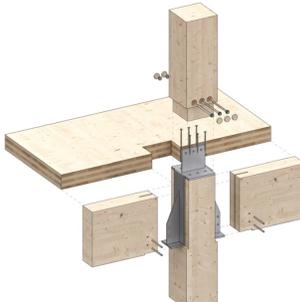


Abbildung 7: Detail Knotenpunkt, Zeichnung: Knipsers Heibig



Abbildung 8: vertikaler Elementstoß



Abbildung 9: horizontaler Elementstoß

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Architektur**
Architekturqualität und Nachhaltigkeit

**IHF-Prolog III
Holzhausbau**
Bauen im Bestand –
Potentiale für die Holzbaubranche



POINT-SUPPORTED CLT FLOORS



Figure 1: Point-supported CLT floor: a) UBC Tall-Wood house, © Fast+Epp; b) Punching shear failure

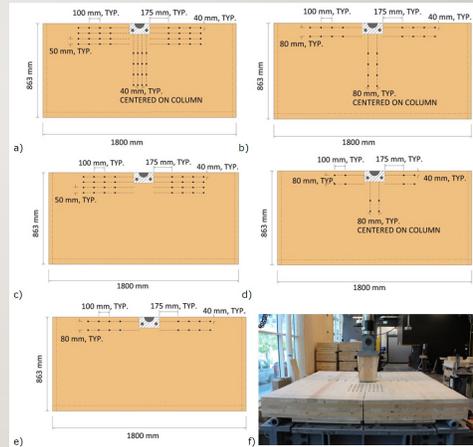


Figure 4: Screw shear reinforced series: a) type 1 (S18); b) type 2 (S19); c) type 3 (S20); d) type 4 (S21); e) type 5 (S22); and f) type 1 series exemplary photo.

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TIMBER-CONCRETE COMPOSITE FLOORS

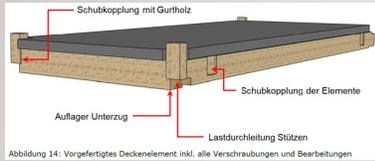


Abbildung 14: Vorgefertigtes Deckenelement inkl. alle Verschraubungen und Bearbeitungen

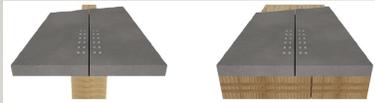


Abbildung 15: Beispiel für Fugenausbildung zur Schubkopplung der Elemente
links: Kopplung auf Deckenbalken
rechts: Kopplung bei Massivholz-Elementen

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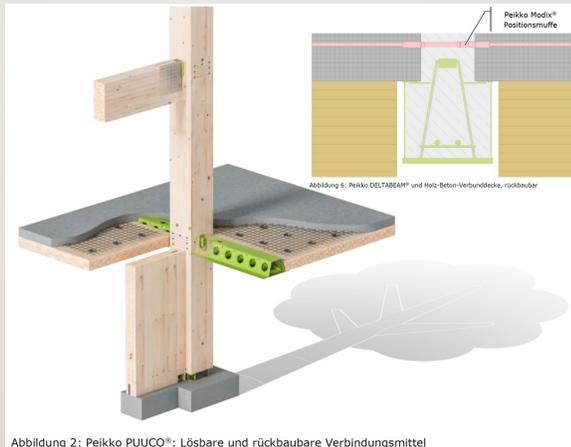


Abbildung 6: Peikko DELTABEAM® und Holz-Beton-Verbunddecke, rückbaubar

Abbildung 2: Peikko PUUCO®: Lösbare und rückbaubare Verbindungsmittel



Abbildung 4: Peikko RAMCO® Auflagerkonsole

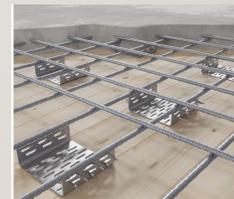


Abbildung 5: Peikko NILCO® Schubverbinder

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FUTURE CHALLENGES



Interactions:

- + reinforcements
- + rigid joints
- + fatigue
- + hybrid structures



Seismic performance



Fire resistance

October 28, 2024
Next-Generation Wood Construction HQP Seminar XIV

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A HIGH-PERFORMANCE CONNECTION...

