Nuuk Lufthavn

74% CO2 besparelse ved skift til stål på Nuuk Lufthavn

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RAMBOLL Bright ideas. Sustainable change.

Agenda

- Introduction (MON)
- Design of the bridge (MPP)
- Challenges (MPP)
- Erection (MPP)
- Material and CO_2 savings (MON)
- Conclusion (MPP-MON)

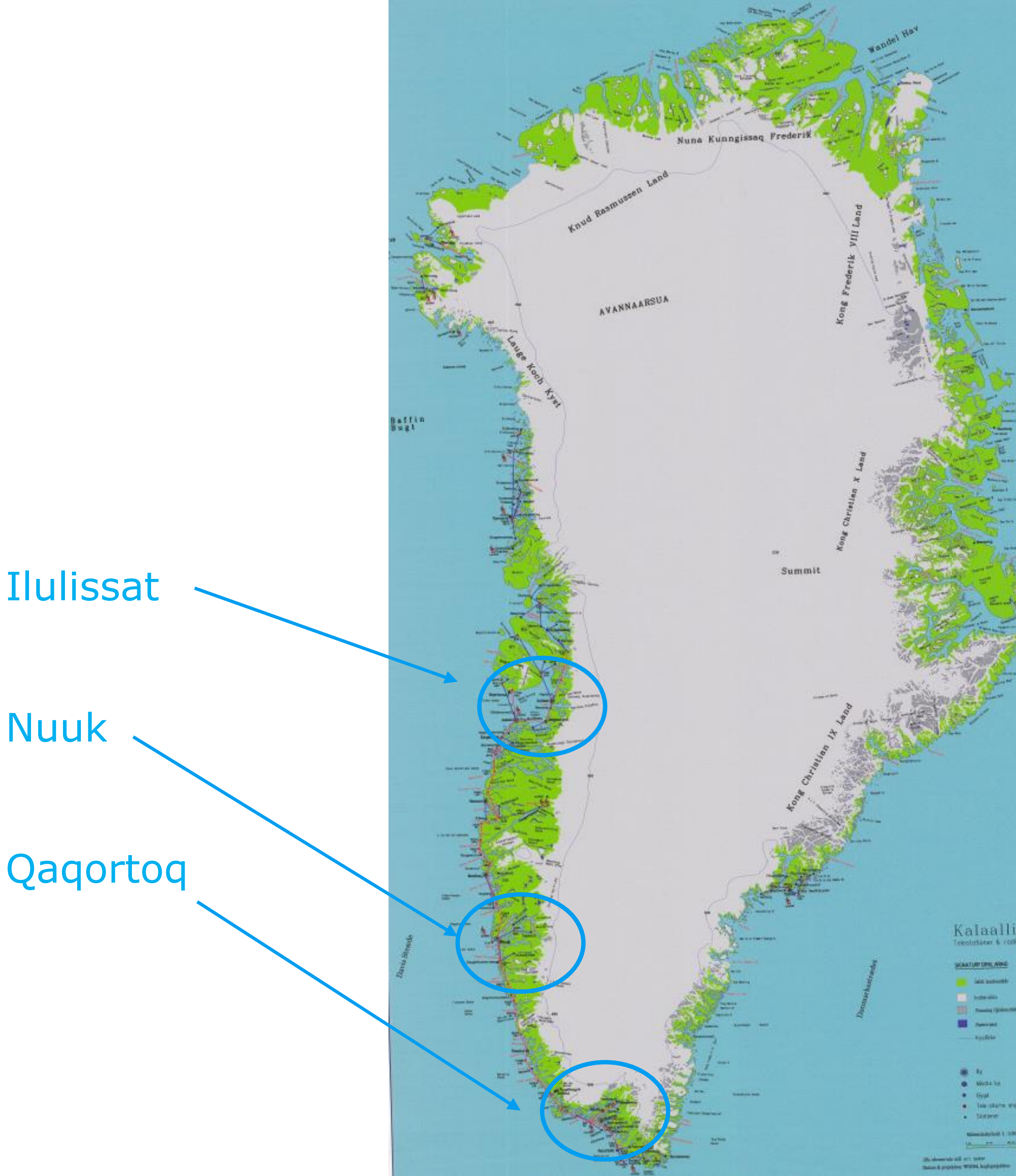
Introduction

Description of the expansion of Nuuk airports

The expansion of the Nuuk airport involves:

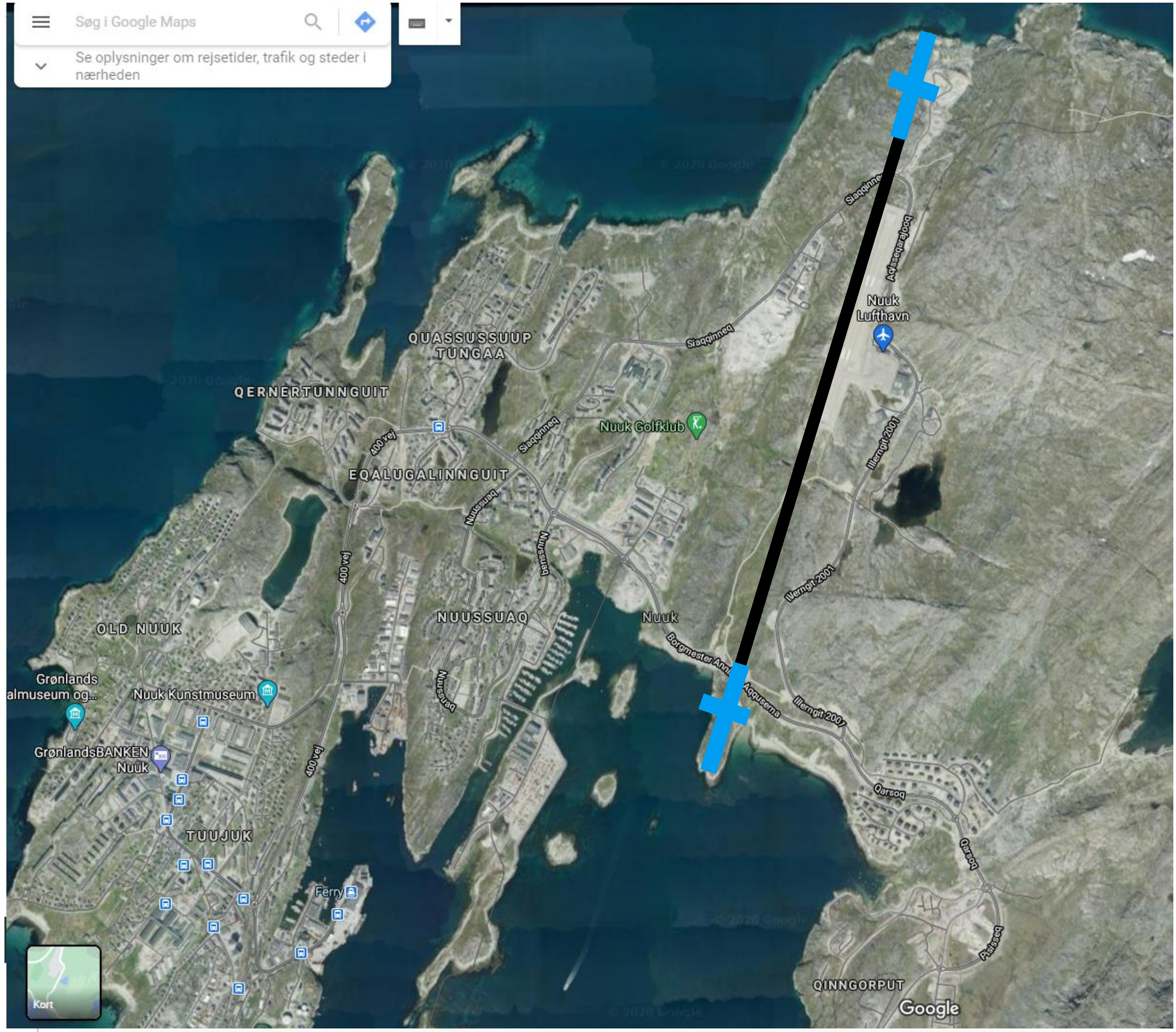
- extension of the runway from 950 m to 2200 m - incl blasting about 6 million m^3 rock.
- 2 new 260 m long bridges for approach lights
- rerouting of and connection to access roads from Nuuk city
- parking in the terminal area
- earthworks for cabling within the railway and terminal area
- water and sewer pipeline
- rerouting of raw water pipeline
- fencing of the airport.

The airports in Nuuk, Ilulissat and Qaqortoq opens 2025 at the latest and costs around 3600 mDKK



Involved parties in the Nuuk bridges

- Owner — KAIR
- Main contractor — Munck
- Steel contractor — Assentoft Silo
- Lights — Strøm Hansen
- Architect — Gottlieb Paludan Architects
- Engineer — Ramboll



Ramboll has helped with:

- Assentoft Silo (steel contractor): Manufacture and assembly

Ramboll: Design and working drawing

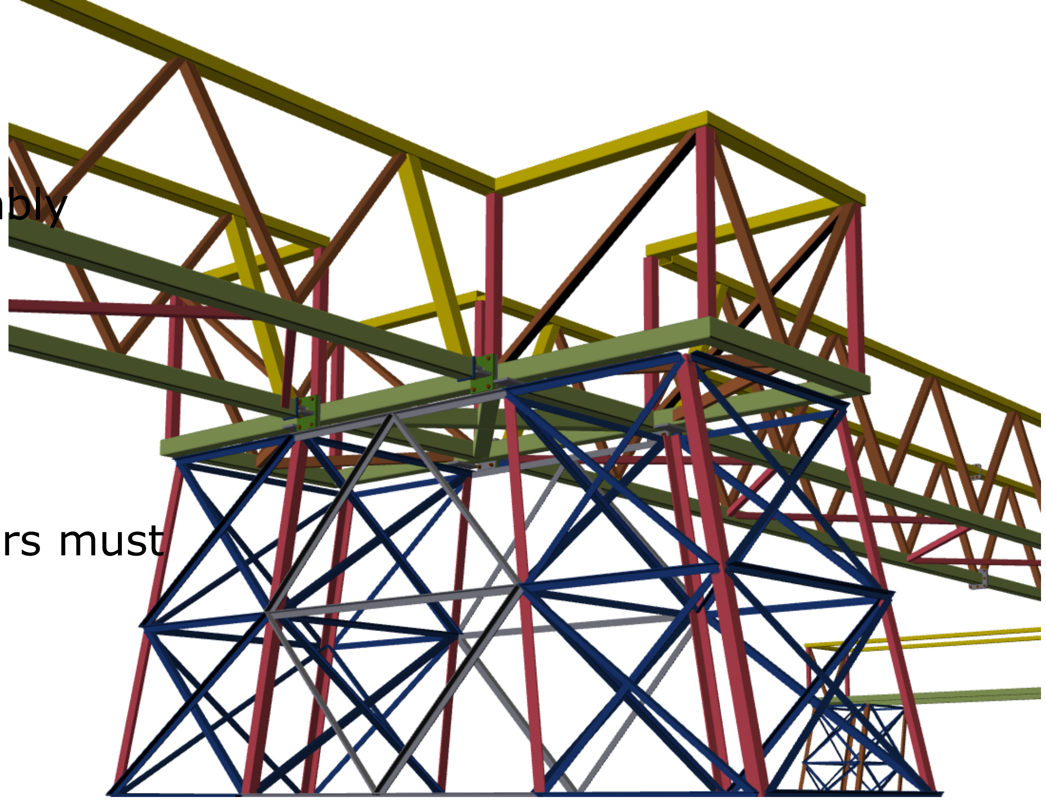
Munck (main contractor): Foundations

Ramboll: Design

Time schedule:

Drawings and casting parts for foundation for land fasteners must be ready for casting 2021-04-01!

