Supplementary Materials File

Section S1. Interview Questions

1. What do you think about the reasons why wooden bridges are preferred?
2. What do you think about the wooden bridges in Finland?
3. What are the possibilities and future outlook of wooden bridge construction in Finland?
4. What are the main obstacles to wooden bridge construction in Finland?
5. What measures does it take to increase the use of wood?
6. What do you think about the impregnation and creosote replacement possibilities used in wooden bridges?
7. What is the difference between Finland and Sweden and Norway's wooden bridge construction?
8. What are the possibilities of CLT in bridge construction?
9. How do you see the possibilities of composite wooden bridges in the future?

Determining of the bridge loads

The loads affecting the structures of the situation under consideration are determined in order to place them in the structural model.

Dimensions of the structures

Deck:

$L := 10\ m$ $b := 5.4\ m$ $h := 0.2\ m$ $HL := 5\ m$ (horizontal clearance)

Girder:

$b_p := 240\ mm$ $h_p := 1080\ mm$

HORIZONTAL LOADS

Wind pressure according to NCCI 1 table C.1:

b/d_{tot}	$z_e \leq 20m$	$z_e = 50m$	$z_e \leq 20m$	$z_e = 50m$	**$z_e \leq 20m$**	**$z_e = 50m$**	$z_e \leq 20m$	$z_e = 50m$	$z_e \leq 20m$	$z_e = 50m$
≤0.5	3.58	4.18	2.54	3.02	**2.23**	**2.75**	1.73	2.28	1.30	1.86
≥4[a]	1.94	2.26	1.37	1.64	**1.21**	**1.49**	0.94	1.24	0.71	1.01
≥5[b]	1.49	1.74	1.06	1.26	**0.93**	**1.15**	0.72	0.95	0.54	0.77

$d' := 2\ m$ Height of road traffic

$d_{tot} := h + h_p + d' = 3.28\ m$ Effect height of the wind

$$\frac{b}{d_{tot}} = 1.646$$

--> $c_{w.k} := 1.895\ \frac{kN}{m^2}$ Wind pressure interpolated in terrain category II

Longitudinal horizontal loads:

Brake load (NCCI 1 section B.4.4.1)

$$L_{lk} := L \cdot \frac{1}{m} = 10$$

$$Q_{lk} := (360 + 2.7 \cdot L_{lk})\ kN = 387\ kN \qquad \frac{Q_{lk}}{HL} = 77.4\ \frac{kN}{m}$$

Wind load (NCCI 1 section C)

$$f_{w.k.pit} := c_{w.k} \cdot d_{tot} \cdot 0.25 = 1.554\ \frac{kN}{m}$$

Transverse horizontal loads:

Slanted braking (NCCI 1 section B.4.4.2)

$$Q_{trk} := Q_{lk} \cdot 0.25 = 96.75\ kN \qquad \frac{Q_{trk}}{L} = 9.675\ \frac{kN}{m}$$

Wind load (NCCI 1 section C)

$$f_{w.k} := c_{w.k} \cdot d_{tot} = 6.216\ \frac{kN}{m}$$

VERTICAL LOADS

The weights of the structures placed in the structural model come automatically. However, we will check that these sizes are correct.

Self weights:

Deck

$\gamma_{deck} := 6.0\ \frac{kN}{m^3}$ NCCI 1 tabel A.1 $L := 10\ m$

$$G_{deck} := \gamma_{deck} \cdot L \cdot b \cdot h = 64.8\ kN$$

Inspection of the structural model

Sofi: $1.2\ \frac{kN}{m^2} \cdot L \cdot b = 64.8\ kN$ OK

Girder:

$\gamma_{girder} := 4.3\ \frac{kN}{m^3}$ According to the density of the glulam

$$G_{girder} := \gamma_{girder} \cdot L \cdot b_p \cdot h_p = 11.146\ kN$$

Inspection of the structural model

Sofi: $1.11 \cdot \frac{kN}{m} \cdot L = 11.1\ kN$ OK

Asphalt + additional pavement

Volumetric weight $\gamma := 25 \frac{kN}{m^3}$

Asphalt thickness: $h_a := 40\ mm$

Additional pavement:

$G_{add} := 1 \frac{kN}{m^2}$

$G_{sw} := \gamma \cdot h_a + G_{add} = 2 \frac{kN}{m^2}$

Railings

$G_{railing} := 1 \frac{kN}{m}$ / side

Traffic loads:

LM1 (NCCI 1 section B.4.3.2)

HL 5m --> 1 lane $Q_{UDL} := 9 \frac{kN}{m^2}$ $Q_{bogie} := 4 \cdot 150\ kN$

LM3 (NCCI 1 section B.4.3.4)

From the edge of the useful width: $0.4\ m + \frac{HL}{20} = 0.65\ m$

$Q_{LM3} := 45 \frac{kN}{m^2}$

STRENGTH OF BEAMS

$b_p := 240\ mm$ $h_p := 1080\ mm$

$\gamma_M := 1.2$ Partial safety factor for glued timber

NCCI 5 draft, picture 1:

Service life 50 years, the length of the cantilever is calculated:

$$s_{cantilever} := 0.5 \cdot (5.4\ m - 4 \cdot 1.08\ m) = 0.54\ m$$

$s_{cantilever} \geq \frac{h_p}{2} = 1$ OK, even the outermost beams can be viewed in the usage category 2.

Usage category 2, when affected by traffic loads, the momentary load time category is used -->

$k_{mod} := 1.1$ (From NCCI 5)

Strength properties for glulam GL30c (NCCI 5 draft, Table 6):

Characteristic values	Dimensioning values
$f_{m.k} := 30\ MPa$	$f_{m.d} := k_{mod} \cdot \frac{f_{m.k}}{\gamma_M} = 27.5\ MPa$
$f_{t.0.k} := 19.5\ MPa$	$f_{t.0.d} := k_{mod} \cdot \frac{f_{t.0.k}}{\gamma_M} = 17.875\ MPa$
$f_{c.0.k} := 24.5\ MPa$	$f_{c.0.d} := k_{mod} \cdot \frac{f_{c.0.k}}{\gamma_M} = 22.458\ MPa$
$f_{v.k} := 3.5\ MPa$	$f_{v.d} := k_{mod} \cdot \frac{f_{v.k}}{\gamma_M} = 3.208\ MPa$
	$E_{0.05} := 10800\ MPa$

Other factors:

Increasing of bending and tensile strengths:

$$k_h := \text{if}\left(h_p < 600\ mm, min\left(\left(\frac{600\ mm}{h_p}\right)^{0.1}, 1.1\right), 1\right) = 1$$

Shape factor of the cross-section:

$$k_{shape} := min\left(1+0.15 \cdot \frac{h_p}{b_p}, 2\right) = 1.675$$

Cross-sectional dimensions:

$$A := b_p \cdot h_p = 2592\ cm^2$$

$$W_y := \frac{b_p \cdot h_p^{\ 2}}{6} = 46656\ cm^3 \qquad W_z := \frac{b_p^{\ 2} \cdot h_p}{6} = 10368\ cm^3$$

$$I_y := \frac{b_p \cdot h_p^{\ 3}}{12} = 2519424\ cm^4 \qquad I_z := \frac{b_p^{\ 3} \cdot h_p}{12} = 124416\ cm^4$$

Torsional resistance:

standard β :

b/c	1	1.5	2	2.5	3	4	5	6	8	∞
α	0.141	0.196	0.229	0.249	0.263	0.281	0.299	0.307	0.313	0.333
β	0.208	0.231	0.246	0.258	0.267	0.282	0.299	0.307	0.313	0.333

$\frac{h_p}{b_p} = 4.5$ Interpolated from the table: $\beta := 0.2905$

$$W_T := \beta \cdot b_p^{\ 2} \cdot h_p = 18071.424\ cm^3$$

ULTIMATE LIMIT STATE

Voltages and corresponding utilization rates (according to NCCI 5 Section 6.1):

Strains: (From Sofistik)

$V_{y.Ed} := 29.1\ kN$ $F_{c.Ed} := 86\ kN$ $M_{y.Ed} := 877\ kN \cdot m$ $T_{Ed} := 3.9\ kN \cdot m$

$V_{z.Ed} := 378\ kN$ $F_{t.Ed} := 64\ kN$ $M_{z.Ed} := 11.7\ kN \cdot m$

Shear resistance:

$$\tau_{y.d} := \frac{1.5 \cdot V_{y.Ed}}{A} = 0.168\ MPa \qquad UR_{L.y} := \frac{\tau_{y.d}}{f_{v.d}} = 0.052$$

$$\tau_{z.d} := \frac{1.5 \cdot V_{z.Ed}}{A} = 2.188\ MPa \qquad UR_{L.z} := \frac{\tau_{z.d}}{f_{v.d}} = 0.682$$