- ... evenly distributes forces in the wood and offers ductile behavior
- ... avoids tension perpendicular to the grain
- ... facilitates assembly, prefabrication, and adjustment
- ... offers adequate fire performance
- ... ensures durability over time
- ... is aesthetic
- ... economical, etc.

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DEVELOPMENT OF SAFE DESIGN PROCEDURES FOR PRODUCTS, ASSEMBLIES, AND SYSTEMS IN WOOD CONSTRUCTION

Investigators

2023 – 2028

Ministère des
Ressources naturelles
et des Forêts

Québec



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DEVELOPMENT OF SAFE DESIGN PROCEDURES FOR PRODUCTS, ASSEMBLIES, AND SYSTEMS IN WOOD CONSTRUCTION

Research objectives

The main objective of the proposed research program is to identify the best performing systems for wind / low seismic and moderate / high seismic zones and to recommend corresponding design approaches.

Specific objectives are as follows:

1. Conduct holistic feasibility studies of various structural systems using wood and wood-based products as structural material in mid-rise and high-rise buildings including those extending beyond 12 storeys.
2. Characterize the performance of the new generation of timber connections and assemblies and advance the design methods to meet the needs of the modern timber construction, including hybrid and composite systems, to resist the gravity, lateral and accidental loads.
3. Develop the design approaches for the best performing hybrid and composite systems using the information gathered in phases 1 and 2.

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TIMBER CONNECTION WORKSHOP

MAY 28, 2025 – day after the [2nd NextGen Wood Conference](#)

HILTON GARDEN INN, DOWNTOWN OTTAWA

Organized by **Thomas Tannert** (UNBC) and **Alexander Salenikovich** (Université Laval).

The workshop will feature three thematic sessions, a keynote address, and a poster session.

The tentative themes are:

- i) Connections for mass-timber structures;
- ii) Connections with self-tapping screws; and
- iii) Novel and hybrid connections.

Submissions from within and outside the NextGen Wood network are welcome.