The rest might just be ready in 2022!



Significant deficiencies in the Client's material

The client's consultant has stated that the masts must be breakable and at least 12m high - a statement that the developer later withdrew after the contract with the contractor was concluded.

According to the ICAO Aerodrome Design Manual, Part 6, Section 1.3.2 (b), the requirement for frangible masts and fracture joints is not a necessity in this project.

The reason is that the masts with approach lights are no higher than the runway embankment "where a supporting structure is surrounded by non-frangible objects, only that part of the structure that extends above the surrounding objects should be frangible".

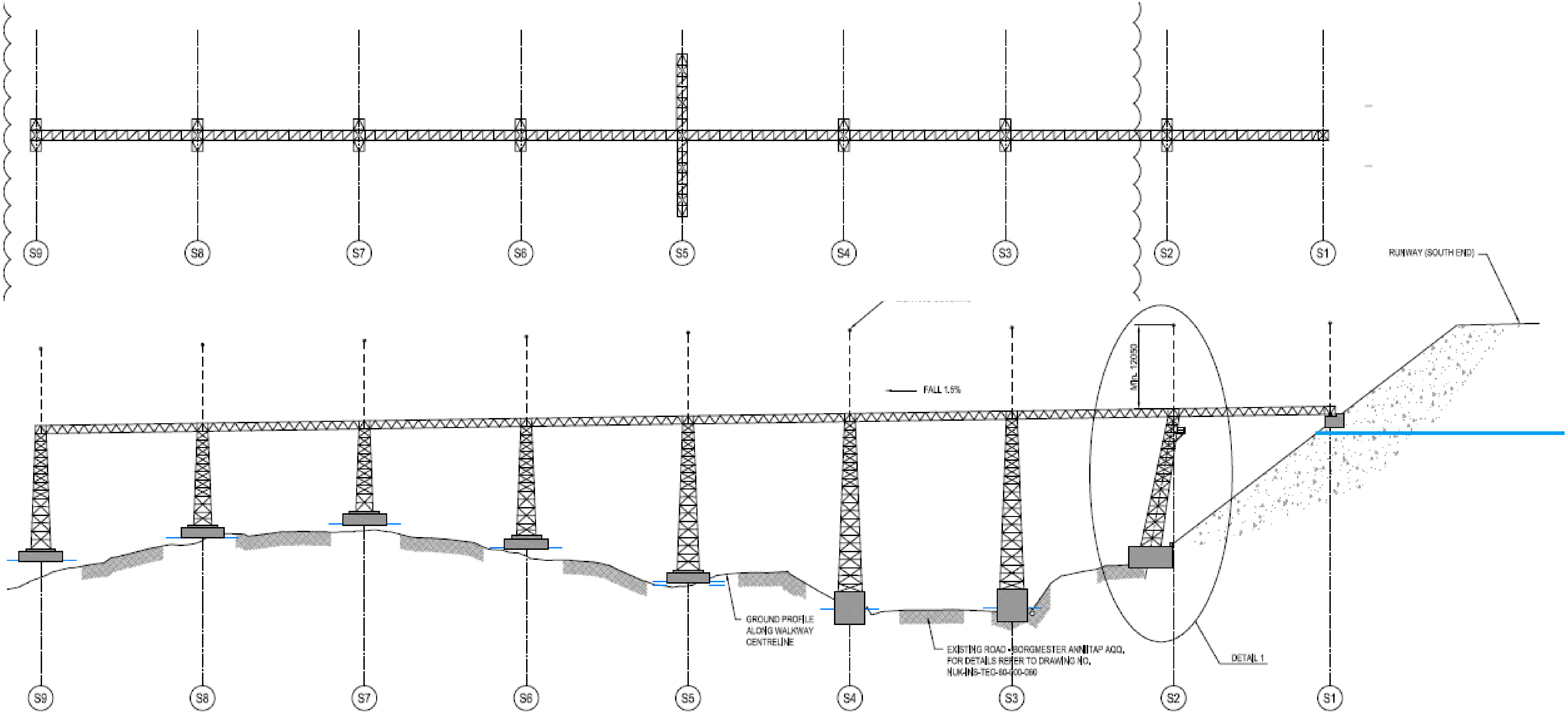
Rock anchors are normally used in Greenland – the client's consultant does not use this to the full extent!

The principle of foundations is unnecessarily expensive, as they do not take advantage of the fact that there is good Rock and can thus use Rock anchors.

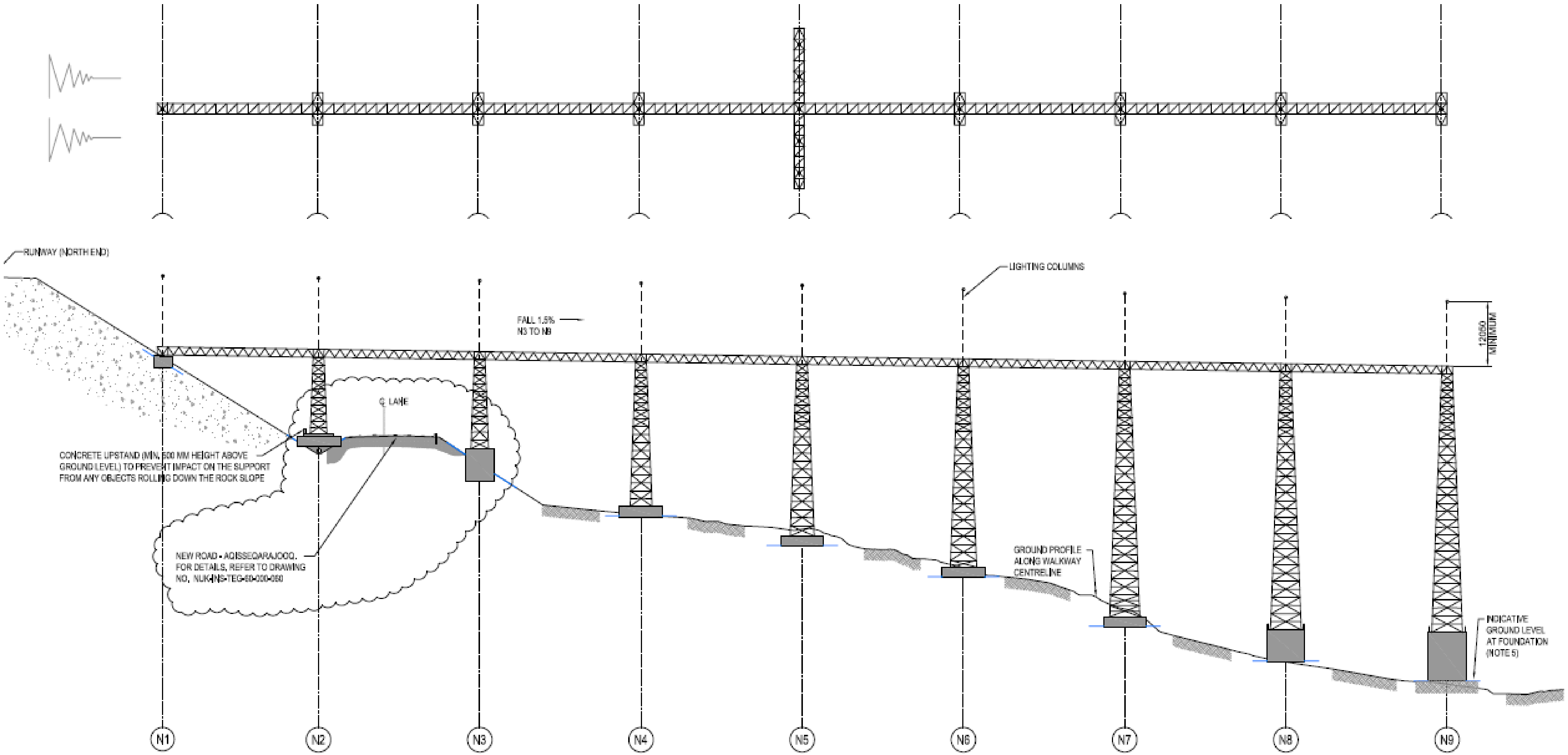
This will save over 6000 m3 of high-quality concrete (C30 - according to Greenlandic conditions) with a value of approx. 50 mDKK.