Compression resistance:

$$\sigma_{c.0.d} := \frac{F_{c.Ed}}{A} = 0.332\ MPa$$

$$UR_P := \frac{\sigma_{c.0.d}}{f_{c.0.d}} = 0.015$$

Tensile resistance:

$$\sigma_{t.0.d} := \frac{F_{t.Ed}}{A} = 0.247\ MPa$$

$$UR_V := \frac{\sigma_{t.0.d}}{f_{t.0.d}} = 0.014$$

Bending resistance:

$k_m := 0.7$ Multiplier for a rectangular cross-section

$$\sigma_{m.y.d} := \frac{M_{y.Ed}}{W_y} = 18.797\ MPa$$

$$\sigma_{m.z.d} := \frac{M_{z.Ed}}{W_z} = 1.128\ MPa$$

$$UR_{T.y} := \frac{\sigma_{m.y.d} + k_m \cdot \sigma_{m.z.d}}{f_{m.d}} = 0.712$$

$$UR_{T.z} := \frac{k_m \cdot \sigma_{m.y.d} + \sigma_{m.z.d}}{f_{m.d}} = 0.52$$

Torsional resistance:

$$\tau_{tor.d} := \frac{T_{Ed}}{W_T} = 0.216\ MPa$$

$$UR_{tor} := \frac{\tau_{tor.d}}{k_{shape} \cdot f_{v.d}} = 0.04$$

Buckling resistance (according to NCCI 5 Section 6.3.2):

Girder length: $L := 10\ m$

Support interval: $a := 10\ m$

Buckling lengths:

$L_{c.y} := 1 \cdot L = 10\ m$

$L_{c.z} := a = 10\ m$

Slimness numbers:

$$\lambda_y := \frac{L_{c.y}}{\sqrt{\frac{I_y}{A}}} = 32.075$$

$$\lambda_z := \frac{L_{c.z}}{\sqrt{\frac{I_z}{A}}} = 144.338$$

Relative slimness:

$$\lambda_{rel.y} := \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c.0.k}}{E_{0.05}}} = 0.486$$

$$\lambda_{rel.z} := \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c.0.k}}{E_{0.05}}} = 2.188$$

Deflection factors:

$\beta_c := 0.1$ For glued wood

$k_y := 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel.y} - 0.3\right) + \lambda_{rel.y}^{2}\right) = 0.628$

$k_z := 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel.z} - 0.3\right) + \lambda_{rel.z}^{2}\right) = 2.989$

$k_{c.y} := \dfrac{1}{k_y + \sqrt{k_y^{2} - \lambda_{rel.y}^{2}}} = 0.976$

$k_{c.z} := \dfrac{1}{k_z + \sqrt{k_z^{2} - \lambda_{rel.z}^{2}}} = 0.199$

$UR_{N.y} := \dfrac{\sigma_{c.0.d}}{k_{c.y} \cdot f_{c.0.d}} = 0.015$

$UR_{N.z} := \dfrac{\sigma_{c.0.d}}{k_{c.z} \cdot f_{c.0.d}} = 0.074$

Rotation resistance (According to NCCI 5 Section 6.3.3):

$c := 0.71$ For glued wood

$l_{ef} := L = 10\ m$ The effective length of the beam without cross support

Critical bending stress in terms of rotation:

$\sigma_{m.crit} := \dfrac{c \cdot b_p^{2}}{h_p \cdot l_{ef}} \cdot E_{0.05} = 40.896\ MPa$

Relatively slimness in terms of rotation:

$\lambda_{rel.m} := \sqrt{\dfrac{f_{m.k}}{\sigma_{m.crit}}} = 0.856$

Strength reduction factor due to the risk of rotation:

$k_{crit} := 1.56 - 0.75 \cdot \lambda_{rel.m} = 0.918$ when 0,75< $\lambda_{rel.m}$ <1.4 (NCCI 5, formula 6.34)

$UR_K := \dfrac{\sigma_{m.y.d}}{k_{crit} \cdot f_{m.d}} = 0.745$

Combined stresses:

Bending + tensile (NCCI 5 Section 6.2.3, formulas 6.17 and 6.18)