**INTERACTION BETWEEN ACADEMIA, DESIGNERS, FASTENER INDUSTRY,
AND WOOD PRODUCT FABRICATORS**



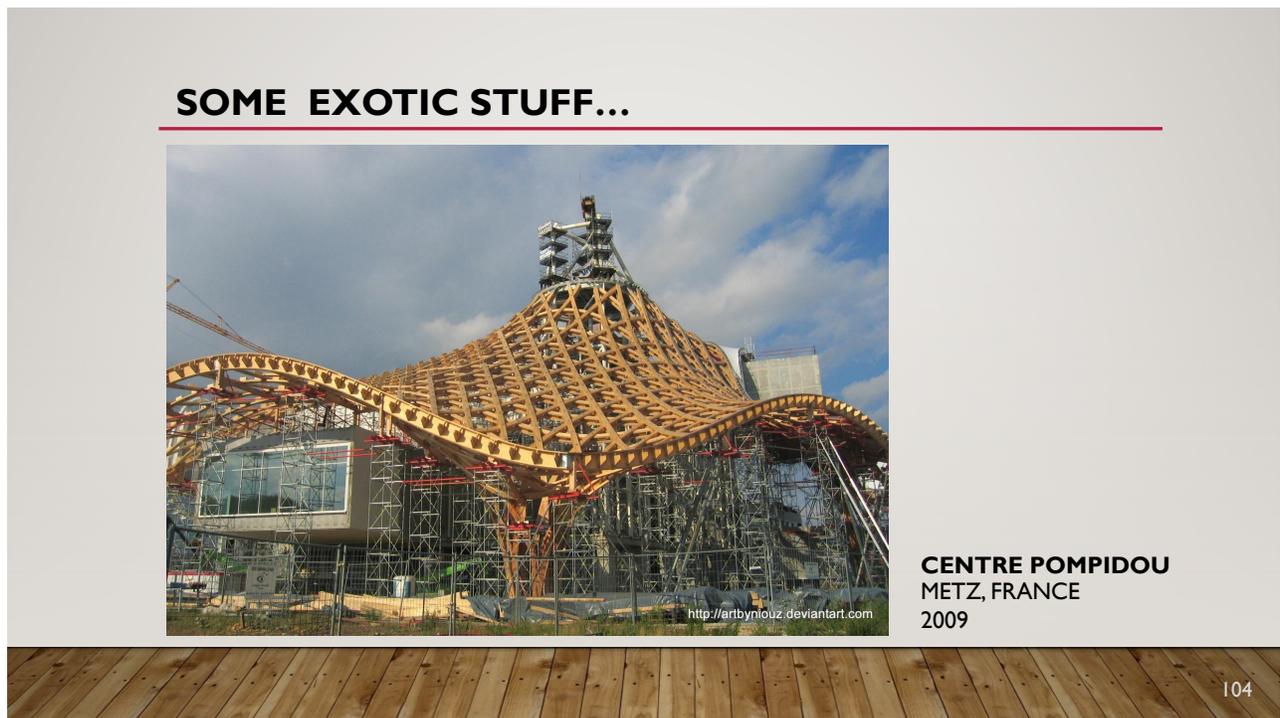
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