Design and Construction of a 160 m long Timber Bridge in Mistissini, Québec, Canada

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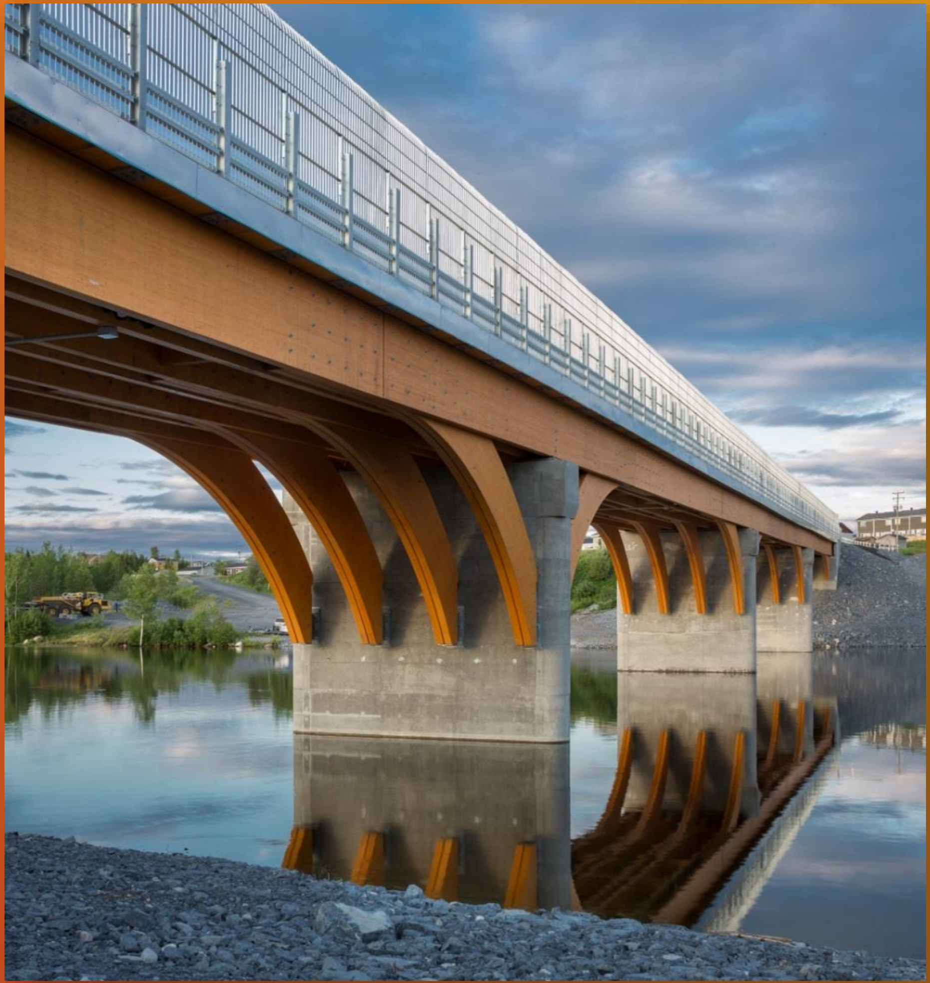

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Timber Bridges in Canada

Past

- Wood was a prominent structural material used in bridge construction up until the 1950s
- Due to abundance of forests
- Mostly railway and covered timber bridges

Timber Bridges in Canada

Currently

- **Steel and concrete dominate**

- **Why not using wood?**
  - Spans associated with conventional wood bridges were relatively limited
  - Wood can decay; treatments can be both a bonus and a penalty
  - Lack of wood design knowledge

Source: MTO/CWC

Trends/Opportunities

+ Municipalities installing timber footbridges
+ Provinces (BC, QC, ON) constructing timber traffic bridges
  - Inspired by recent interest in timber across NA
+ FPI/CWC market studies promising
+ Bridge Engineers still have concerns:
  - Cost
  - Durability/service life
  - Maintenance requirements
  - Strength properties of specific materials

Kiskatinaw bridge, BC 1943
Photo credit BC MOTI

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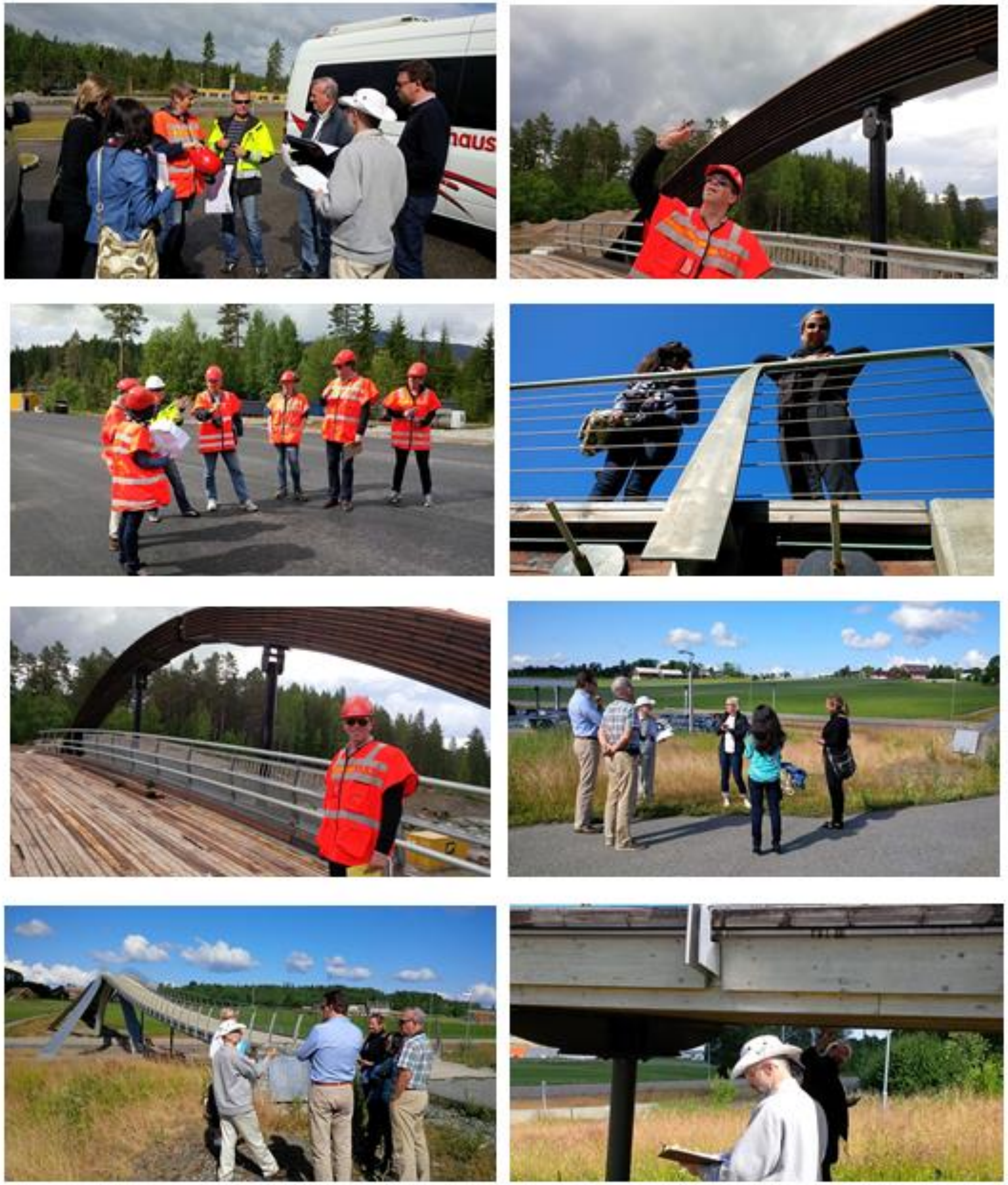
Timber Bridges in Canada

Currently and Future Direction/Trend

- New technologies
  - High quality EWP
  - Composite configuration: Carbon and glass fibre reinforced polymers (FRP), high performance concrete and epoxies, innovative connection systems
  - Major improvement in treatment methods
- Resurgence of wood as a modern and yet sustainable bridge building material
- Aesthetic and cultural considerations

Norway Provides a Good Example



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Norway Provides a Good Example

+ Total 17,100 bridges, less than 200 timber
+ Increasing % of new bridges are timber
+ Nordic Timber Bridge Project
  - 1995 to 2002, ~ CDN$4 Million
  - Led by Erik Aasheim of the Norwegian Wood Technology Institute
  - Funded by Timber industry, road authorities, and national research funds
  - Norway, Sweden, Denmark and Finland