$UR_V + \max\left(UR_{T.y}, UR_{T.z}\right) = 0.726$

Bending + compression (NCCI 5 Section 6.2.4, formulas 6.19 and 6.20)

$$UR_P^2 + \max\left(UR_{T.y}, UR_{T.z}\right) = 0.712$$

Bending + buckling (NCCI 5 Section 6.3.2, formulas 6.23 and 6.24)

$$\max\left(UR_{N.y} + UR_{T.y}, UR_{N.z} + UR_{T.z}\right) = 0.727$$

Rotation + buckling (NCCI 5 Section 6.3.3, formulas 6.35)

$$\frac{UR_P}{k_{c.z}} + UR_K^2 = 0.629$$

SERVICE LIMIT STATE

Deflection

$$w_{perm} := \frac{L}{400} = 25\ mm$$

From Sofistik:

$$w_{inst} := 23.3\ mm$$

$$UR_T := \frac{w_{inst}}{w_{perm}} = 0.932$$

Vibration

Girders features:

Density

$$\rho_{mean.p} := 430\ \frac{kg}{m^3}$$

Elastic modulus

$$E_{mean.p} := 13000\ \frac{N}{mm^2}$$

$$b_p = 0.24\ m$$

$$h_p = 1.08\ m$$

$$I_{girder} := \frac{b_p \cdot h_p^3}{12} = 0.025\ m^4$$

$$A_{girder} := b_p \cdot h_p = 0.259\ m^2$$

$$EI_{tot} := 1.2 \cdot E_{mean.p} \cdot I_{girder} = \left(3.93 \cdot 10^8\right)\ \frac{kg \cdot m^3}{s^2}$$

Elastic modulus increased (NCCI 5 draft, Section 7.3.3.1)

A factor depending on the support and the order of vibration:

$$\varphi_i := \pi$$

When both supports have free support and number of times is 1

$$m := \rho_{mean.p} \cdot A_{girder} = 111.456 \ \frac{kg}{m}$$

Calculation of characteristic frequency (NCCI 5 Section 7.3.5):

$$f := \frac{\varphi_i^{\ 2} \cdot \sqrt{\frac{EI_{tot}}{m}}}{2 \cdot \pi \cdot L^2} = 29.497 \ \frac{1}{s}$$

$$f > 5 \ \frac{1}{s} = 1$$

When the condition is met (characteristic frequency is over 5 Hz) vibration dimensioning is not needed.

DECK SLAB STRENGTH

Starting information for side plank deck:

$b := 50\ mm$ $h := 200\ mm$ $HL := 5\ m$ $n_{pp} := 5$

Distribution of main beams: $s_{pp} := 1.08\ m$

The width of the main beams: $b_{pp} := 240\ mm$

The distance between the surfaces of the main beams: $b_{spacing} := s_{pp} - b_{pp} = 0.84\ m$

The length of the overhang of the deck plate: $b_{cantilever} := \left(\frac{HL}{2} - \left(\frac{n_{pp}-1}{2}\right) \cdot s_{pp}\right) - \frac{b_{pp}}{2} = 0.22\ m$

Lumber C24, class of use 2, loads time class momentary:

$k_{mod} := 1.1$ $\gamma_M := 1.4$

Cross-sectional grooves:

$A := b \cdot h = 100\ cm^2$ $W_y := \frac{b \cdot h^2}{6} = 333.333\ cm^3$

Material properties:

Characteristic values	Dimensioning values
$f_{m.k} := 24\ MPa$	$f_{m.d} := k_{mod} \cdot \frac{f_{m.k}}{\gamma_M} = 18.857\ MPa$
$f_{v.k} := 4\ MPa$	$f_{v.d} := k_{mod} \cdot \frac{f_{v.k}}{\gamma_M} = 3.143\ MPa$

The stresses of the side plank deck are examined both between the beams and in the cantilever area. The subject of examination are bending and shear resistance.

The durability review is carried out on one plank, for which the determination of the determining case with Sofistik turned out to be challenging, as it presents the stresses of a larger field. Consequently, the stresses have been determined by hand calculation

LM1 truck load and area of influence (NCCI 1 section B.4.3.2):

$Q_k := 150\ kN$ $b_k := 400\ mm$ $h_k := 400\ mm$

$$c_1 := min\left(b_k, h_k, b_{spacing}\right) = 400\ mm$$

$$c_2 := min\left(b_k, h_k, b_{cantilever}\right) = 220\ mm$$

$$c_3 := min\left(b_k, h_k, b_{spacing}, b_{spacing} - 2\ h\right) = 400\ mm$$

$$c_4 := \max\left(min\left(b_k, b_{cantilever}, b_{cantilever} - h\right), 0\ mm\right) = 20\ mm$$

$$q_k := \frac{Q_k}{b_k \cdot h_k} \cdot b = 46.875\ \frac{N}{mm}$$

Calculation of stresses:

Between the beams

$$M_{k.spacing.LM1} := \left(\frac{3 \cdot q_k \cdot c_1 \cdot b_{spacing}}{24} - \frac{q_k \cdot {c_1}^3}{24 \cdot b_{spacing}}\right) = 1.82\ kN \cdot m$$

$$V_{k.spacing.LM1} := q_k \cdot \frac{c_3}{2} = 9.375\ kN$$

Cantilever area

$$M_{k.cantilever.LM1} := q_k \cdot c_2 \cdot \left(b_{cantilever} - \frac{c_2}{2}\right) = 1.134\ kN \cdot m$$

$$V_{k.cantilever.LM1} := q_k \cdot c_4 = 0.937\ kN$$

Load diagram LM2 is very rare as the determining load for the main girders, but for the deck slab LM2 should be considered as it creates local stresses.

LM2 truck load and area of influence (NCCI 1 section B.4.3.3):

$Q_k := 200\ kN$ $\quad$ $b_k := 600\ mm$ $\quad$ $h_k := 350\ mm$

$$c_1 := min\left(b_k, b_{spacing}\right) = 600\ mm$$

$$c_2 := min\left(b_k, b_{cantilever}\right) = 220\ mm$$

$$c_3 := min\left(b_k, b_{spacing}, b_{spacing} - 2\ h\right) = 440\ mm$$

$$c_4 := \max\left(min\left(b_k, b_{cantilever}, b_{cantilever} - h\right), 0\ mm\right) = 20\ mm$$

$$q_k := \frac{Q_k}{b_k \cdot h_k} \cdot b = 47.619\ \frac{N}{mm}$$

Calculation of stresses:

Between the beams

$$M_{k.spacing.LM2} := \left(\frac{3 \cdot q_k \cdot c_1 \cdot b_{spacing}}{24} - \frac{q_k \cdot c_1^{\ 3}}{24 \cdot b_{spacing}} \right) = 2.49\ kN \cdot m$$

$$V_{k.spacing.LM2} := q_k \cdot \frac{c_3}{2} = 10.476\ kN$$

Cantilever area

$$M_{k.cantilever.LM2} := q_k \cdot c_2 \cdot \left(b_{cantilever} - \frac{c_2}{2} \right) = 1.152\ kN \cdot m$$

$$V_{k.cantilever.LM2} := q_k \cdot c_4 = 0.952\ kN$$

Dimensioning stresses:

Between the beams

$$M_{d.spacing} := 1.35 \cdot \max\left(M_{k.spacing.LM1}, M_{k.spacing.LM2}\right) = 3.361\ kN \cdot m$$

$$V_{d.spacing} := 1.35 \cdot \max\left(V_{k.spacing.LM1}, V_{k.spacing.LM2}\right) = 14.143\ kN$$

Cantilever area

$$M_{d.cantilever} := 1.35 \cdot \max\left(M_{k.cantilever.LM1}, M_{k.cantilever.LM2}\right) = 1.556\ kN \cdot m$$

$$V_{d.cantilever} := 1.35 \cdot \max\left(V_{k.cantilever.LM1}, V_{k.cantilever.LM2}\right) = 1.286\ kN$$

Shear resistance (between the beams and the cantilever area):

$$\tau_{y.d.spacing} := \frac{1.5 \cdot V_{d.spacing}}{A} = 2.121\ MPa \qquad UR_{V.spacing} := \frac{\tau_{y.d.spacing}}{f_{v.d}} = 0.675$$

$$\tau_{y.d.cantilever} := \frac{1.5 \cdot V_{d.cantilever}}{A} = 0.193\ MPa \qquad UR_{V.cantilever} := \frac{\tau_{y.d.cantilever}}{f_{v.d}} = 0.061$$

Bending resistance (between the beams and the cantilever area):

$$\sigma_{m.d.spacing} := \frac{M_{d.spacing}}{W_y} = 10.084\ MPa \qquad UR_{M.spacing} := \frac{\sigma_{m.d.spacing}}{f_{m.d}} = 0.535$$

$$\sigma_{m.d.cantilever} := \frac{M_{d.cantilever}}{W_y} = 4.667\ MPa \qquad UR_{M.cantilever} := \frac{\sigma_{m.d.cantilever}}{f_{m.d}} = 0.248$$