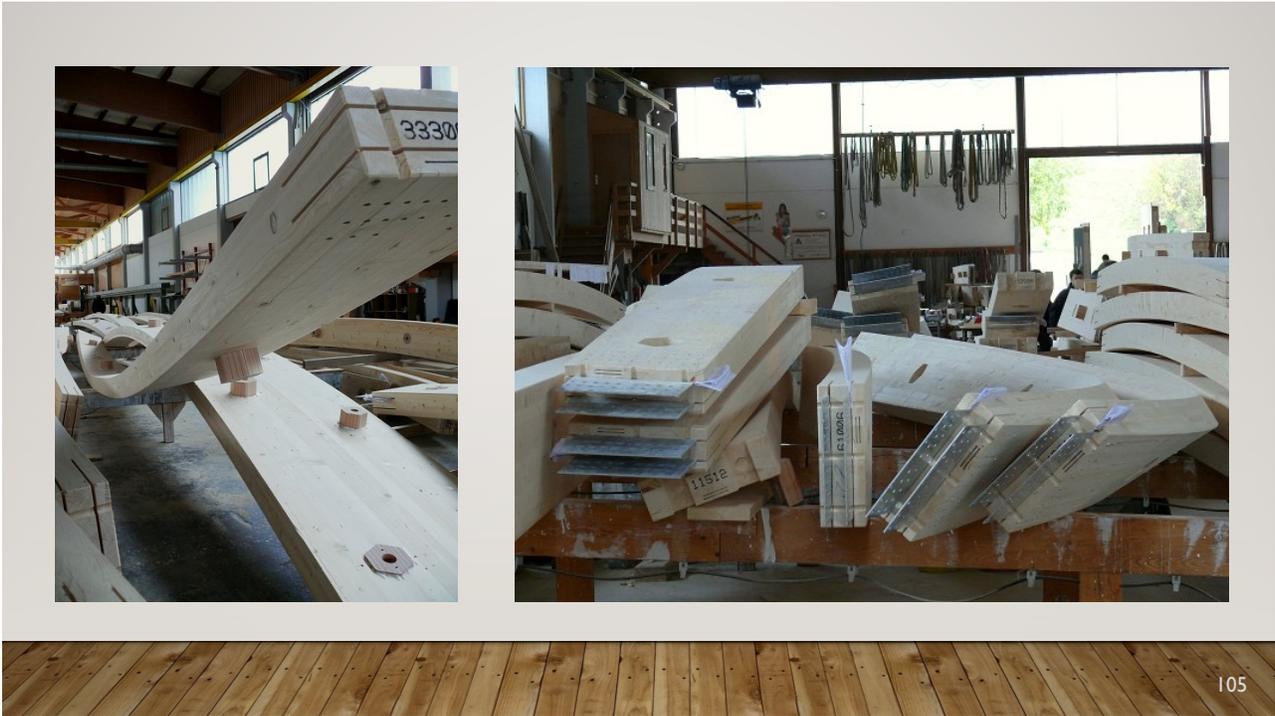
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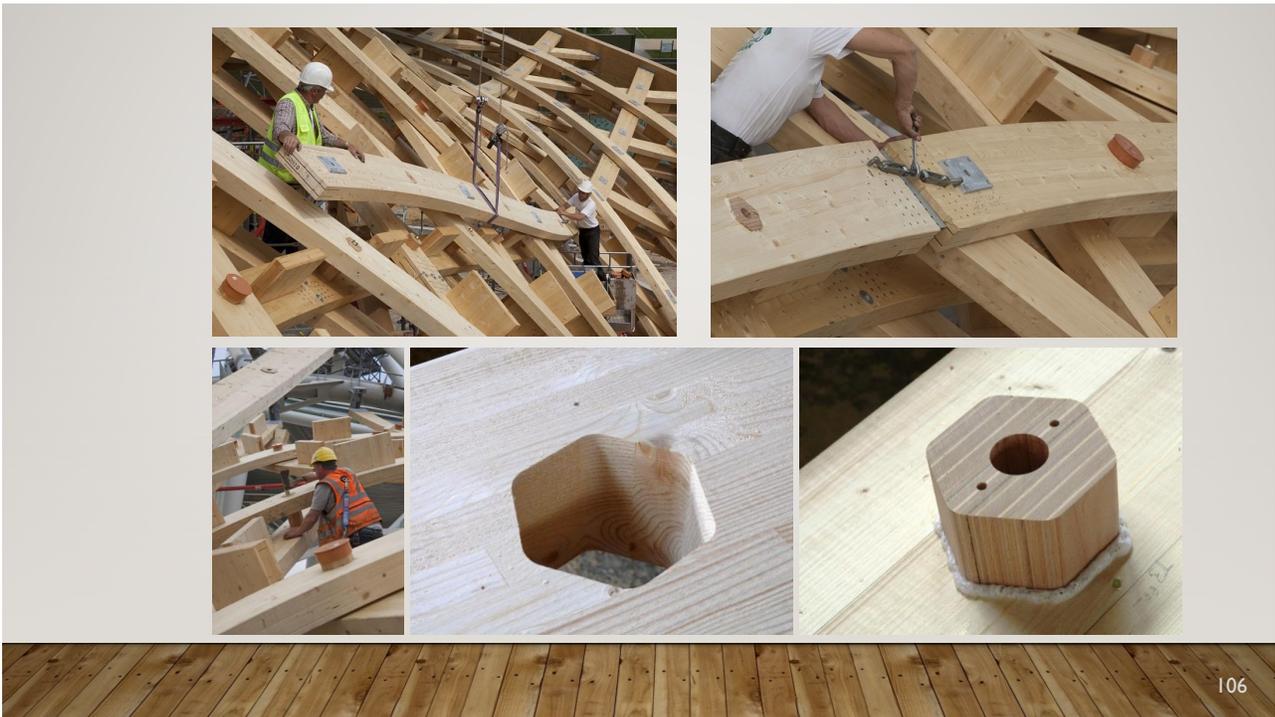