Tretten (148 m) - 2012

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Evenstad (5 spans @ 36 m - 180m) - 1996

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Kjøllsæter (145 m) - 2006

Hybrid concrete/wood:

Supports heavy military vehicles and equipment (100 tons). Good detailing

Flisa (196 m) - 2003

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Åset (37m) - 2014

Modern Timber Bridges in Canada

Modern Timber Bridge in Canada

Use of CLT in Bridges, Quebec (Girder box)

Banff Pedestrian Bridge

80 m span

Epp et.al. ICTB, 2013

Mistissini Bridge over Uupaachikus Pass

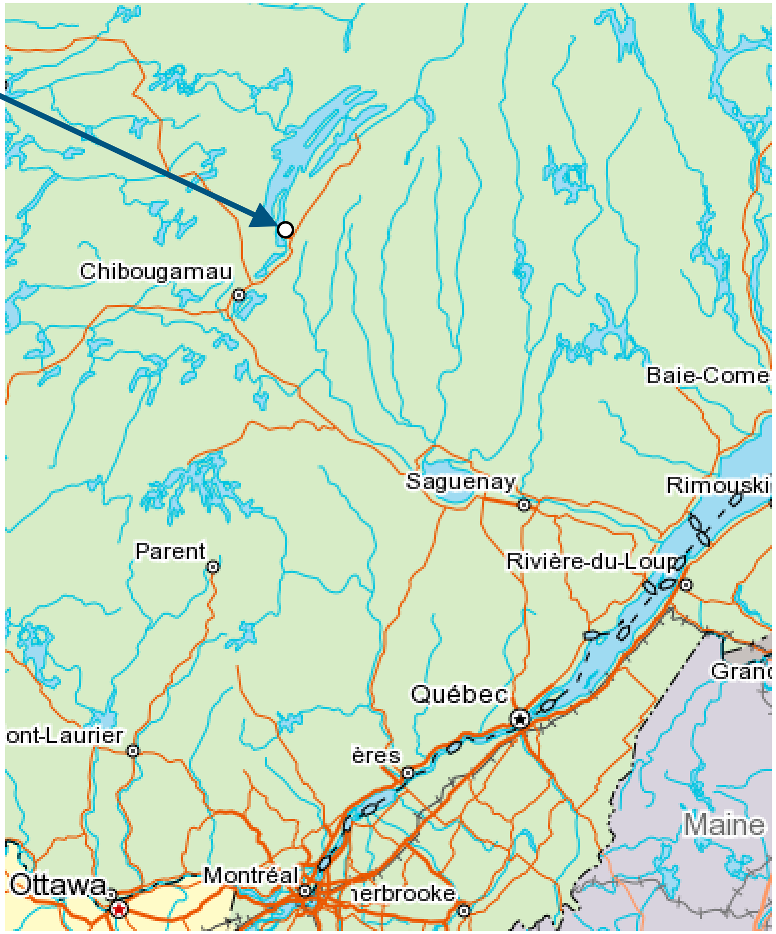
Wood deck on Wood Girders

- Length: 160 m
- Width: 9.25 m
- Lane width: 3.0 m
- Sidewalk: 1.8 m
- 2 abutments and 3 piers
- Shallow foundations (no piles required)
- Durability by design

Source: Denis Lefebvre Stantec

Background: Mistissini

Mistissini, Québec



Bridge localisation

Mistissini

Uupaachikus pass of Lake Mistassini

Background

Why building a bridge in Mistissini?

- Access to a larger territory for the Cree community, and;
- Access to a large gravel pit in order to satisfy the growing demand for gravel used in the construction projects of the community.

What are the expectations of the community?

- Needs a bridge…
- No particular expectation for architecture

Back to Design

Composite Steel Concrete vs Wood solution

- **Cost of the preliminary design:**
  - 8.8 M$ for composite steel concrete solution
  - 8.7 M$ for wood solution
- **Advantages of the wood solution:**
  - Atheistically pleasing
  - Glulam factory is located 90 km from the site
  - Negative carbon footprint
  - Black spruce comes from the region

Choice of Wood Option

Carbon Footprint

Émissions équivalentes de CO_2 en kg/m³			
Matériaux	**Athena**	**Moyenne Athena**	**Ademe**
	kg/m³	kg/m³	kg/m³
Béton 30MPa	301	302	209
Béton 60MPa	304		
Acier d'armature	4697	9721	8580
Plaques laminées à chaud	8968		
Plaques en acier galvanisé	13678		
Quincaillerie	11543		
Béton bitumineux	127	127	145
Bois Nordic LAM	-765	-765	-825

- Total emissions for Steel/Concrete: 969 tonnes of CO_{2e}
- Total emissions for Wood : - 497 t (Total of 1270 m³ of wood)
- Total potential carbon benifit : 1466 tonnes ≡ 640 000 L of gas

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Nordic Glulam (from Black Spruce)

+ Bending : f_b = 30.7 MPa
+ Longitudinal shear : f_v = 2.2 MPa
+ Compression : f_c = 33 MPa
+ Tensile strength (gross area) : ft = 15.3 MPa
+ Tensile strength (net area) : ft = 20.4 MPa
+ Elastic modulus : E = 12400 MPa
+ Elastic modulus (compression) : E_{05} = 10788 MPa
+ Thermal expansion 3 to 5 x 10^{-6}
+ Density : 500 kg/m³

Steel and concrete

+ Concrete f'_c = 35 MPa, E=28,000 MPa, CTE = 10 to 11x10^{-6}, 2,400 kg/m³
+ Steel f_y = 350MPa, E=200,000 MPa, CTE = 11.7x10^{-6}, 7,850 kg/m³

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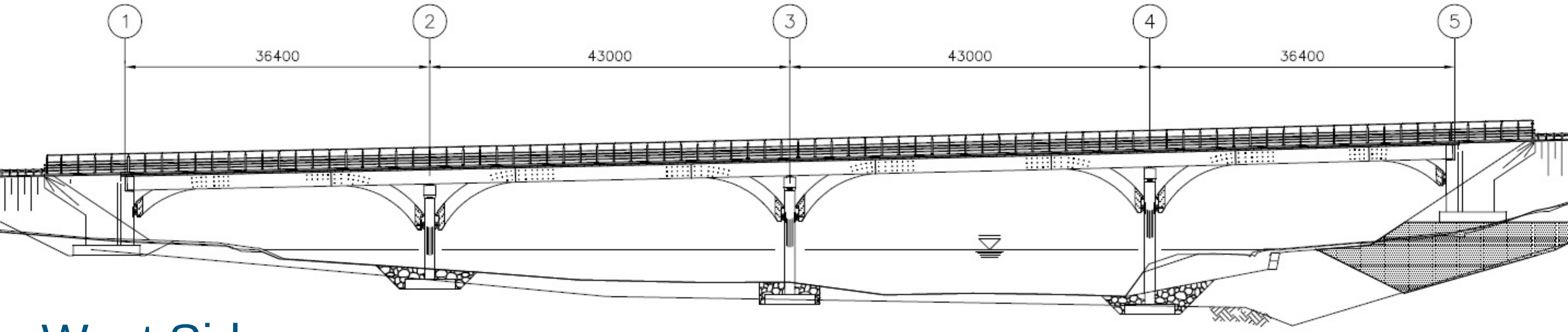
Elevation view of the bridge



West Side

(Gravel pit)