Photos from February 2021

The client: the south bridge

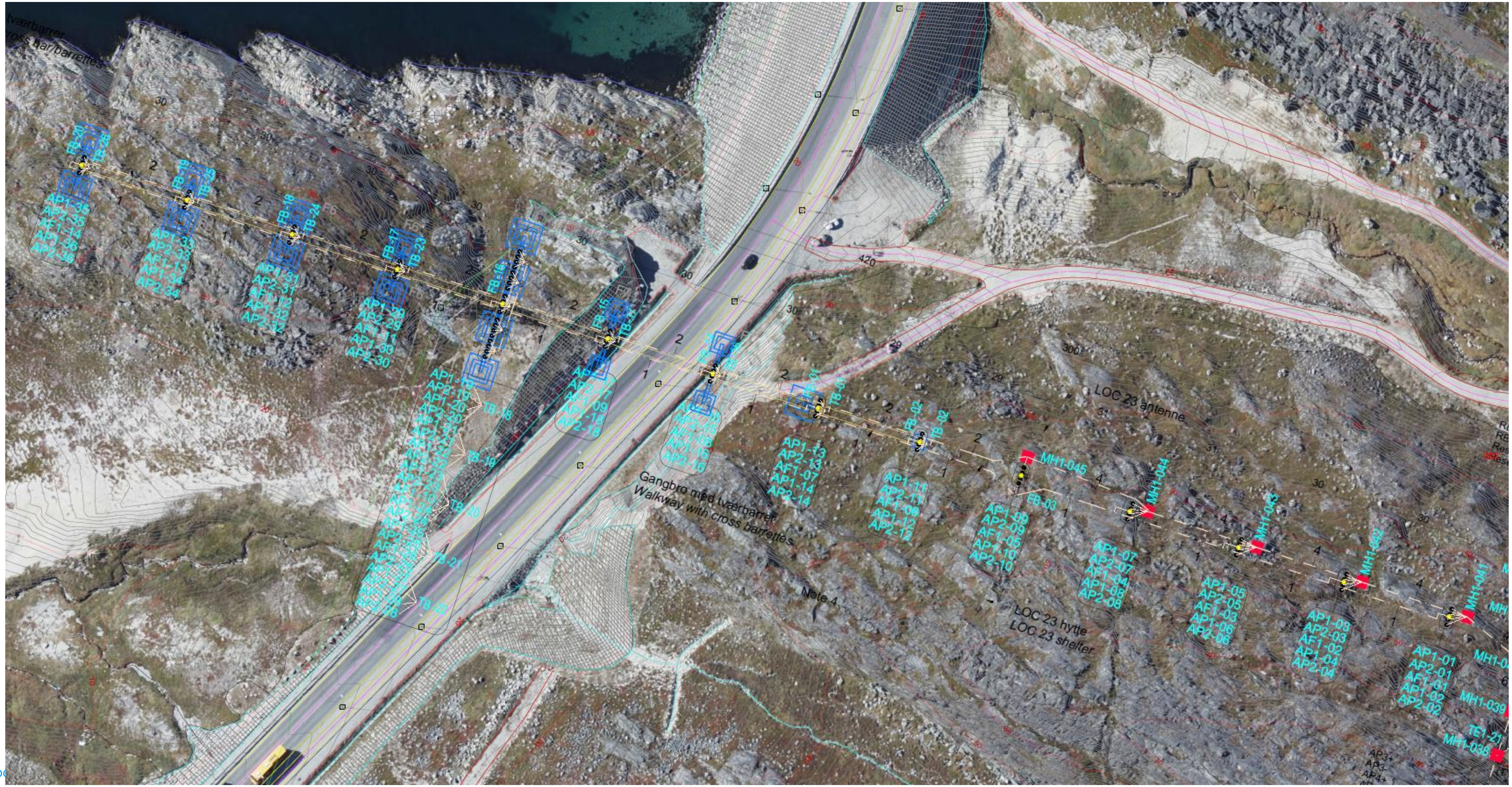


The Builder: North Bridge

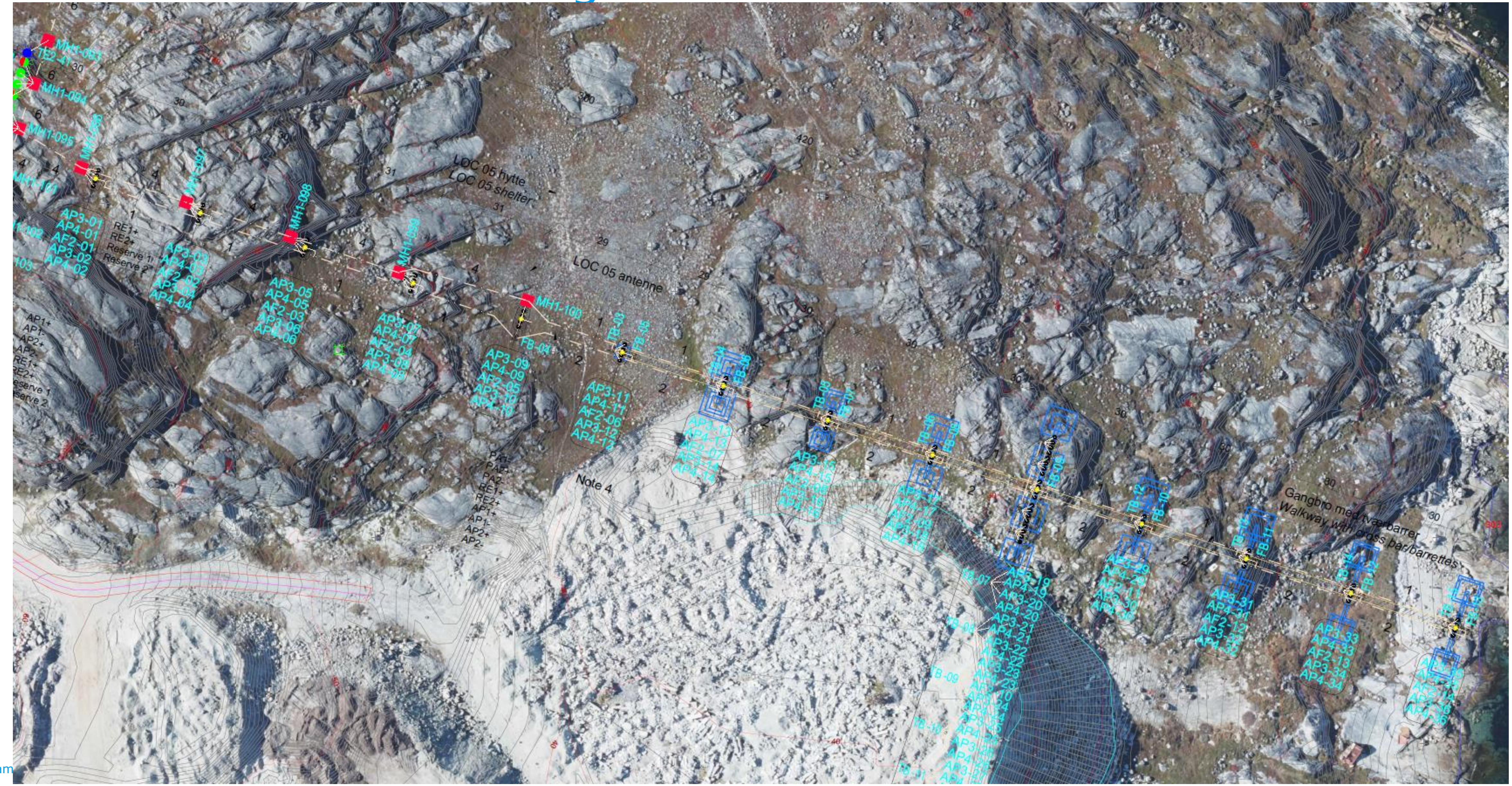


ELEVATION (FOUNDATIONS SHOWN FOR EAST SIDE)
SCALE 1:500

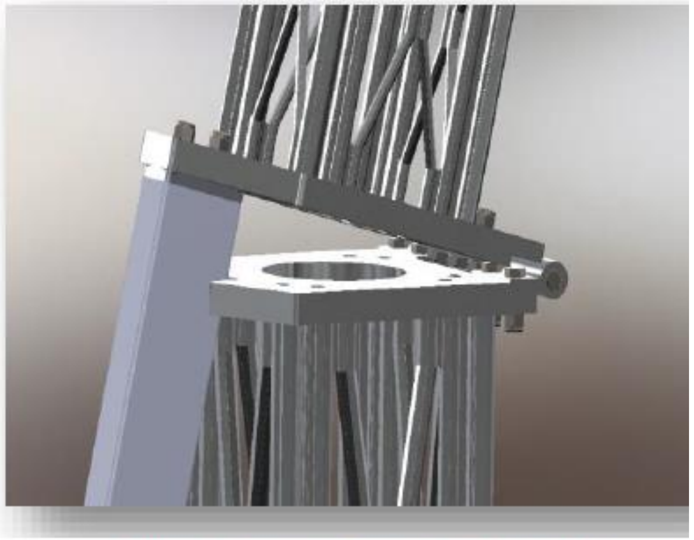
The area – South Bridge



The area – North Bridge

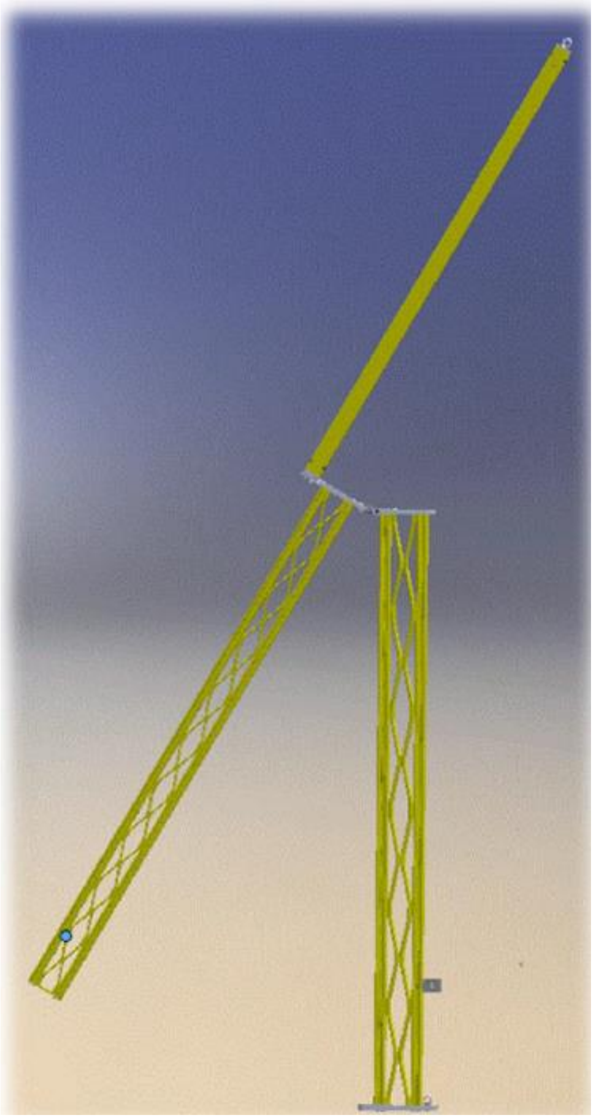


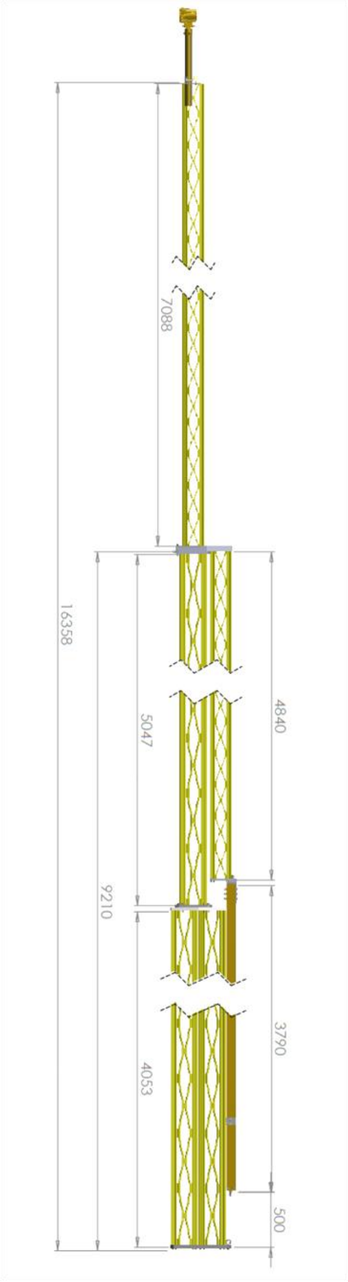
Folding frangible light masts up to 16.9 m