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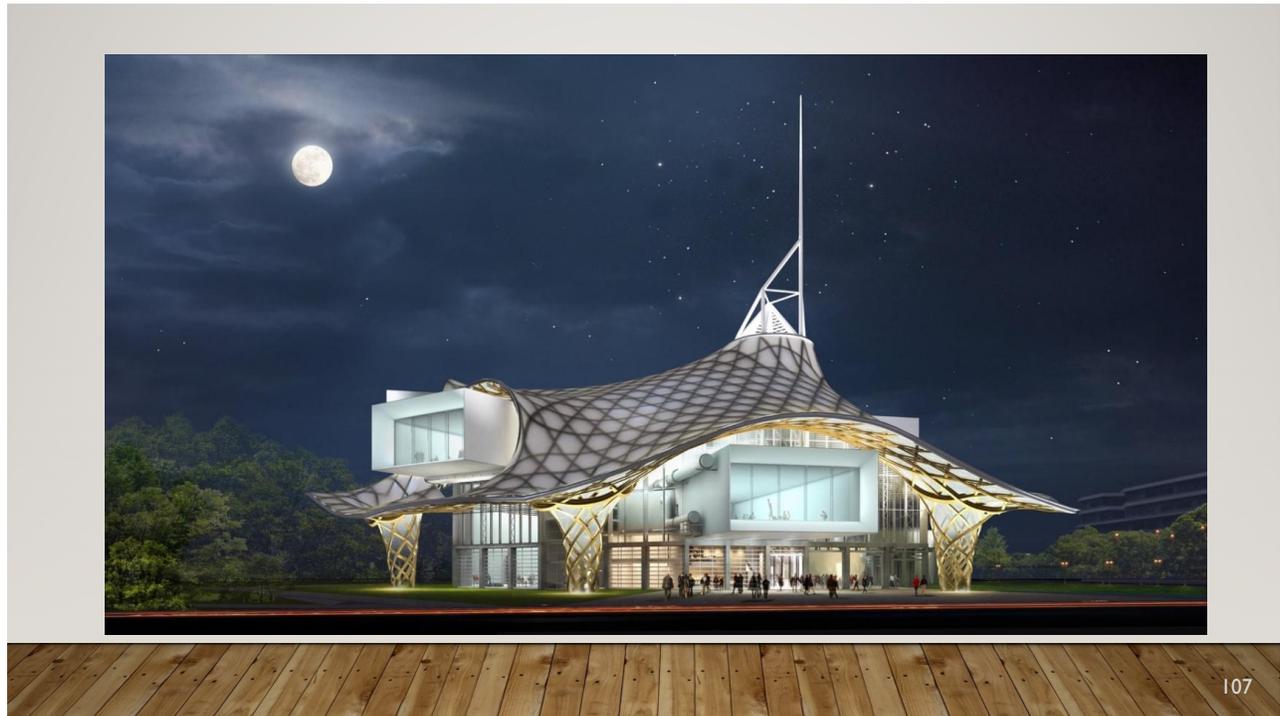
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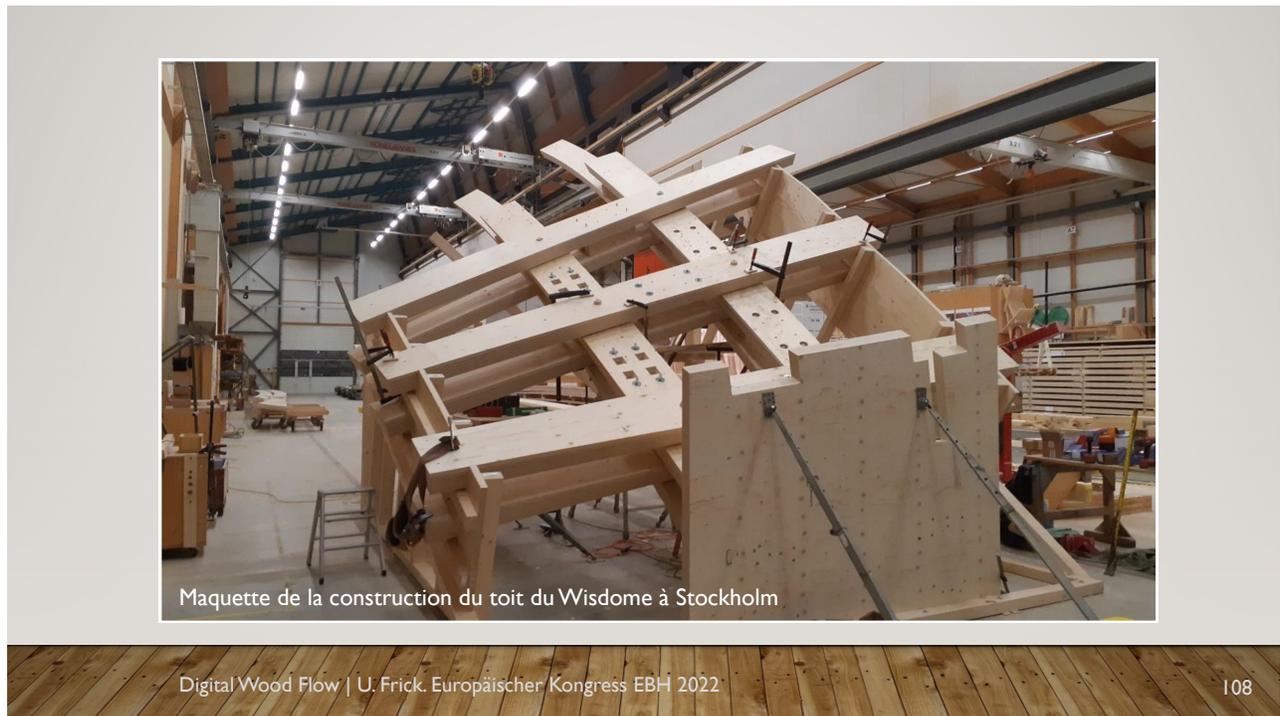