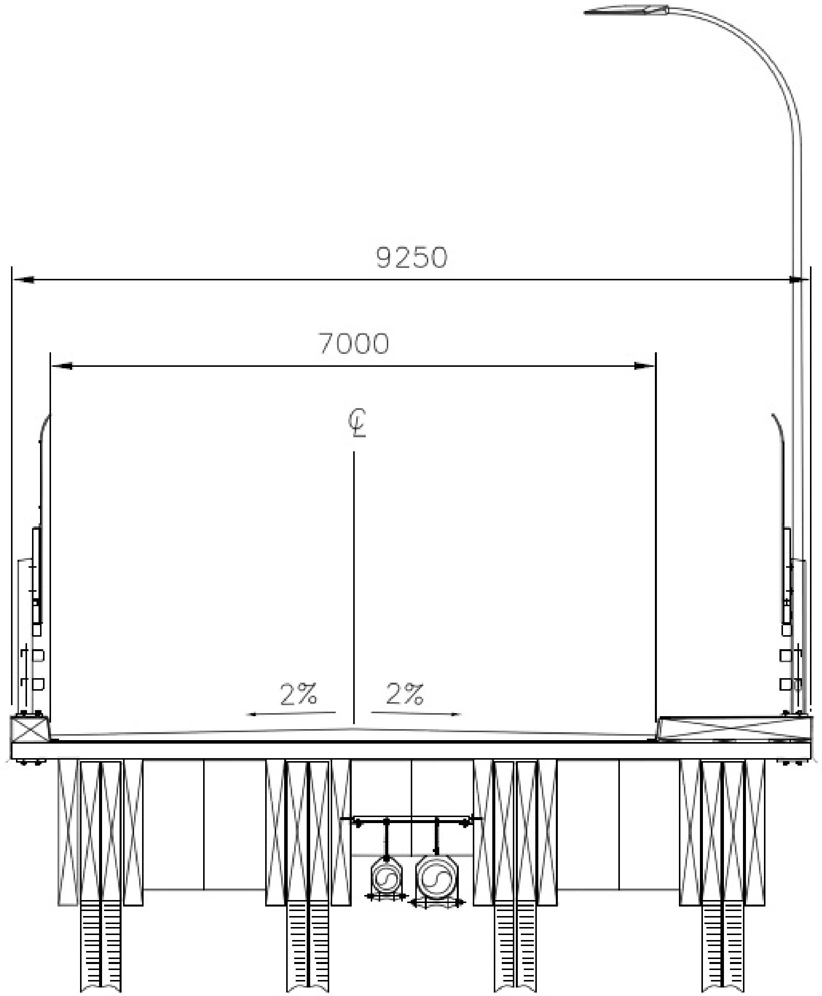
East side

Mistissini

Back to Design

Cross section of the bridge

+ No expansion joint
+ Weight of the wood deck is 3 times lighter than a steel-concrete deck
+ Bridge designed for loads due to braking forces, temperature and seismic effects are all taken into account



Geometric Constraints

+ Client criteria:
  - Bridge of 160 m of span opposite Main Street
  - 4m elevation between the west and east shore
  - A Twin Otter aircraft must be able to navigate under the bridge (dimensions of the aircraft: width 20 m, length 16 m, height 6 m)

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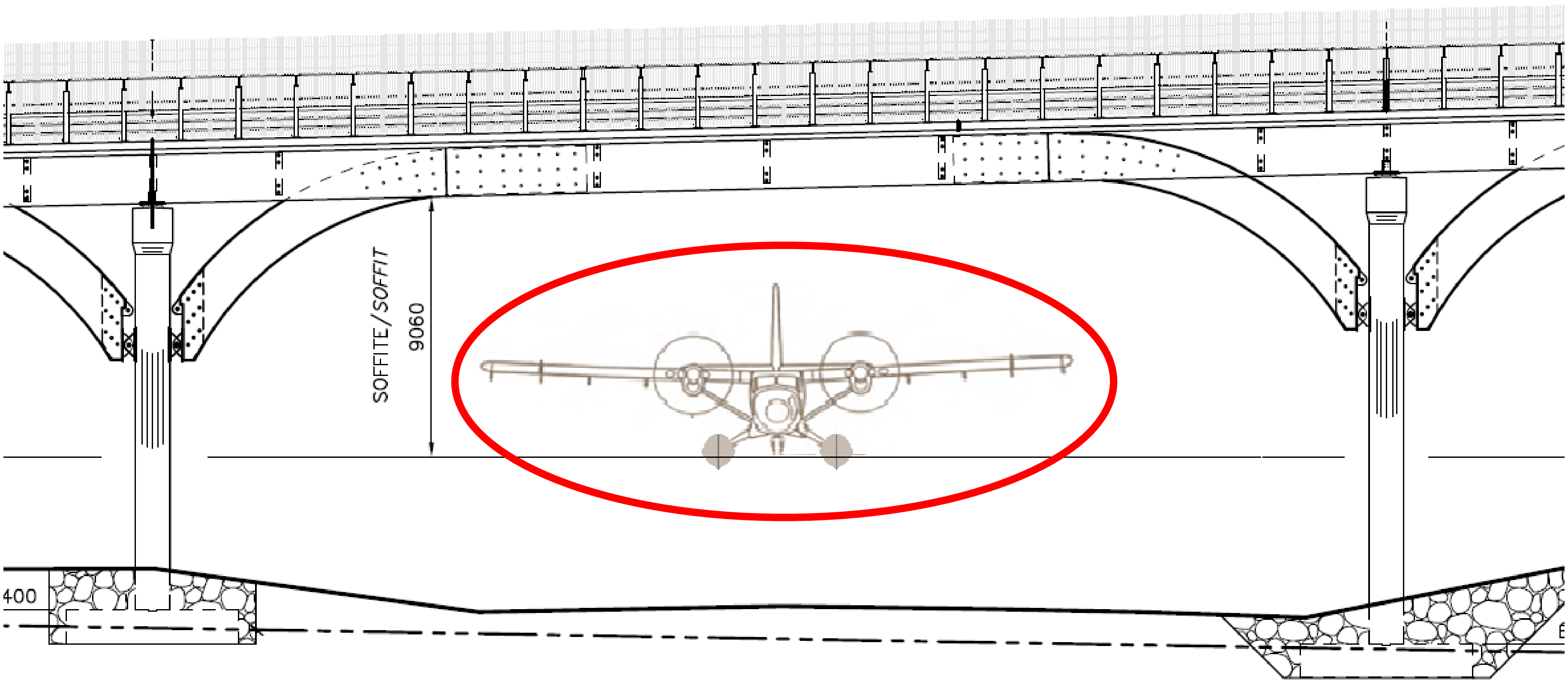
Geometric considerations



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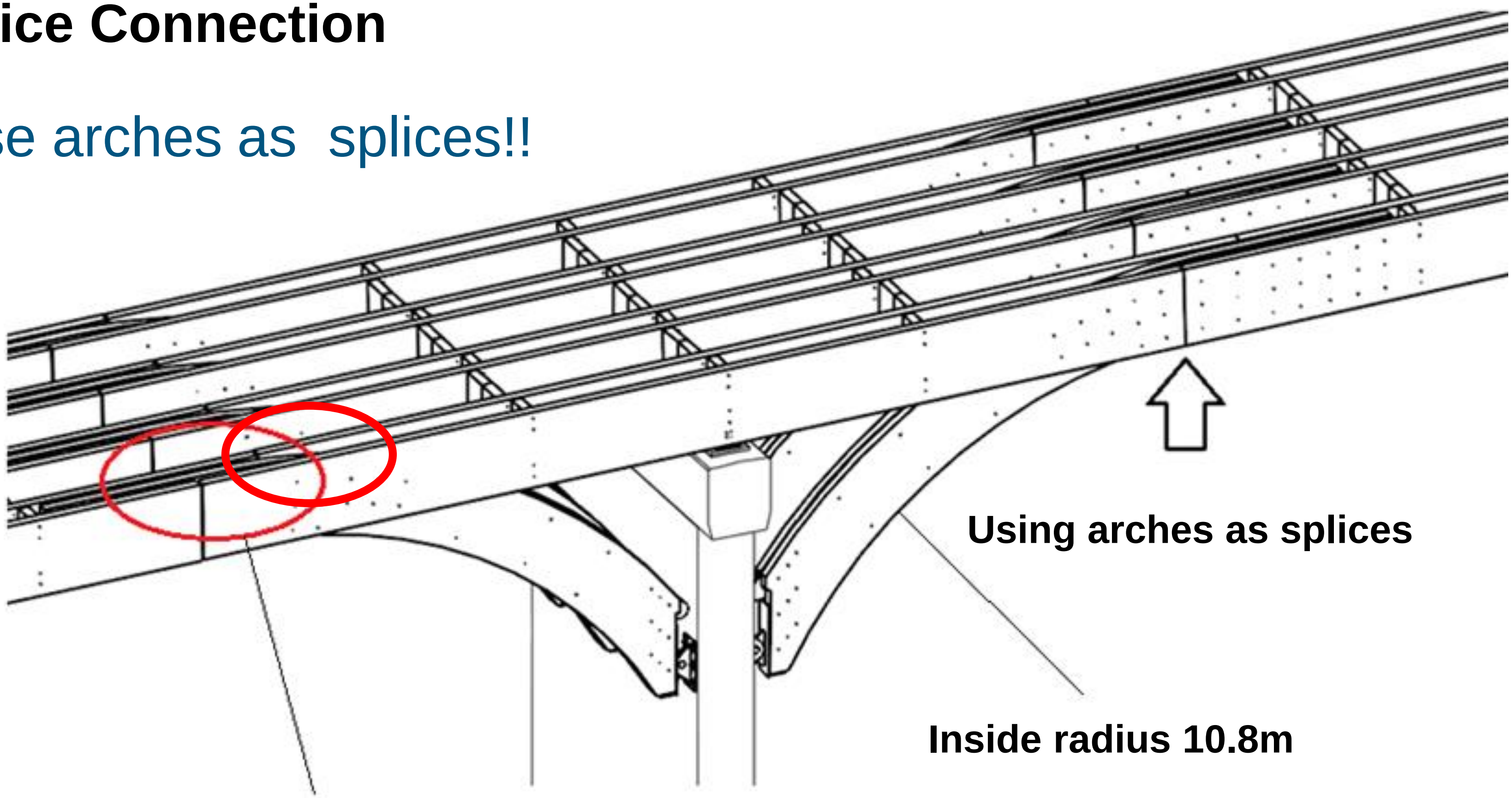
Splice Connection

Use arches as splices!!