7 Hinged connection plate (4S to 4M)

Masts are also breakable,
Although it is not a
requirement





Flash lys ikke vist

Challenges and Solutions

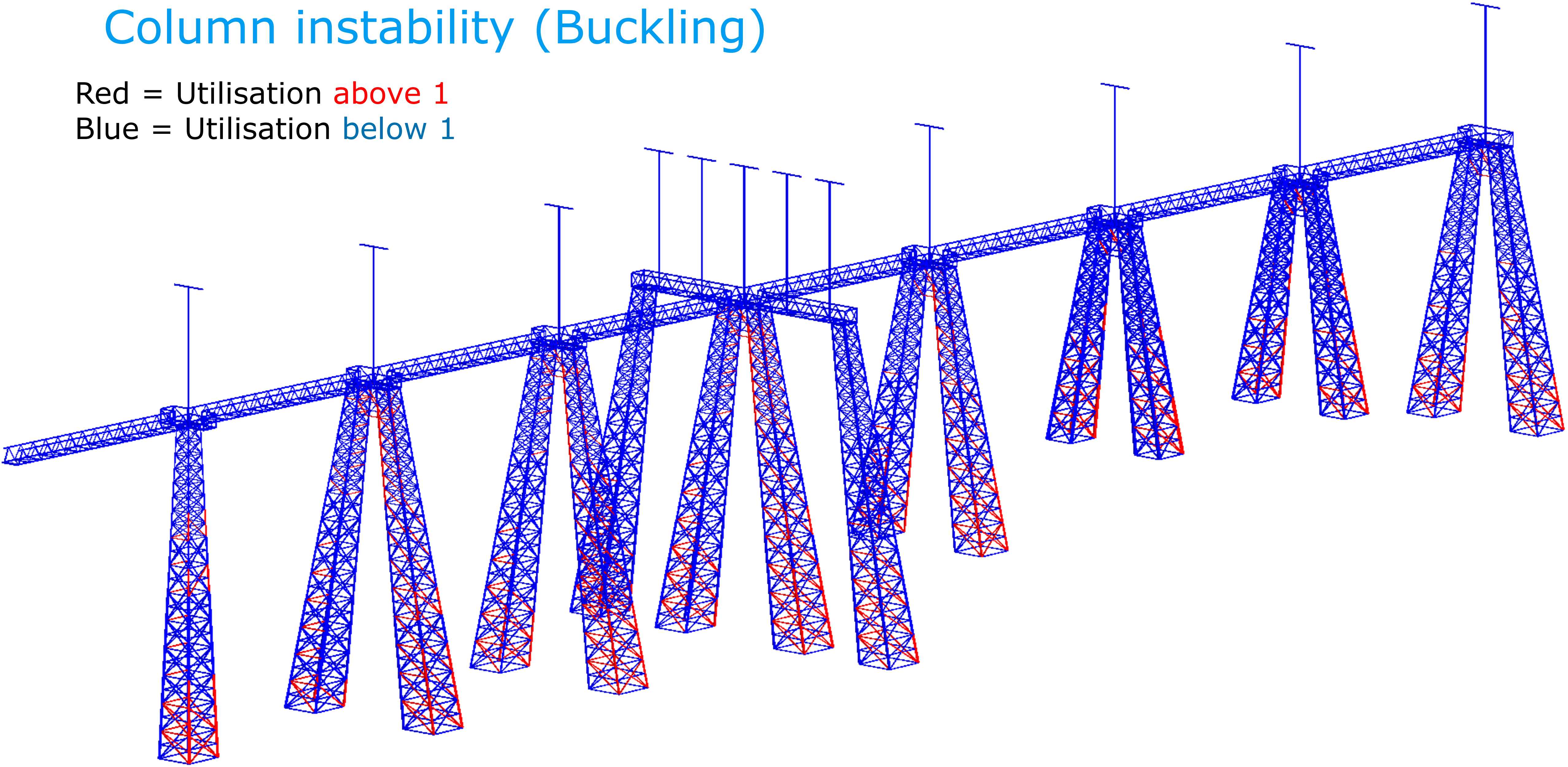
1	This is not sustainable design. Among other things, because too much concrete is used, which is also difficult to obtain in Greenland!	Both: A more sustainable design with Rock anchors.
2	A It is difficult to get frangible masts that can withstand a design wind speed of 288 km/h (83 m/s) and 5 cm of ice. B The approach lights must be correctly oriented. It can be problematic to place them in the right end setting when the mast is folded.	Both: The bridges are designed so high that the lights can be placed and serviced directly from the bridge.
3	Varying height of frangible light masts, whereby the developer gets light masts that are unnecessarily high (up to 16.9m), and thus the lights are difficult to maintain.	South: The South Bridge is lifted
4	Foundations for S3 and S4 should be placed at the edge of the road's snow layoff zone. The large block foundations can be a danger to traffic - especially in winter when there is slippery and a lot of snow, so you can drive into them while they are hidden in the snow.	South: Change the design so that single masts are used, and they are not placed directly under the light masts.
5	Foundations and masts are clear ‘ugly' and have been debated in the press.	The masts are placed on top of the Rock and open up to the visual gate.
6	There is a risk of ice fallout. According to the ISO standard in this area, the ice falls as far away from the summit horizontally as the height above ground (up to 45^{o}). It can be fatal - especially when it is the worst ice class used here. It is not acceptable for the road to be closed.	Both: It may be necessary to create a tunnel that can protect the cars. Tele Greenland has done something similar at their radio chain station Sanderson Hope (SAHO). Alternatively, a meteorological warning system can be introduced (Telenor Infra has a similar meteorological warning system near a television mast near Oslo)

Challenges and Solutions

7	Masts and foundations for N9 are located at sea edge (3-5m tide). This causes problems with the durability of concrete and the bottom of the steel mast. The mast foundation is affected by the ice foot in the intertidal zone, whereby a large chunk of sea ice can form in winter.	North: The outer mast is removed and the design of the bridge is changed with a cantilevered part.
8	It is difficult to get more approx. 6000 m^3 of concrete delivered to the site in quality C30, as the concrete plant in Nuuk is normally only allowed to deliver quality C15 and the stated quantities are extreme according to Greenlandic conditions (approx. 800 concrete trucks in total – there are no concrete cannons in Greenland). The project may be delayed due to delayed deliveries Large concrete foundations are usually not accepted in the open nature in Greenland (Large freestanding concrete foundations have not been accepted on the high voltage lines in Greenland)	Both: Masts are designed with uneven leg lengths and single foundations with Rock anchors. A solution normally used in Greenland.
9	Mast S2 stands at an angle and is partly grounded in filling	South: The mast is moved further away from the runway so that it stands vertically and stands on the Rock.
10	1.2 km ladders with fall protection and rest platforms must be inspected and maintained (If they were in Denmark, they had to be inspected every year). It is not immediately possible to get around all corners of the masts - despite the ladders (e.g. when maintaining the masts).	Both: The mast can be maintained without ladders by rappelling down from the bridge instead of using ladders - this allows all corners to be reached.
11	At the northern bridge there is an iron dump, which is located in a natural gorge. The current extent of the iron dump is not known.	North: Map the iron dump with depth down to sustainable layer.

Utilisation in tower profiles: Column instability (Buckling)

Red = Utilisation above 1
Blue = Utilisation below 1

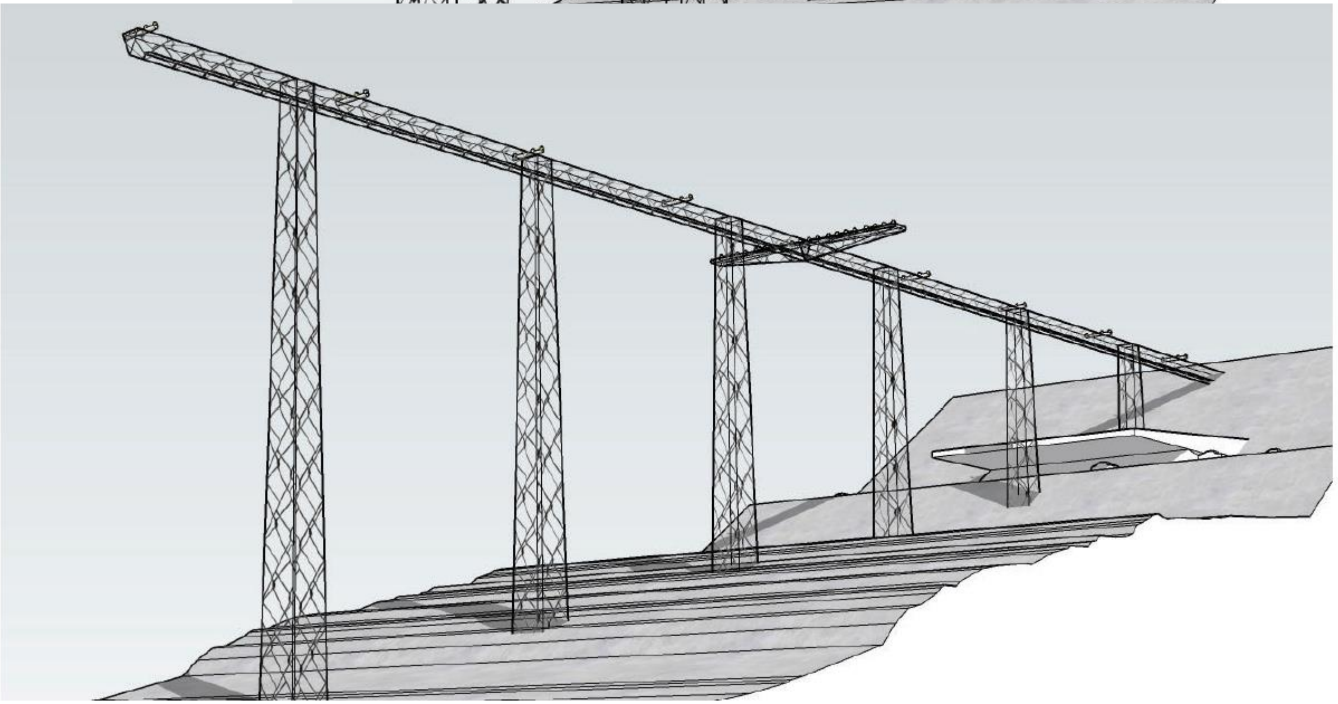


Result of architectural competitions

Idea:

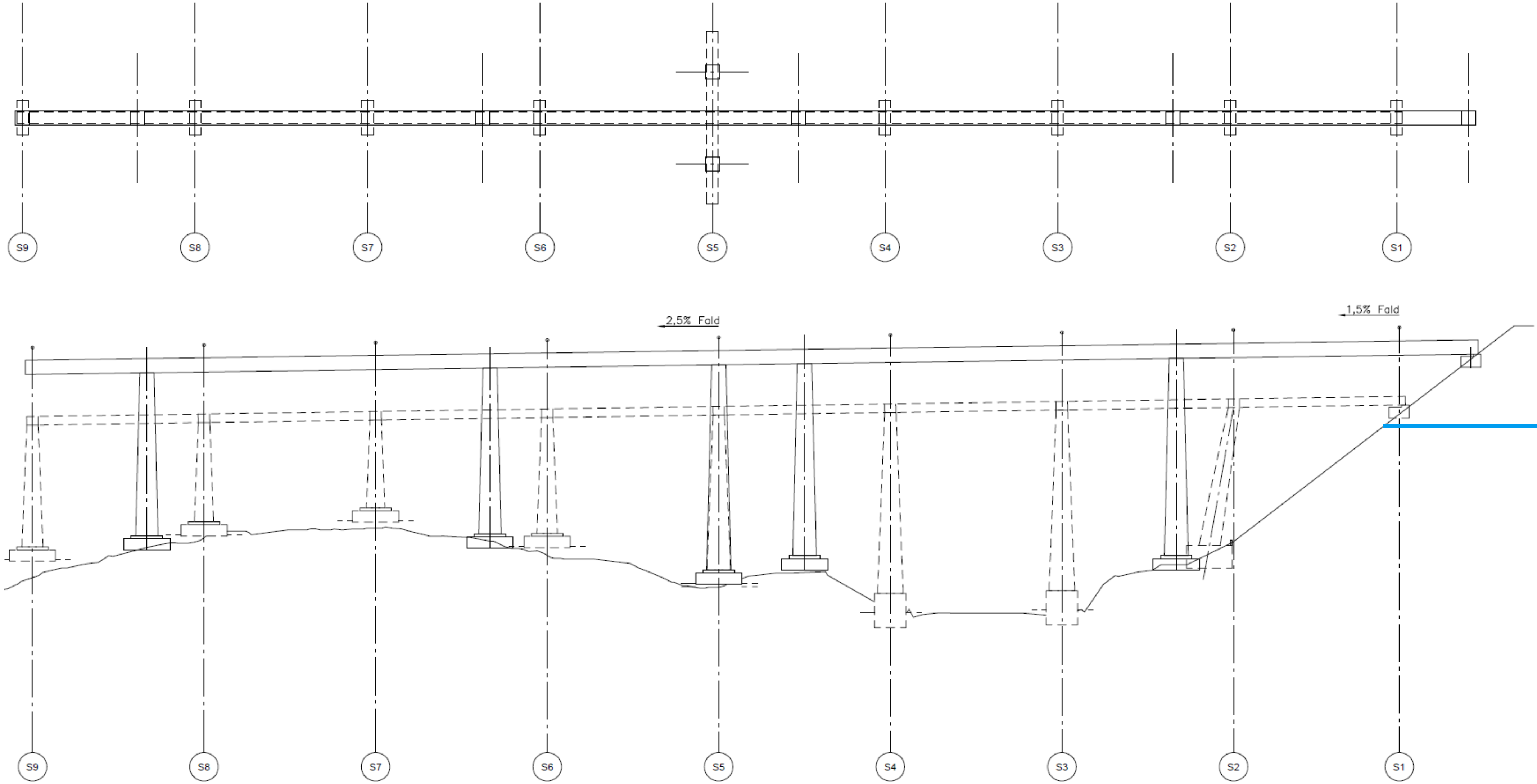
- Reduce the number of towers from 15 to 6
- Less members in the towers
- Move the bridge deck higher to remove frangible masts
- Cross-bridge do not need support