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Maquette de la construction du toit du Wisdome à Stockholm

Digital Wood Flow | U. Frick. Europäischer Kongress EBH 2022

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[Construction Free Form | Tekniska Museet Stockholm | Wisdome \(blumer-lehmann.com\)](#)

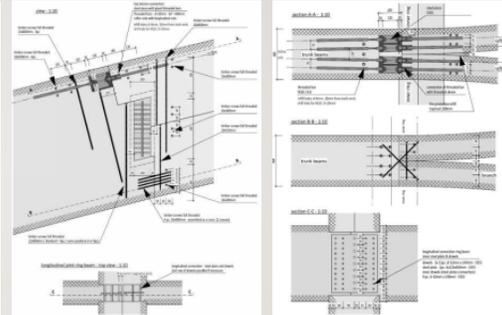
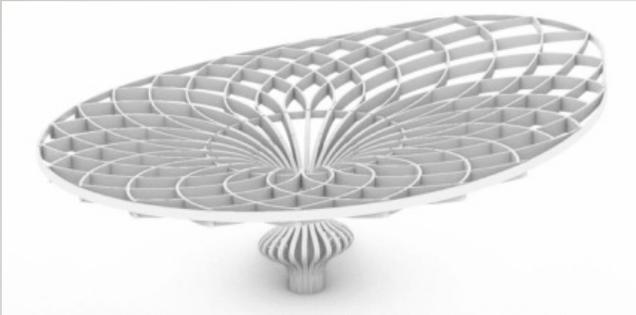


[Wisdome Stockholm | Holzbau | Architektur | Free Form | Blumer Lehmann - YouTube](#)

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Eine Tulpe als Glücksbringer – Spielcasino Venlo