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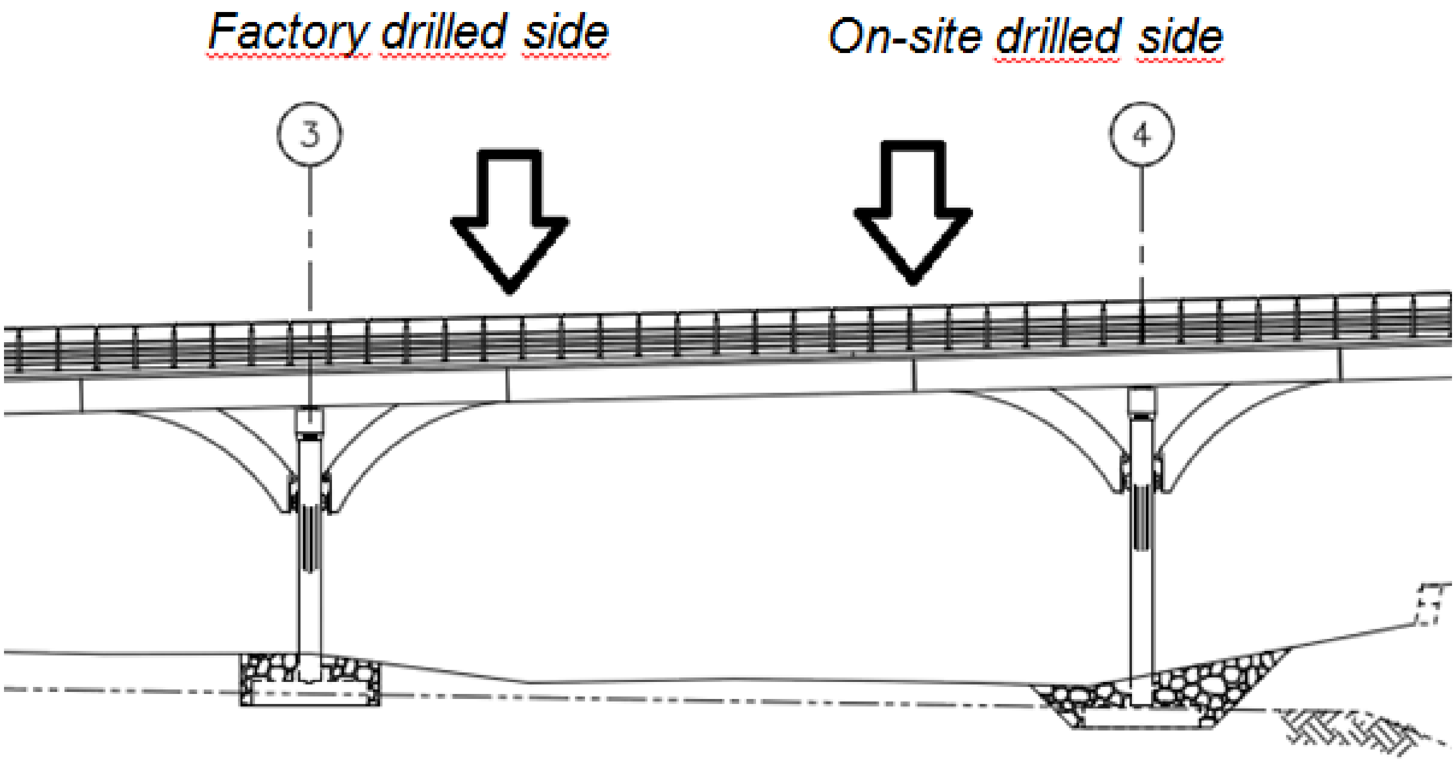
Strategy for drilling…



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Bridge Design Concept

Geotechnical Conditions

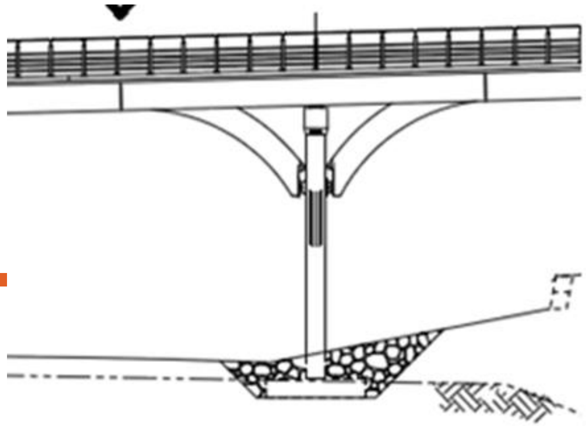
- Strong moraine with very good bearing capacity:

  500 kPa at the ELUT

- Construction of the bridge on shallow foundations

- Controlled backfill required on the abutment side of Axis 5

  (steeper moraine position deeper at this location)



Geotechnical Conditions

Controlled backfill required on the abutment side of Axis 5

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Design Criteria for the Wooden Bridge

- Designed for legal purposes CL-625 loading (S6 Cnd Highway Bridge Code)
- Two lanes traffic
- Speed: 50 km / h
- Low seismic zone with a = 0.036
- Seismic category: Emergency bridge
- Design Verification with S6-06 and O86-09
- Maximum deflection L/1000 (maximum @ mid-span of 43 mm)

Construction Details

Fabrication of glulam beams

- Laminations are made of 38mm x 38mm black spruce pieces
- Laminations are cut to the desired width
- Then, glued to create a straight or curved beam ...
- The notches, the curves and the holes are prefabricated using CNC machines

Curtsey of Nordic

Fabrication of Glulam Beams

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Fabrication of Glulam Beams

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Fabrication of Glulam Beams

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Fabrication of Glulam Beams

Planing, sanding, drilling & profiling using CNC machines

Fabrication of Glulam Beams

Pre-assembly of beams and splices at the plant to ensure good fit.

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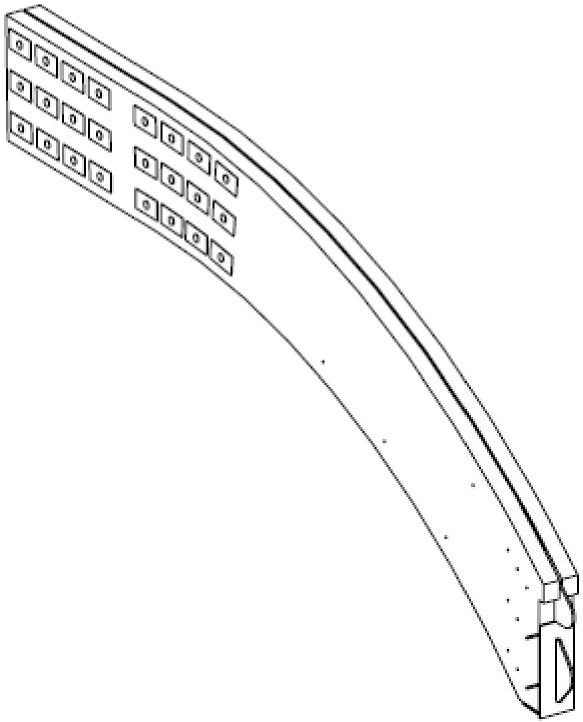
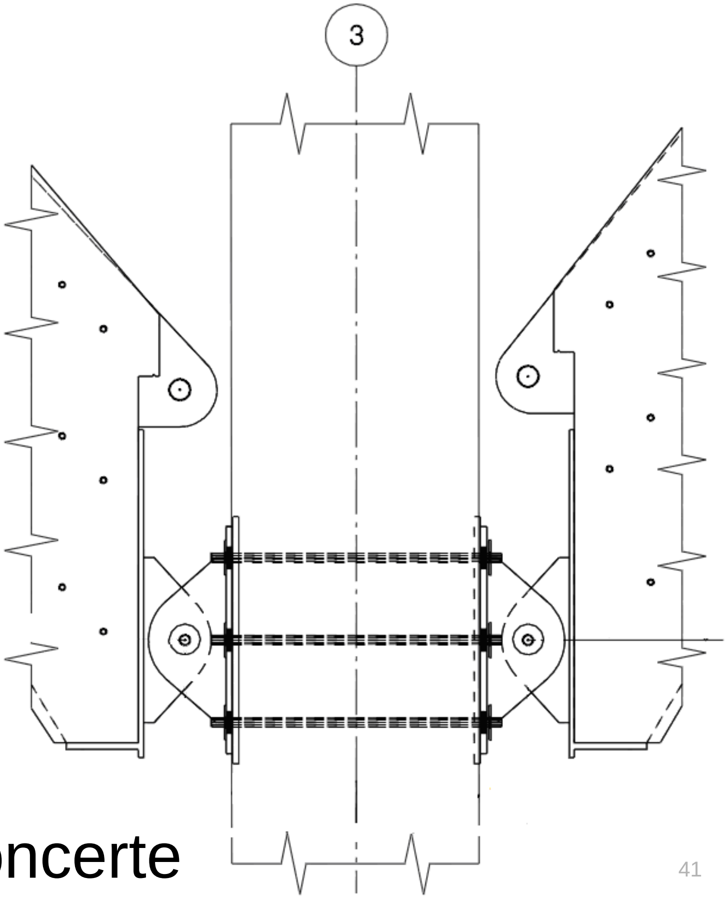
Construction Details