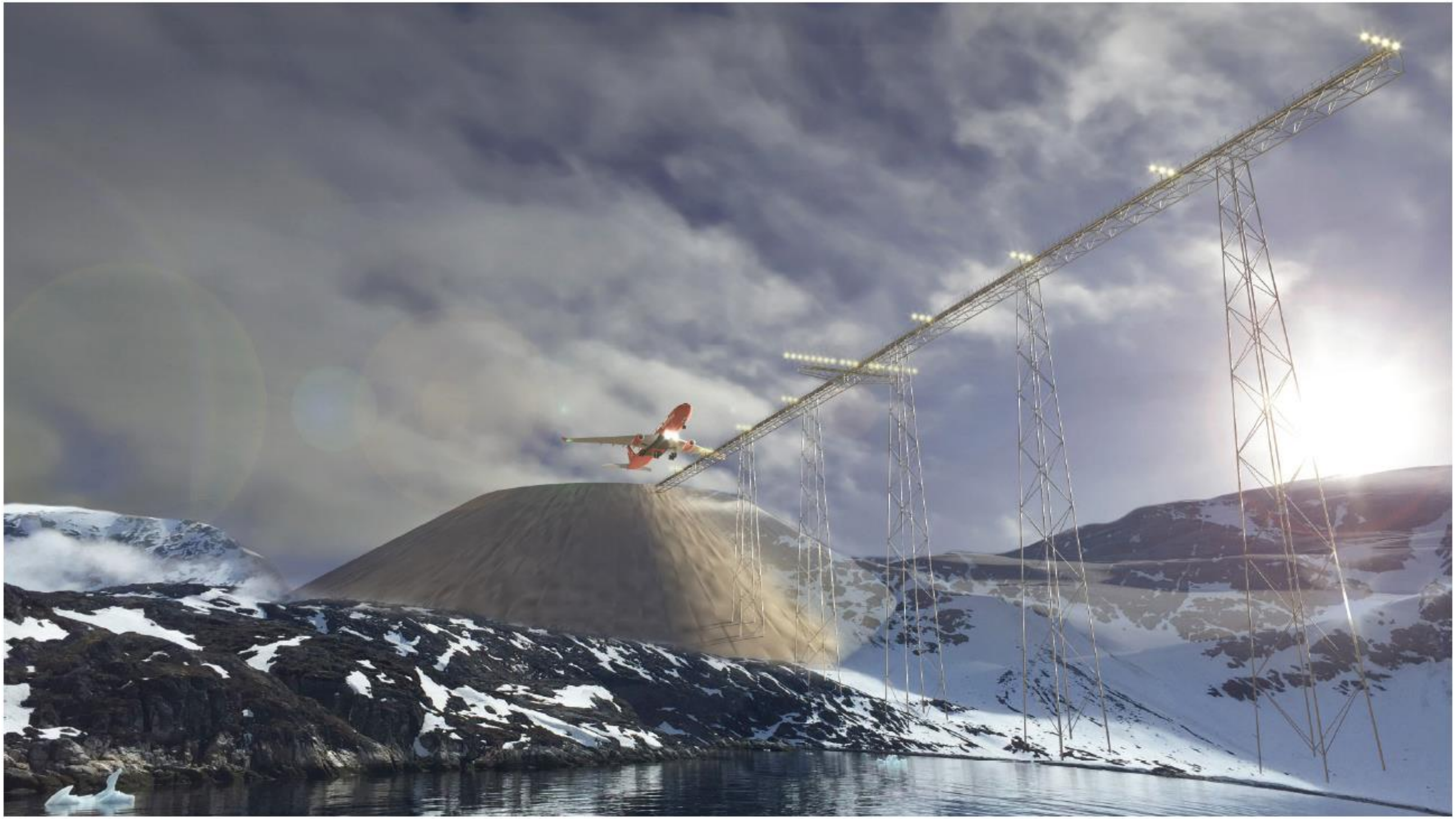
GOTTLIEB PALUDAN ARCHITECTS



GOTTLIEB PALUDAN ARCHITECTS

Ramboll: South Bridge





Design of the Bridge

Design Requirement

Ultimate Limit State (ULS) (50 years):

- Basis wind: 40 m/s (Gust wind at level 65 m: 288 km/h or 80 m/s).
- Ice: 30mm, density 900 kg/m^3.
- The wind speed is based on site specific wind analysis including directional factors and orographic factors.

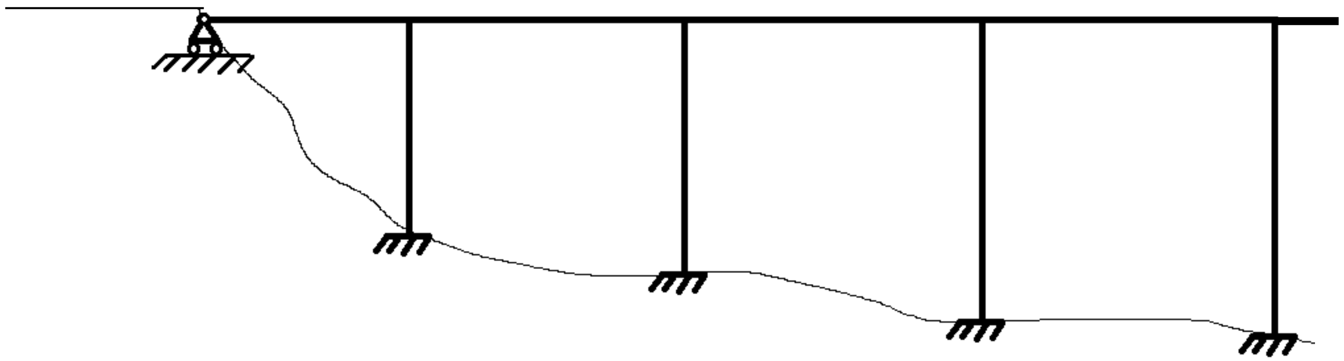
Service Limit State (SLS):

- Requirements of "ICAO, Aerodrome Design Manual, Part 6: Frangibility" for maximum rotation of approach lights:
  - 2^o on vertical axis.
  - 5^o on horizontal axis.

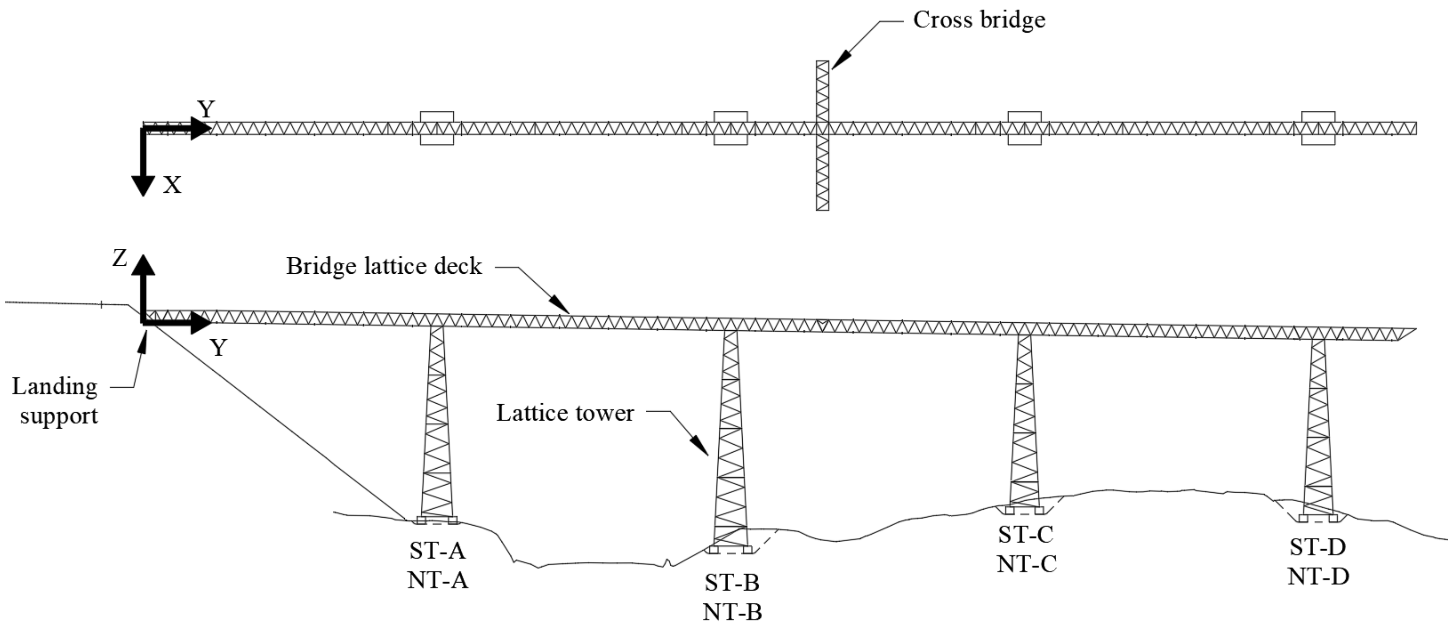
Ramboll Proposal: Static model

A. Walkway is placed on top of a load-bearing bridge
B. A load-bearing bridge (width approx. 2.5 m) is placed supported by masts
C. Stand-alone masts with 4 corner irons support the bridge
D. Land fasteners are placed on a slope with backfill and absorb vertical forces – as well as horizontal forces perpendicular to the bridge
E. Plinths with Rock anchors are used under each corner iron
F. The lengths of corner irons are adapted to the current geometric conditions
G. Lights are placed directly on handrails and a swingarm so that the lights can be serviced directly from the bridge
H. All parts are transported in container