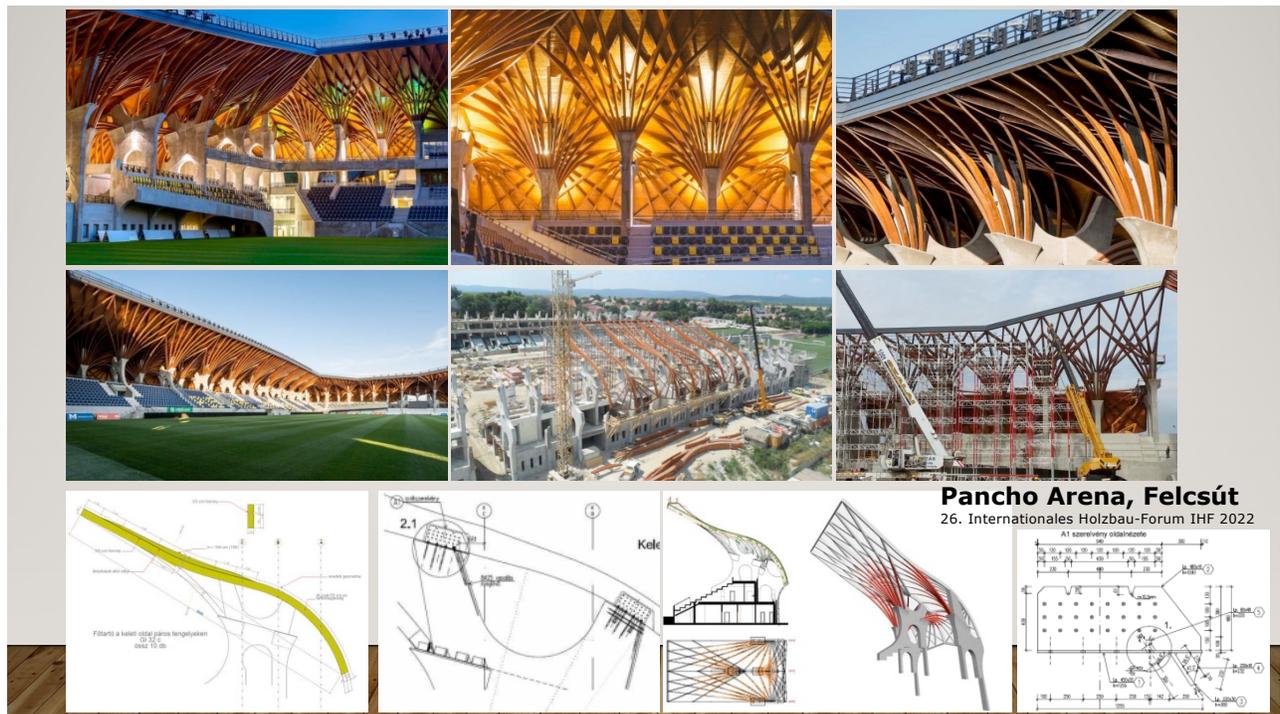
26. Internationales Holzbau-Forum IHF 2022

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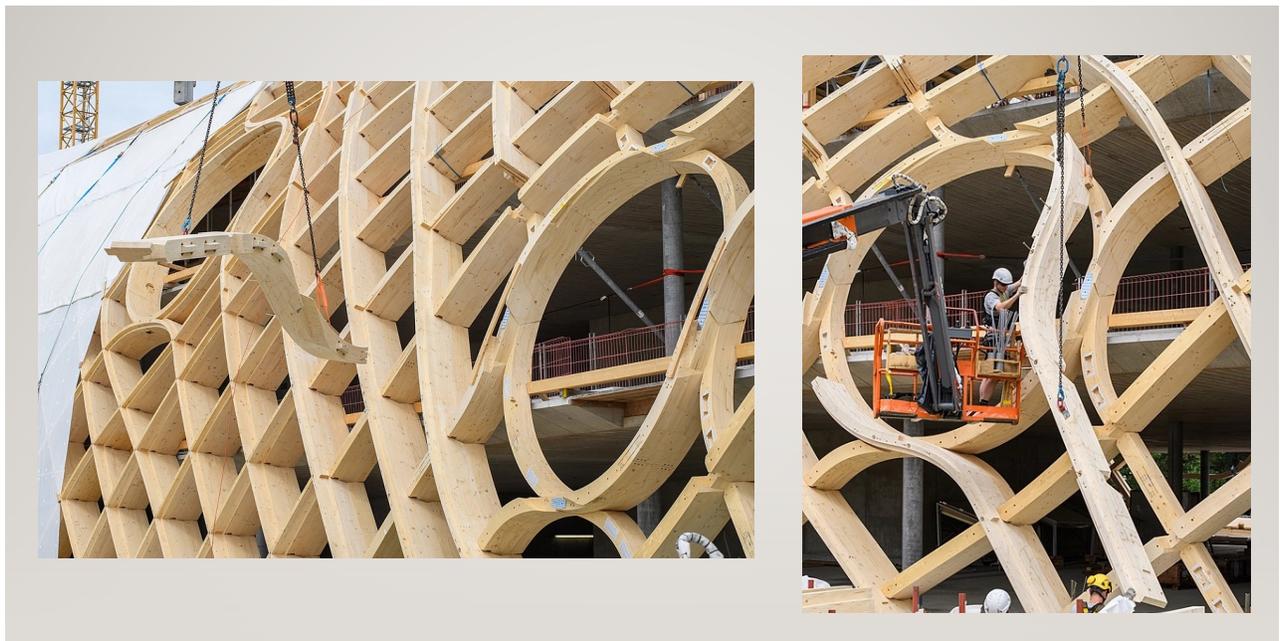
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SWATCH Headquarters, Biel/Bienne, Switzerland, 2019