Arches and connections



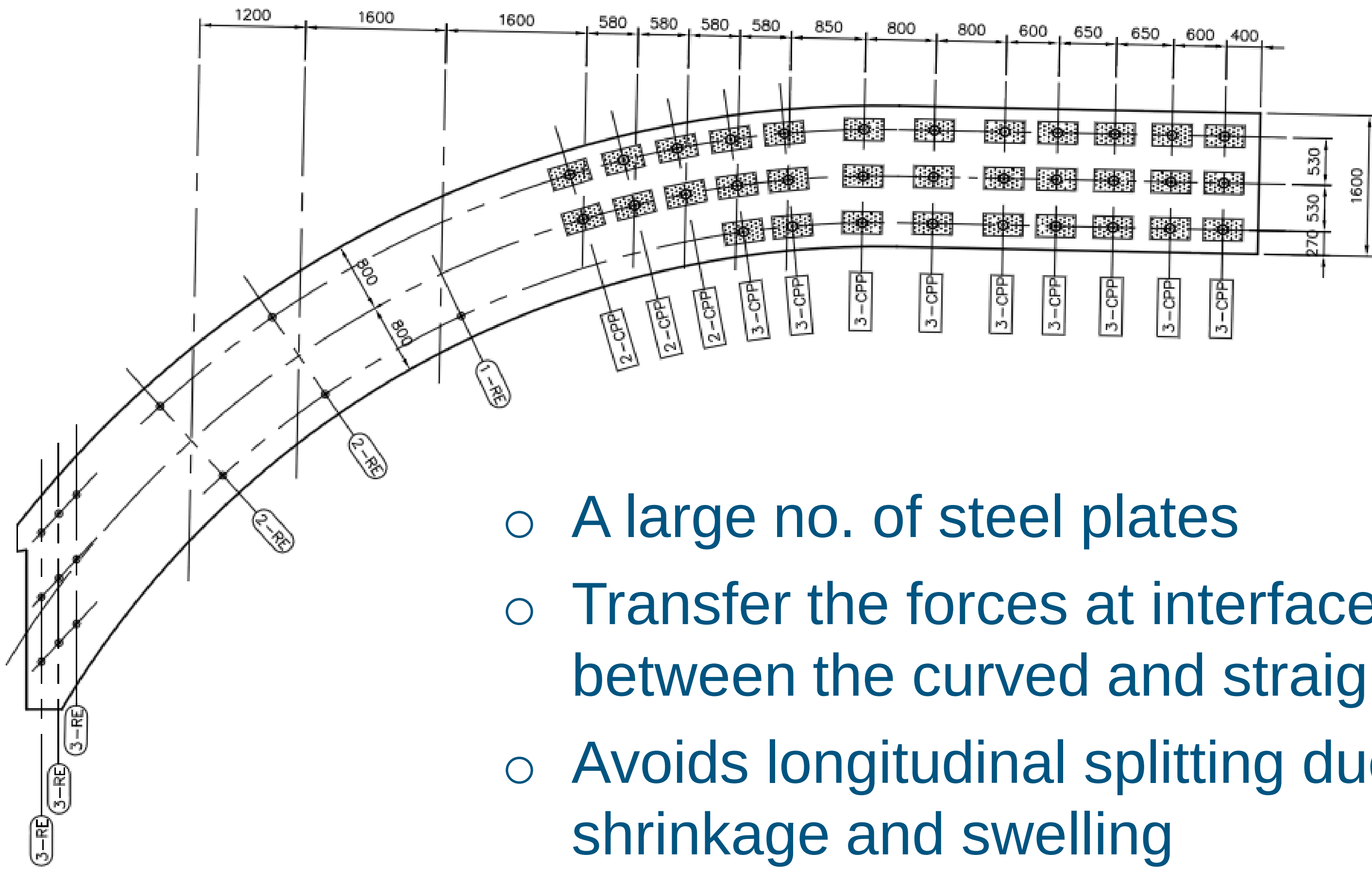


Steel plate with pin connection to concerte piers/abuttments

Construction Details

Construction Details

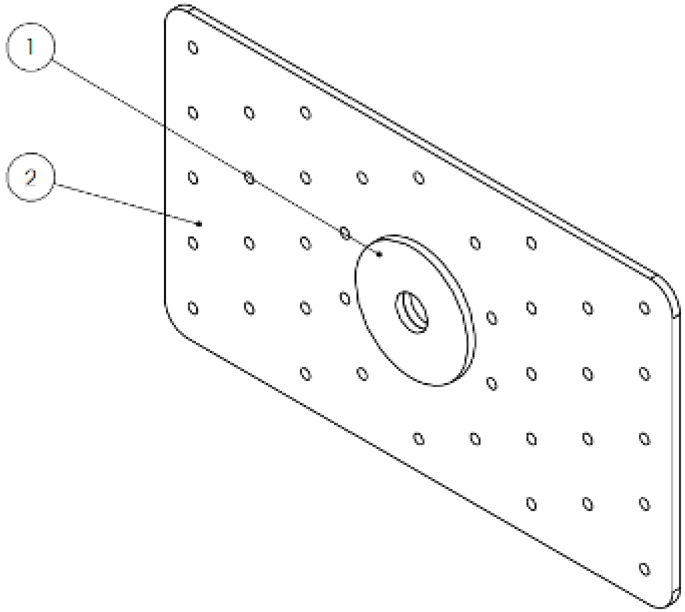
Splice Connections



- A large no. of steel plates
- Transfer the forces at interface between the curved and straight beams
- Avoids longitudinal splitting due to shrinkage and swelling