Static model



Design of the Bridge



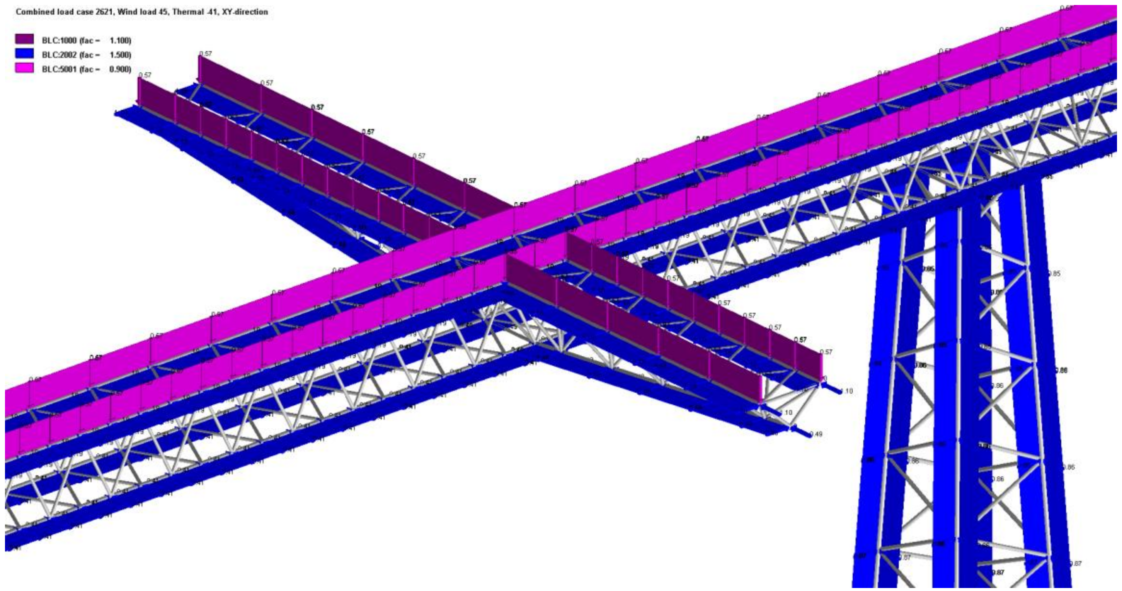
Main components

- 4 lattice towers (height 25m – 65m)
- 260m bridge lattice deck
- 30.5m cross bridge

Design of the Bridge

Design of the Bridge

- A full 3D FE model (ROSAP) with main structural members has been made for each bridge.
- Loads such as wind load, ice load and temperature are applied and combined with correct combination factors.



Advantages of tubes compared to angle profiles

- Main structural members are limited by compression capacity. The compression capacity is governed by instability of the member.

Advantages:

- Tubes are great as the moment of inertia per weight ratio is high.
- Tubes have better drag factors than flat elements such as L/profiles.
- It is difficult to get large L profiles

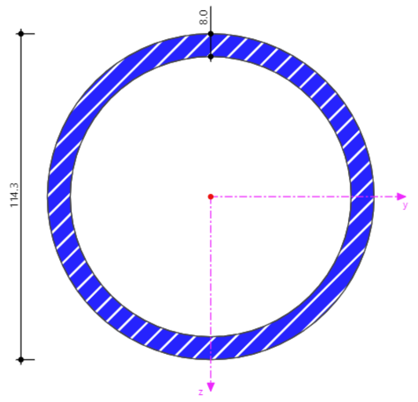
Disadvantages:

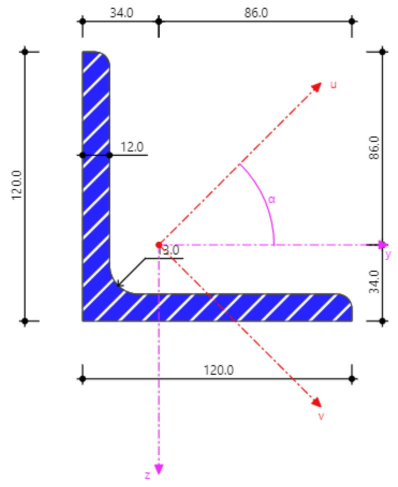
- Connections can be more difficult to produce for tubes structures.

Example:

Profile	Weight	Moment of inertia about weak axis	Drag coefficient
L120x120x12	21.6 kg/m	$1.52 \cdot 10^6$ mm^4	~2.1
Ø114.3x8	21.0 kg/m	$3.79 \cdot 10^6$ mm^4	~1.2

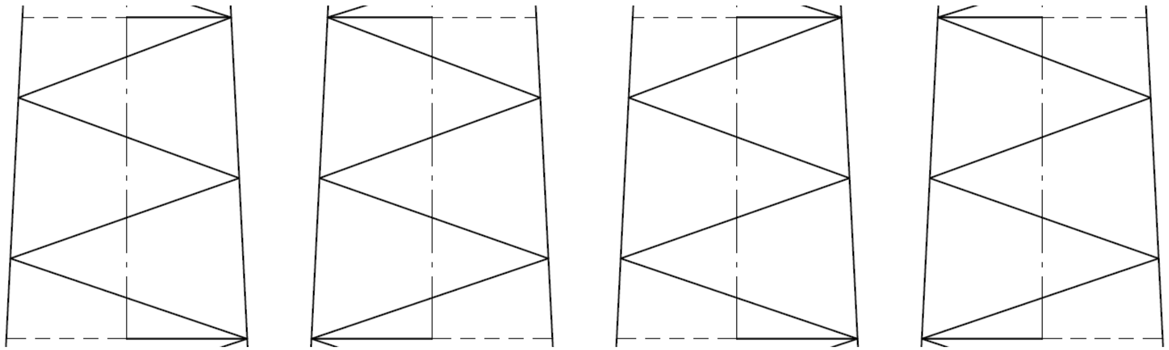
About 2.5 x higher stiffness and 0.6 x lower drag





Diamond V-lattice

- The lattice in the towers are design with a “diamond” pattern.
- This means that four diagonals meets at the same location.



Joints

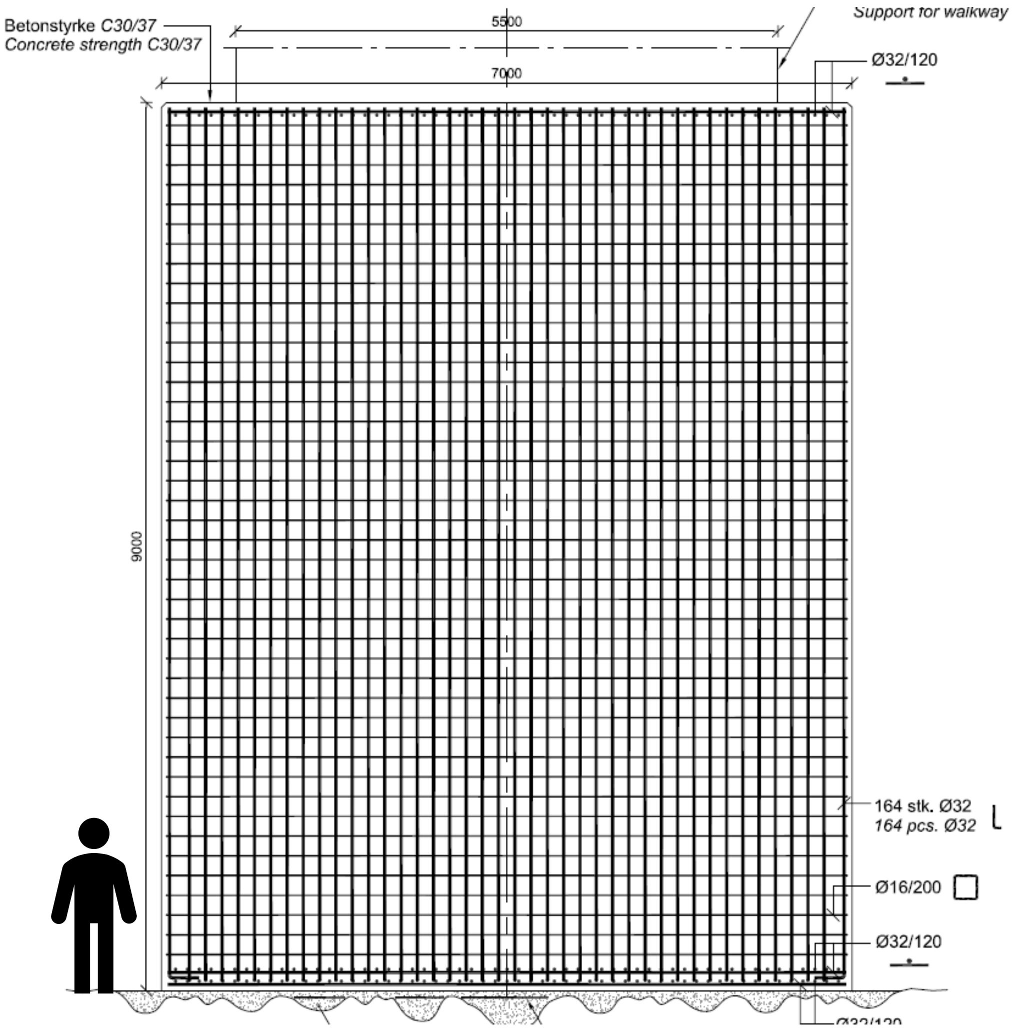
- All joints are made with bolts.
- The diagonal connection plate is made as a “fork”.
- The connection between sections is made as a flange connection.

Joints

- The walkway on top of the bridge is connected to the bridge by special clamp connections.