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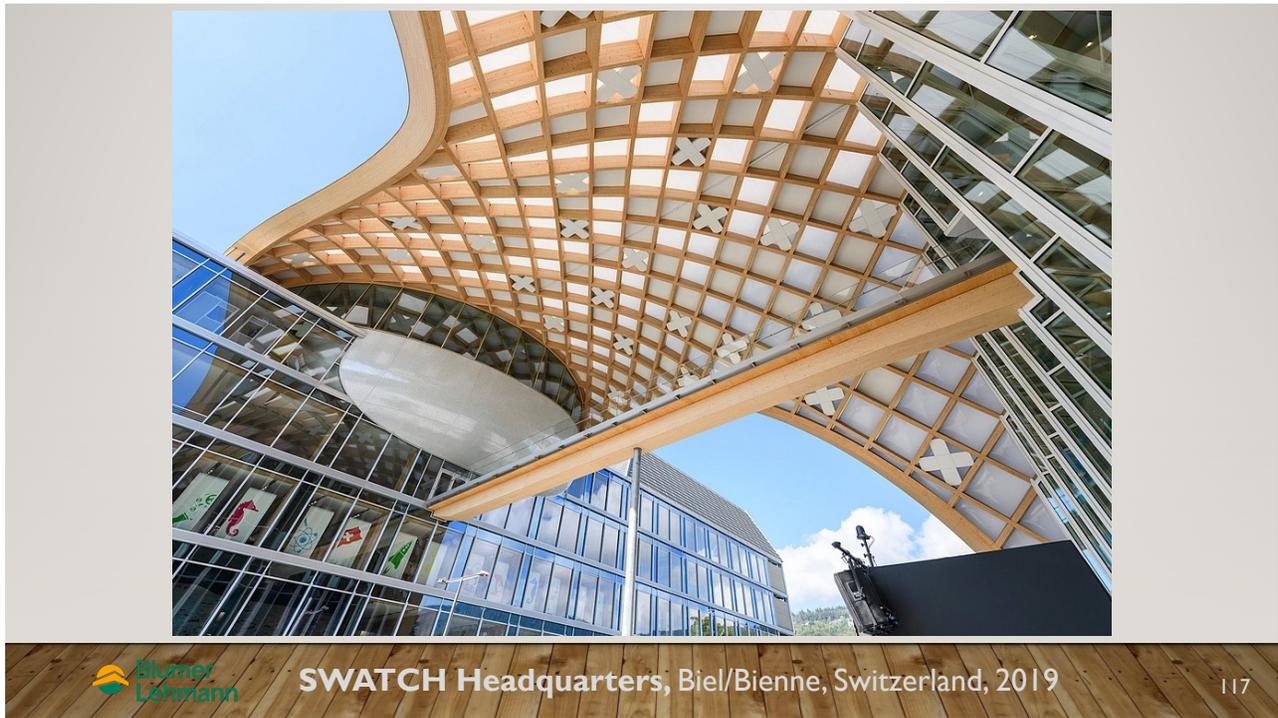
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SWATCH Headquarters, Biel/Bienne, Switzerland, 2019

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