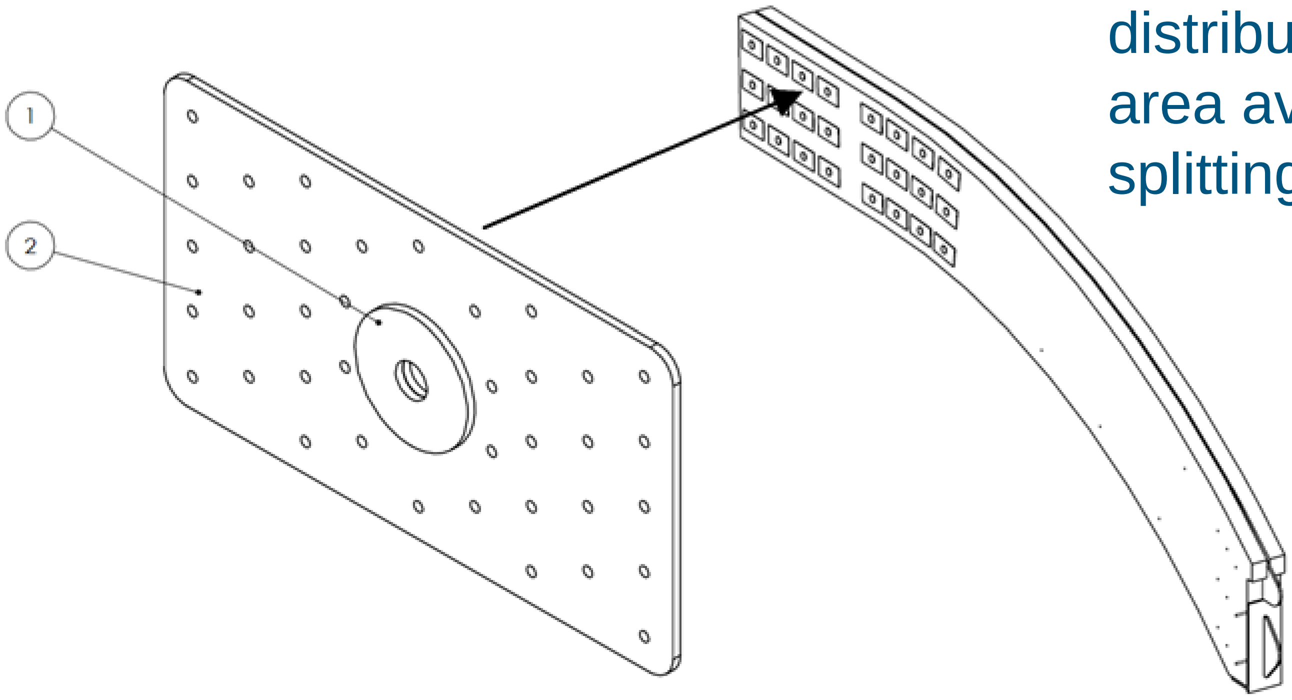
Construction Details

Splice connections with steel plates



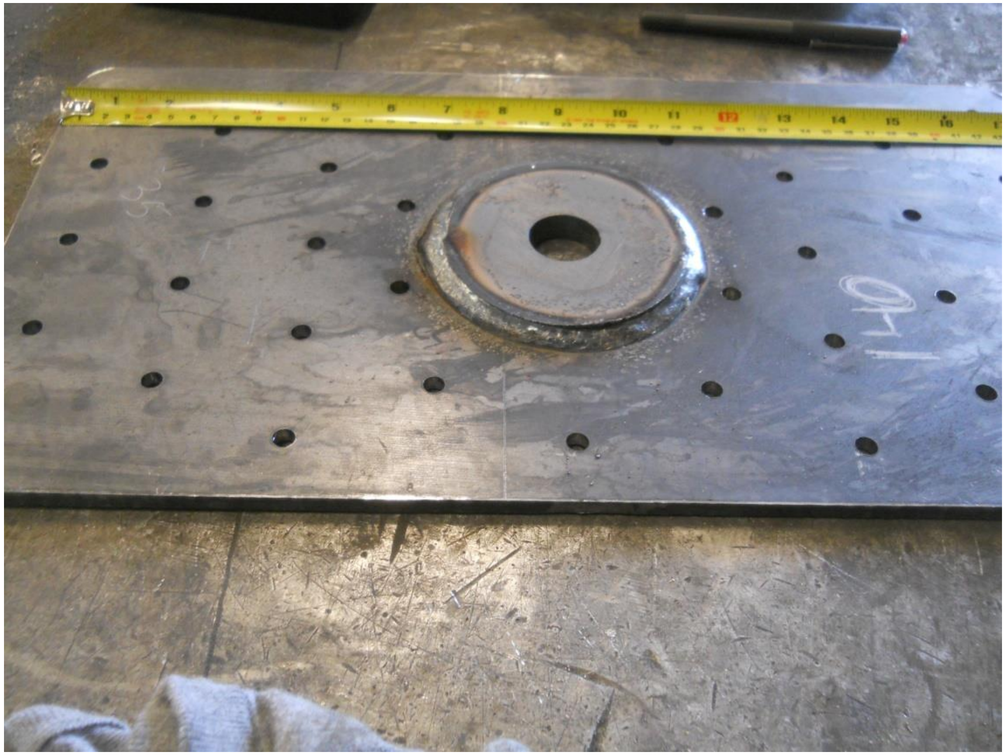
- Allows to develop ~ 70 kN in shear (all directions)
- Fixed with 38 ring nails of 6mm x 60mm
- Creates an air gap between wood beams

Hardware – Splice between Arch and Beam



By installing several plates like this, shear stresses are distributed over a larger area avoiding potential splitting

Hardware – Splice between Arch and Beam



4000 steel plates x 38 nails = 152,000 nails

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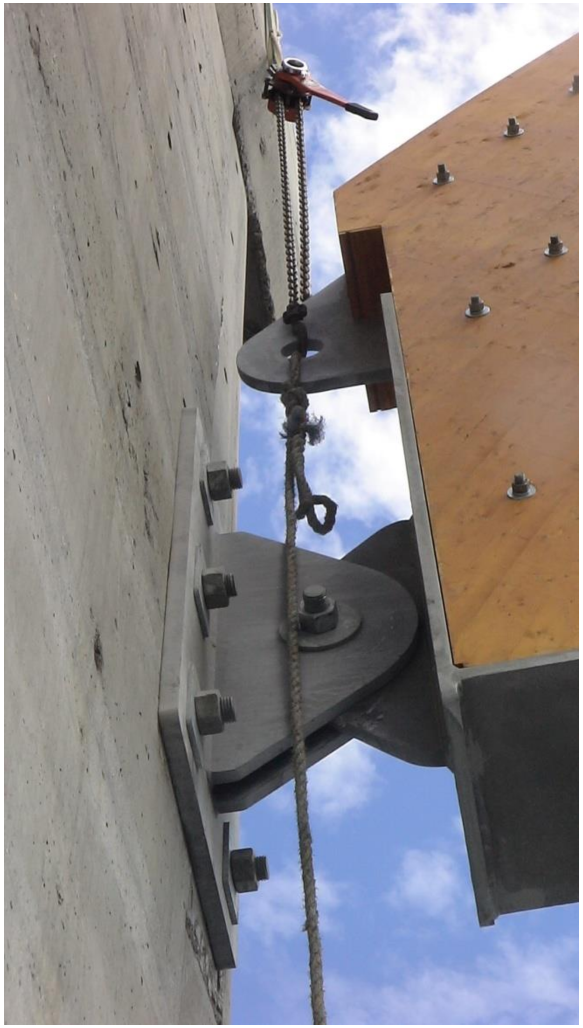
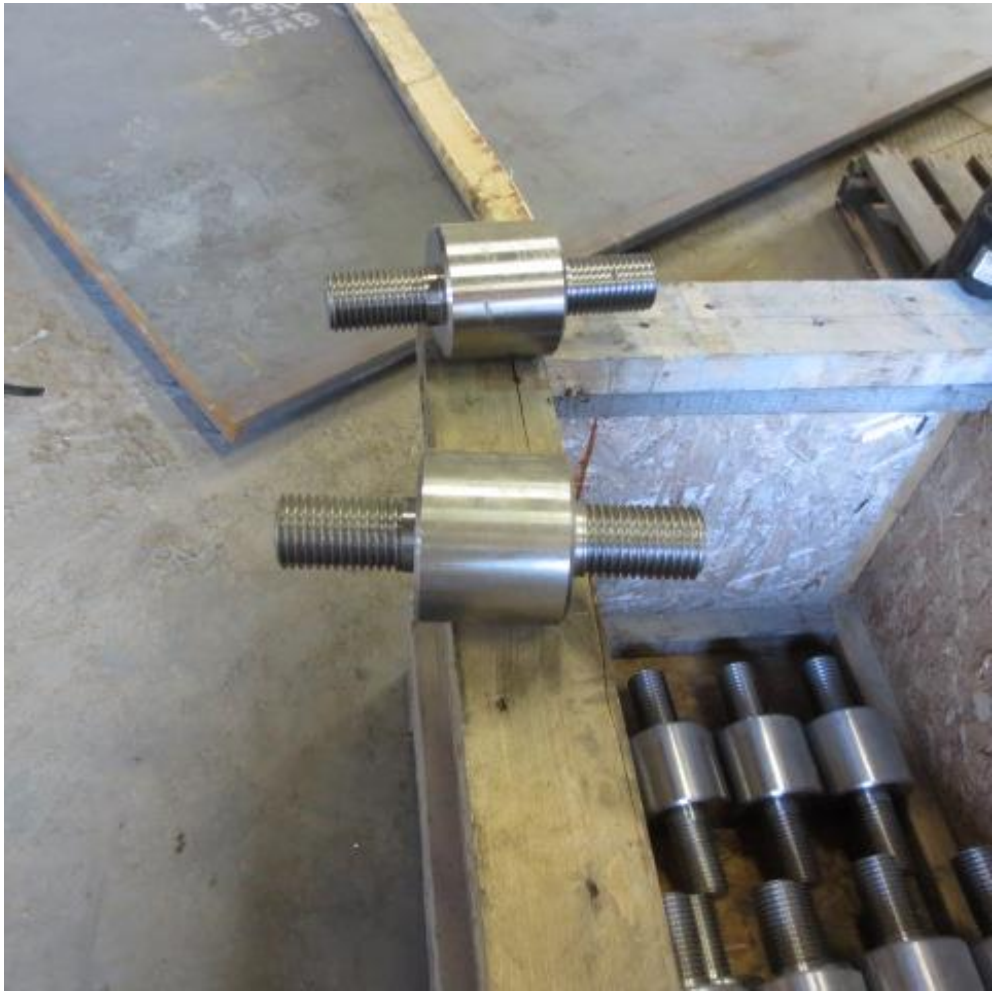
Hardware – Splice between Arch and Beam