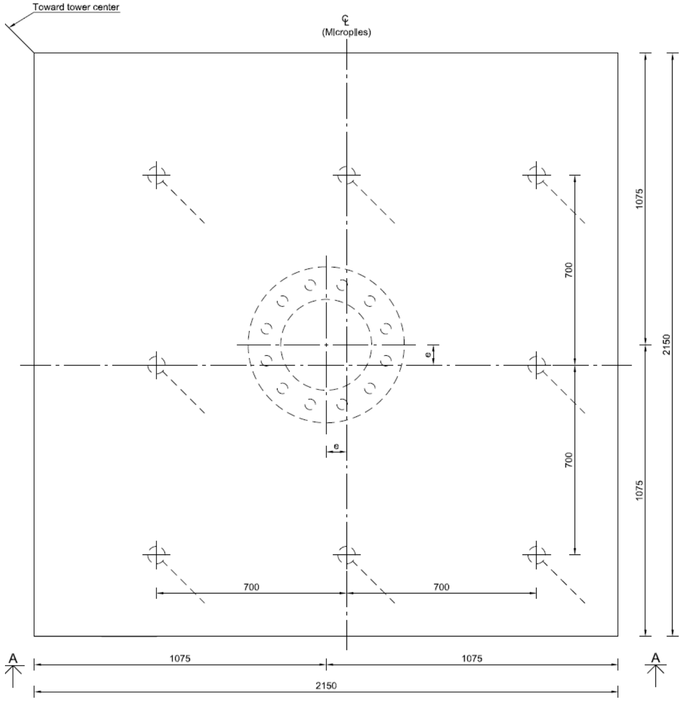
Preliminary foundation design

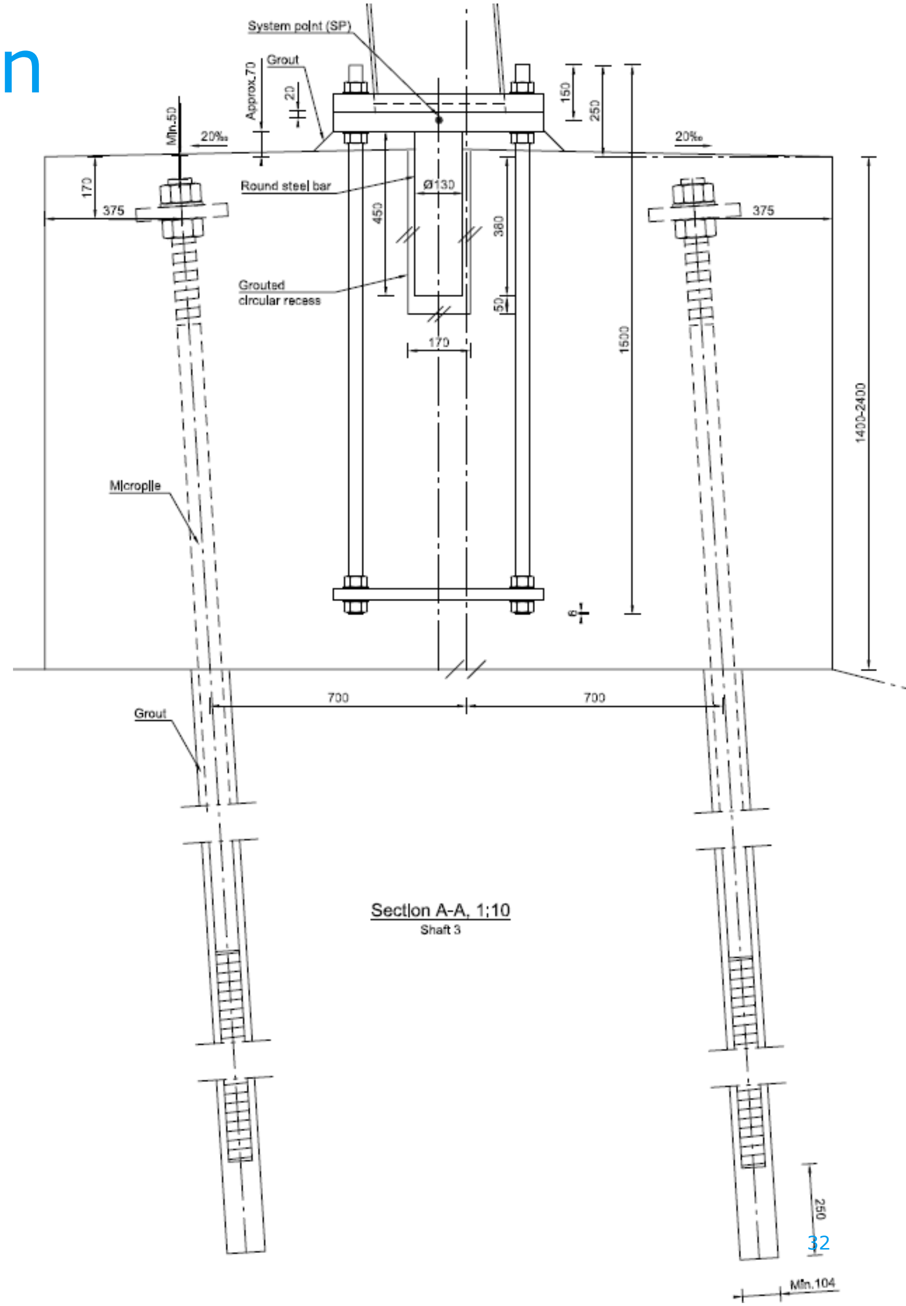
- The foundation must be able to take the tension from the bridge due to overturning moment.
- The preliminary design included huge concrete foundation blocks - Up to 9 meter high! Thus, it is the weight of the concrete that keep the bridge from turning over.
- Concrete in Greenland is difficult as the production capacity of concrete is low.
- The soil condition in Nuuk is manly good bedrock so why not utilise the rock?



Rock anchor foundation – a better solution

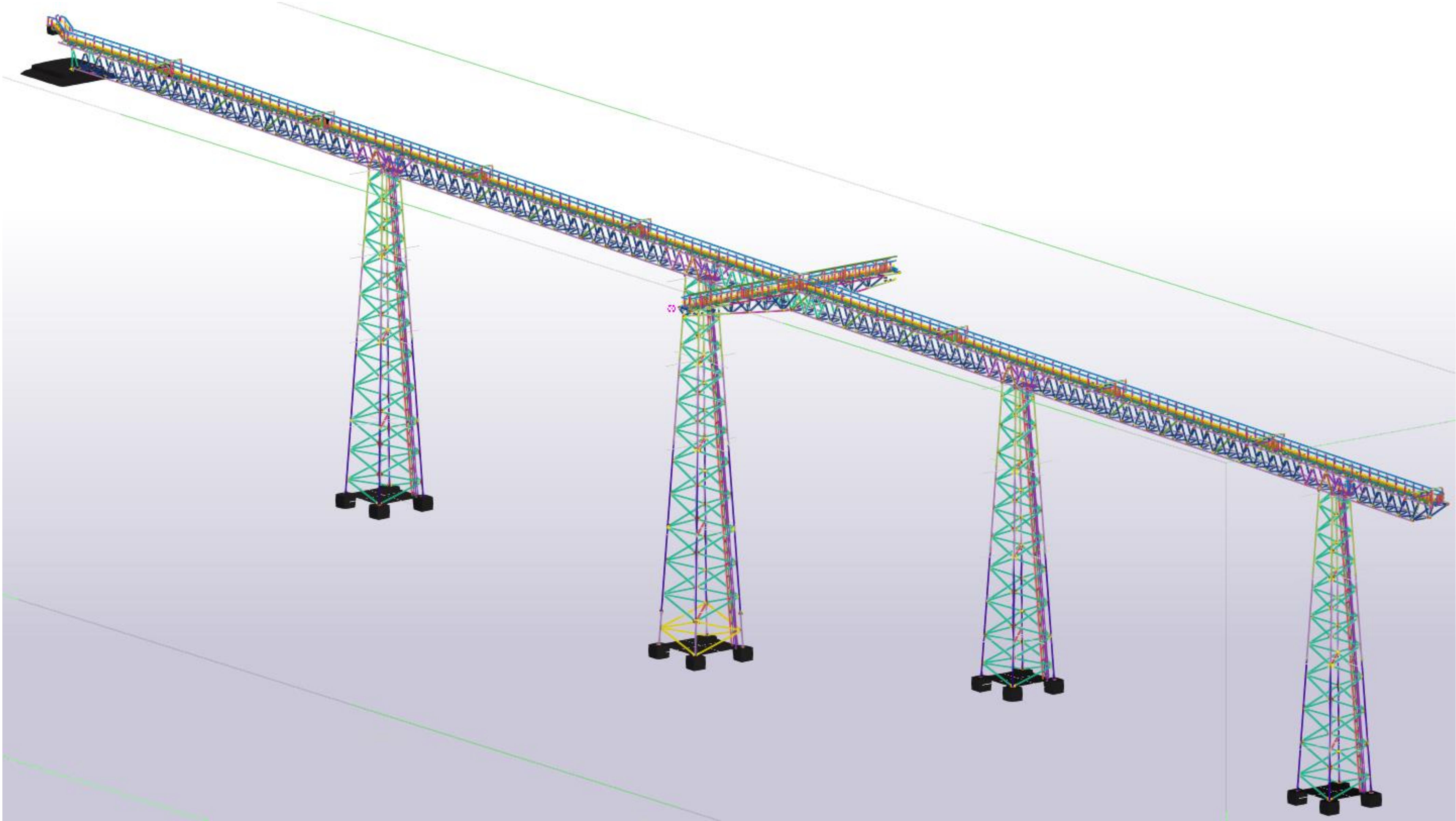
- 4 concrete blocks for each tower – one for each leg.
- The concrete block is 2.2x2.2x1.4 m.
- 8 Ø54 rock anchors per concrete block with a length of 7.5 m. The rock anchors are installed with the same inclination as the tower legs.
- In this way the tension is transferred from the leg to the bedrock.