Hardware – Pin Connection

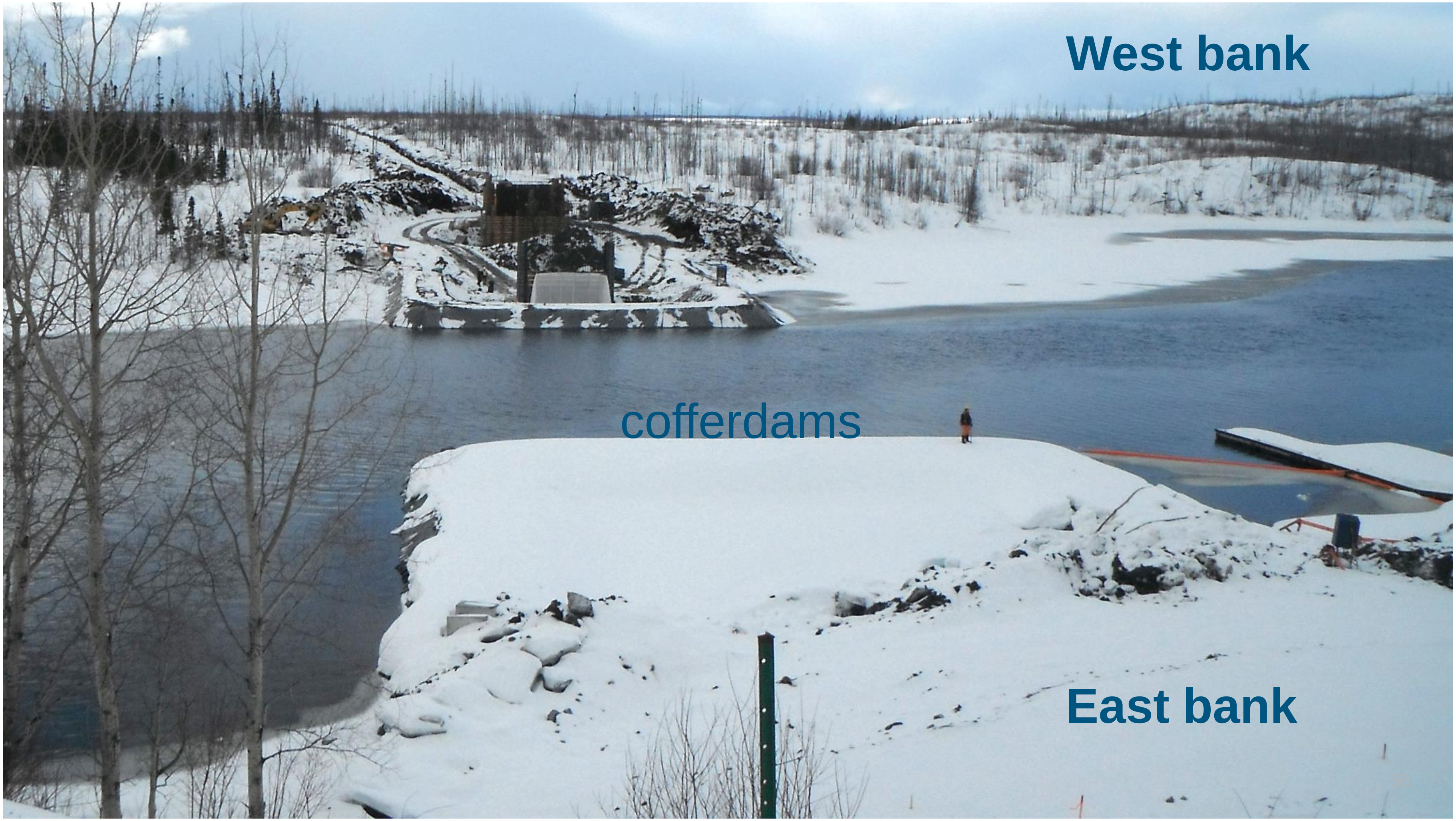




Hardware – Structural Bearing

Bearing of straight beams on piers and abutments

Foundations – Cofferdams



Cofferdam: Installation of the Steel Frame

Sonotubes and Pumping

Starting the Concrete Work

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Cutting and Removing the Cassion

Foundations - Casting Pier 2 (West)

Assembly of the Wooden Bridge Super Structure

Assembly of the Wooden Bridge Super Structure

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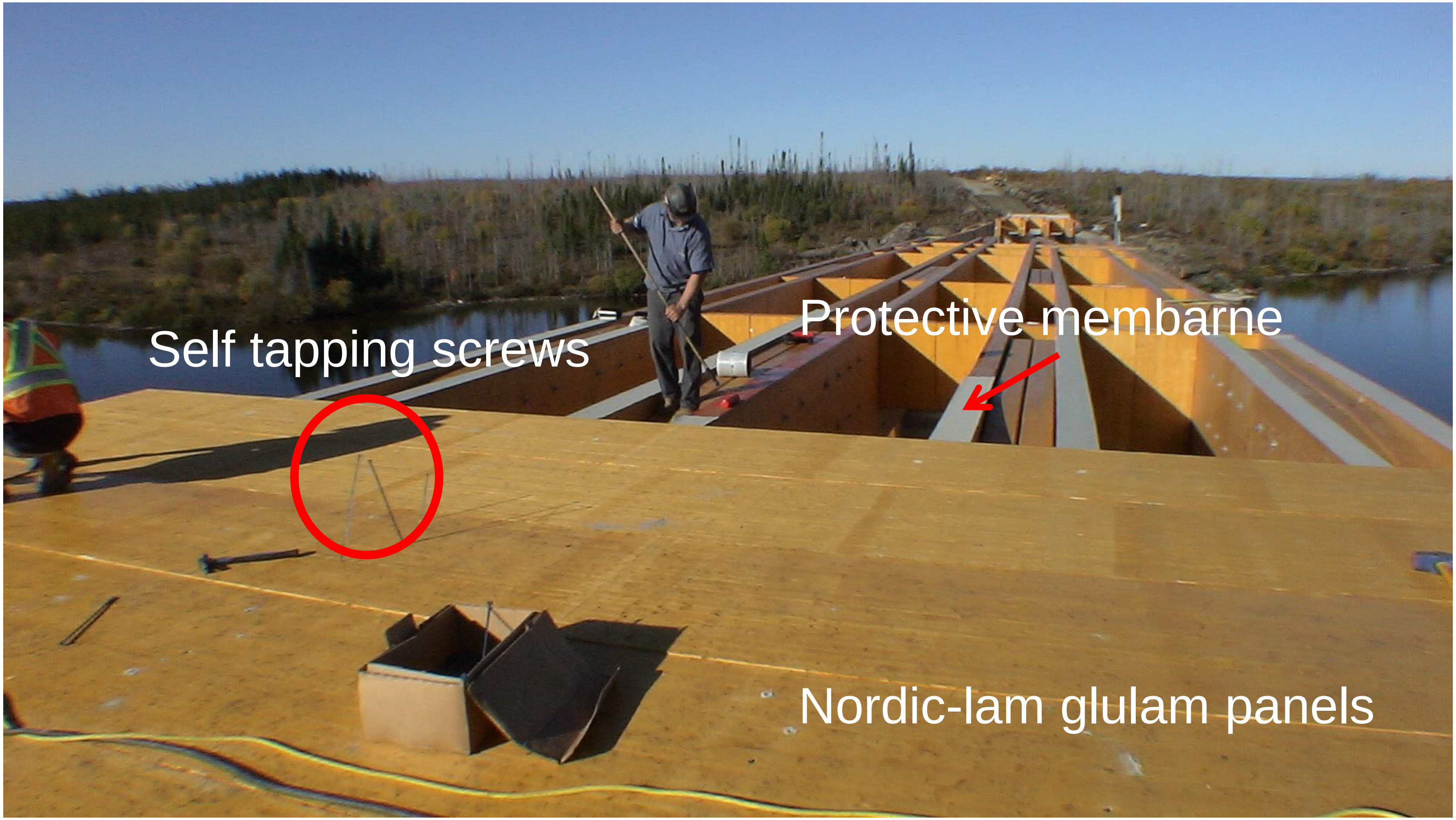
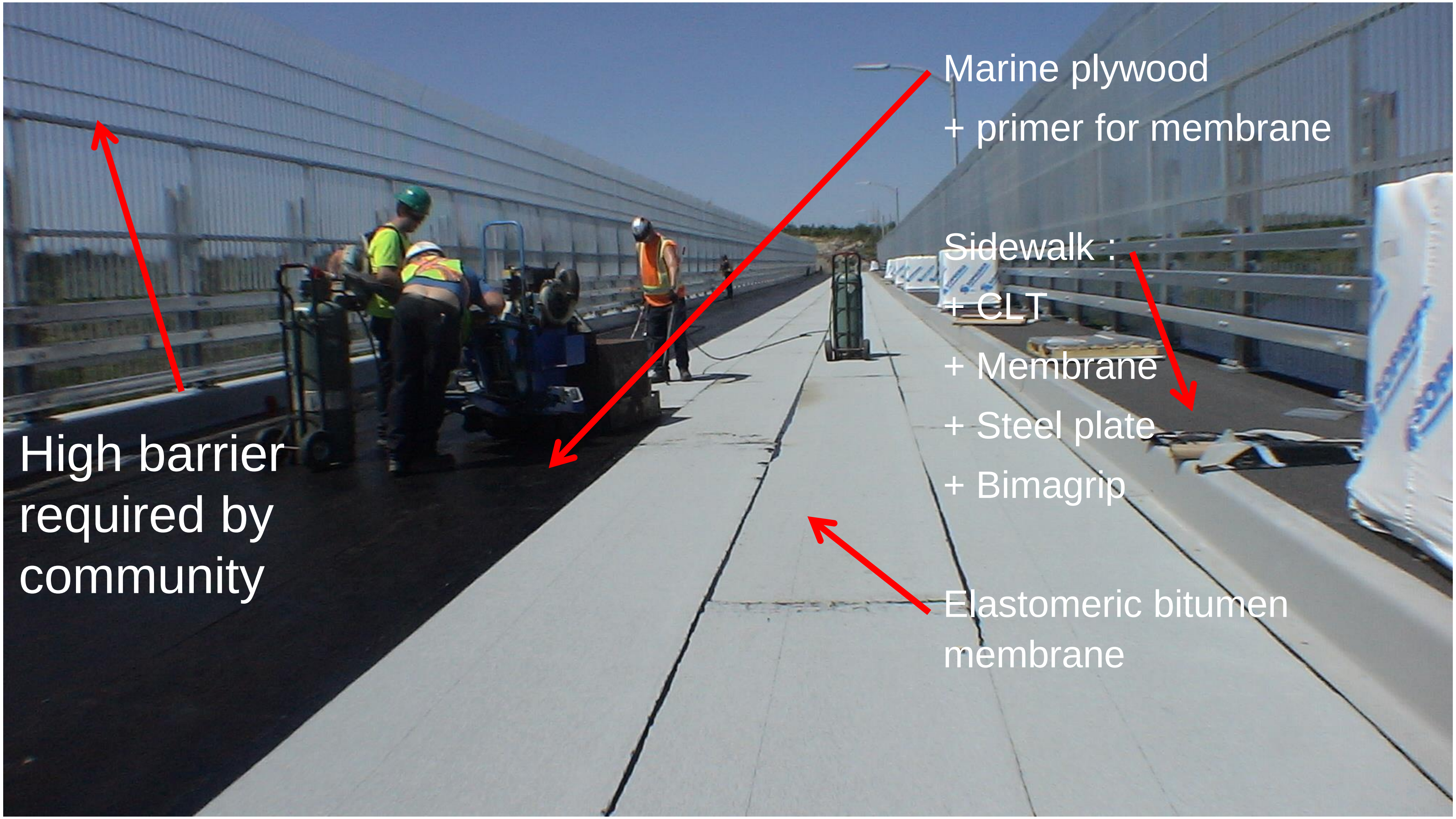
Assembly of the Wooden Bridge Super Structure

Installation of Glulam Deck



Protecting the Deck and Girders



Sidewalk, Curb, Membrane and Bimagrip

Fiberglas used to prevent water infiltration at the curb

Sidewalk, Curb, Membrane and Bimagrip

Final Assembly of the Wooden Bridge

Final Assembly of the Wooden Bridge

Final Assembly of the Wooden Bridge

Final Assembly of the Wooden Bridge

How many workers were involved in the construction of this bridge?

4

Including crane operator

Final Assembly of the Wooden Bridge

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Final Assembly of the Wooden Bridge

Final Assembly of the Wooden Bridge

Final Assembly of the Wooden Bridge

Final Assembly of the Wooden Bridge

Lessons Learnt

Strategy for the drilling…to change…

On-site drilled on each side

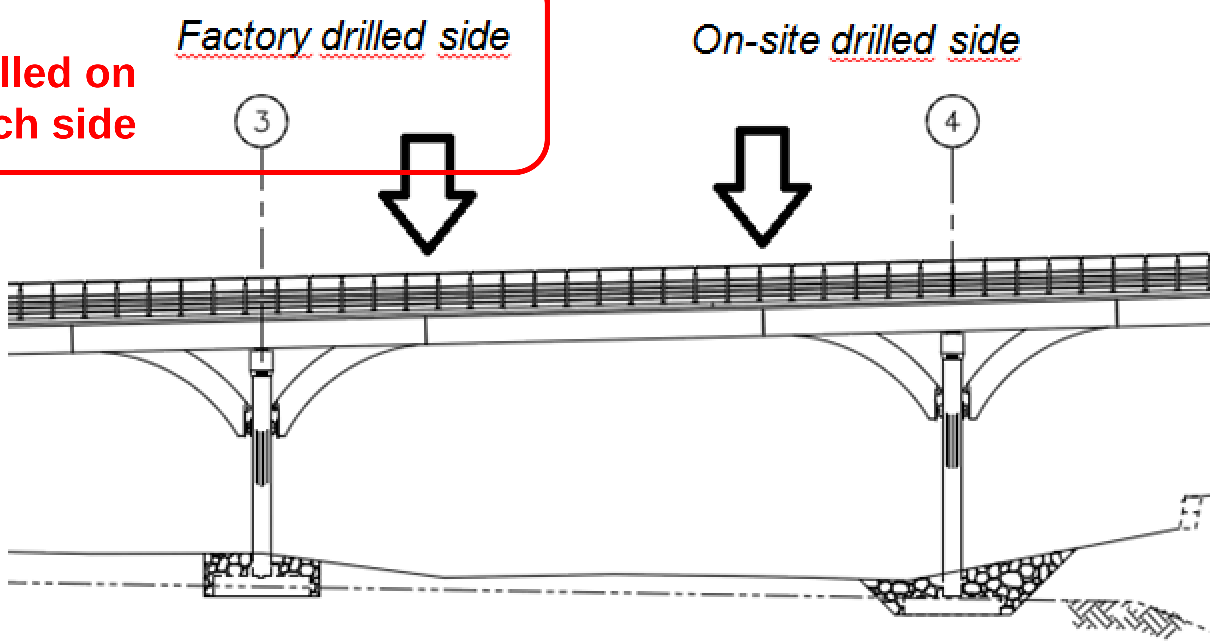
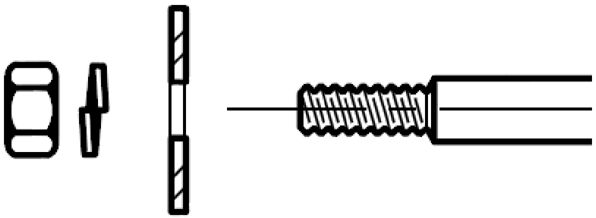


Figure 5: Pre-drilled and on-site drilled connectors

Lessons Learn

Change Torpedo's profile.. Didn't work well. Got jammed!



Lessons Learnt

Better tolerances…

Diameter of the steel bar is 25.4 mm (1 in):

+ Holes in steel plate was 28 mm change by 29 mm;
+ Holes in wood was 29 mm, keep the same value;

Statistics

Quantity of construction materials used in the bridge:

Foundation

+ 1200 m^3 of concerte
+ 100 tonnes of steel reinforcement

Bridge Super Structure

+ 4000 steel plates, 152,000 nails
+ 900 m^3 of glulam beams/girders
+ 300 m^3 of glulam panels
+ 70 m^3 de CLT sidewalk
+ Total of 1270 m^3 of wood
+ 20 Dowels
+ 2200 threaded rods
+ 6800 SFS Blue Max 15”

Total Final Cost: $8.7 M CAN (0$ extra!!!)

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