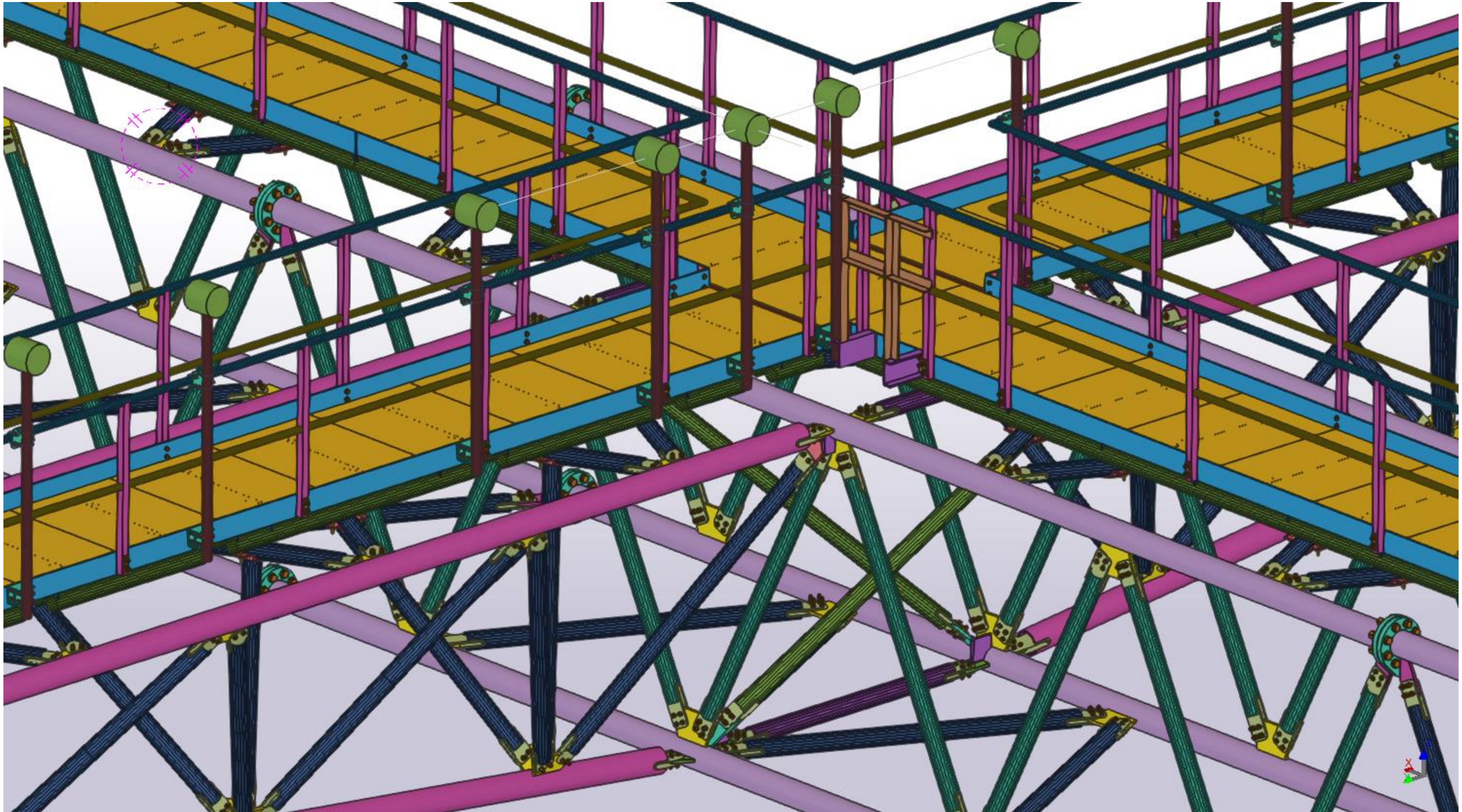


Rock anchor foundation

A full Tekla 3D model…



…Makes it easier to find clashed between elements

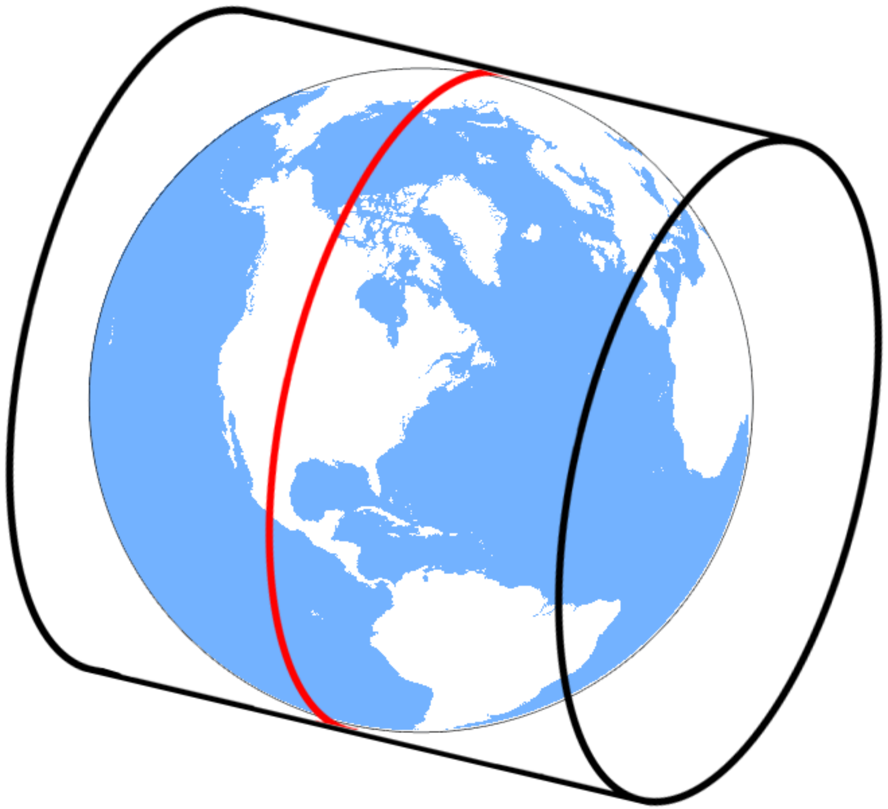


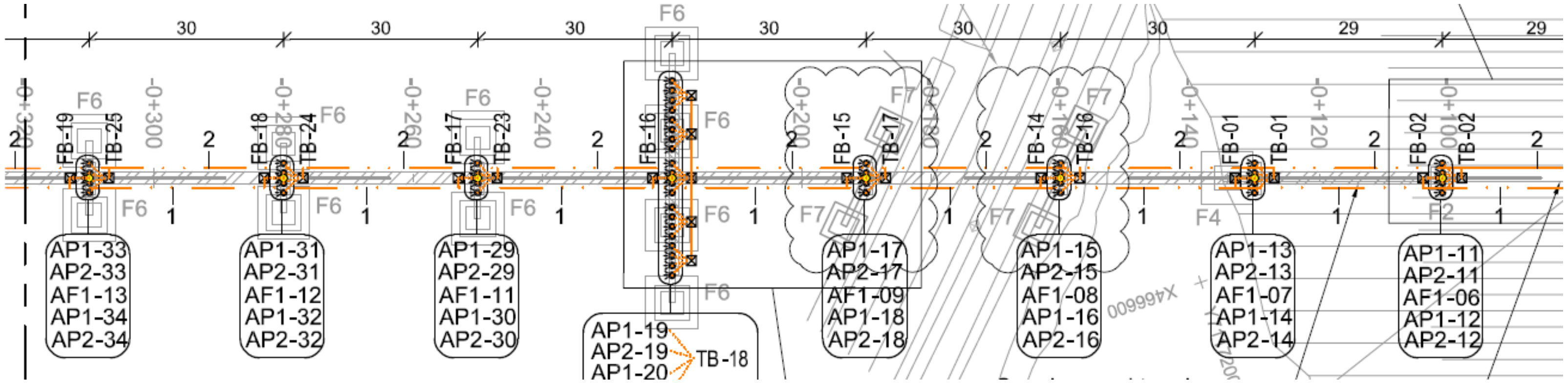
Challenges in the project

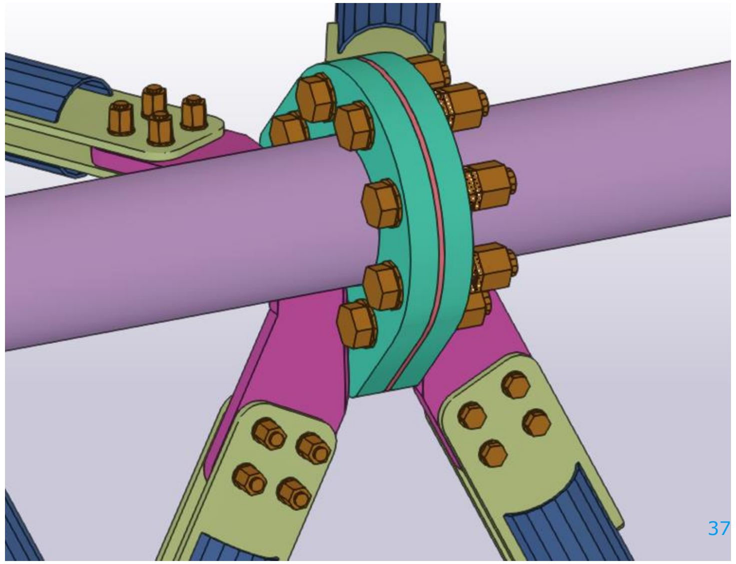
And how they were solved

Coordinate system

- The position and distance between the approach lights are given in UTM coordinates.
- UTM follows the curvature of the earth.
- A straight line from A to B should be curving in UTM to find the true distance.
- The result is that the bridge should not be 260m but 260m + 48mm due to the level of the bridge compared to ground.
- This is solved by 12 mm shim plates in the flange connections.

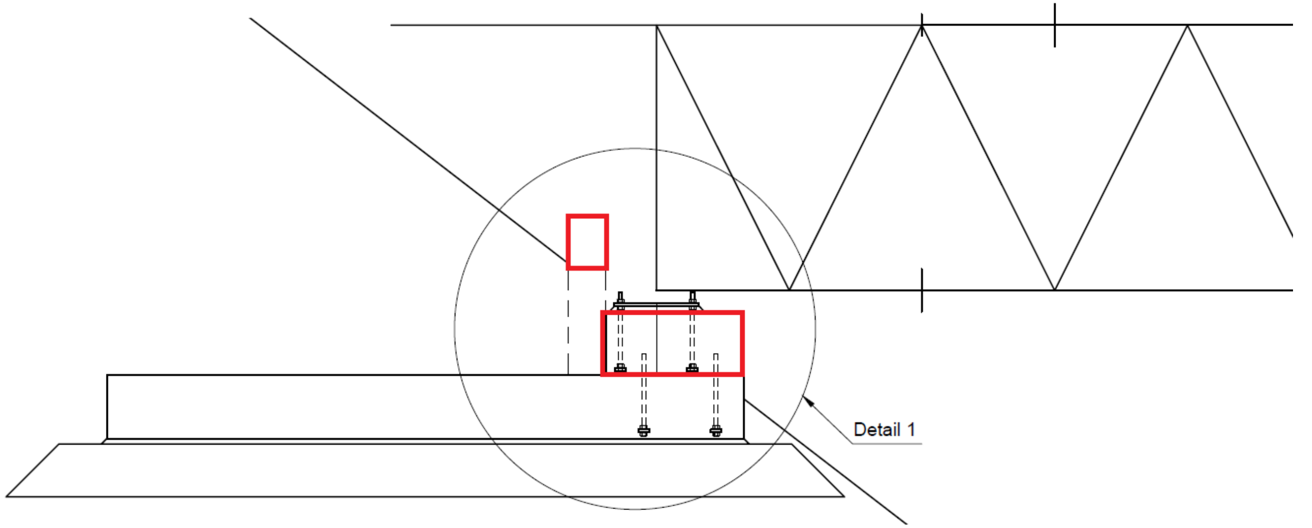


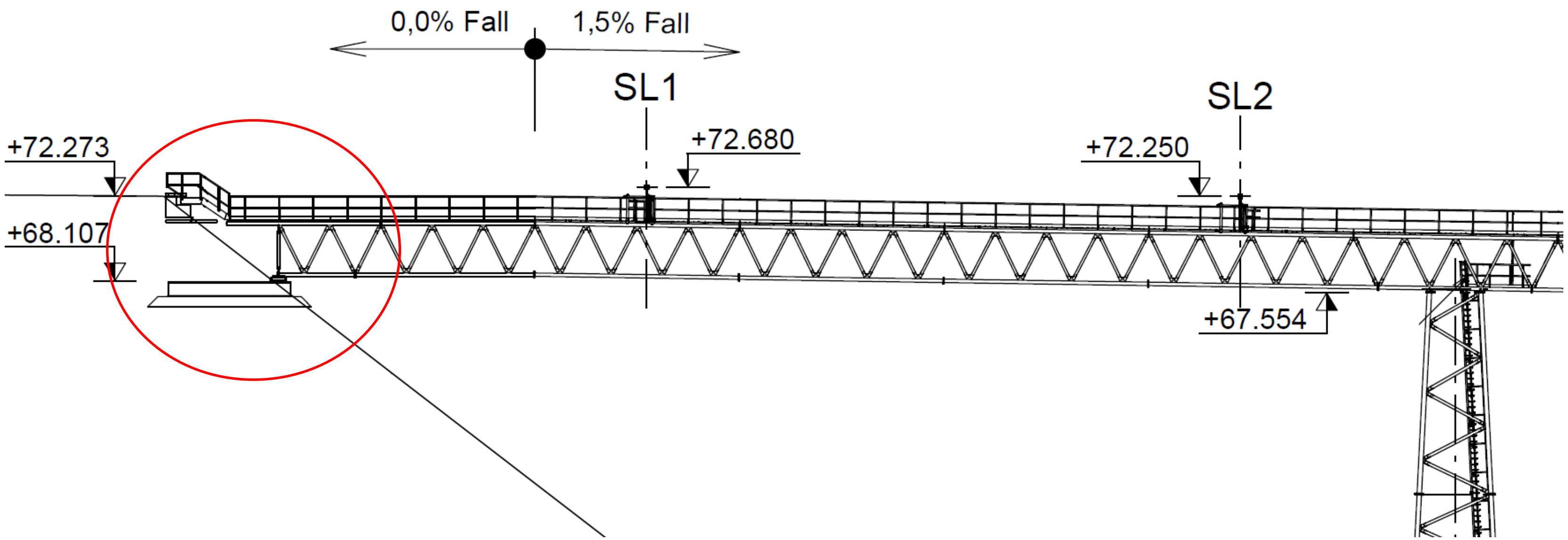




Settlements of the Landing Foundation

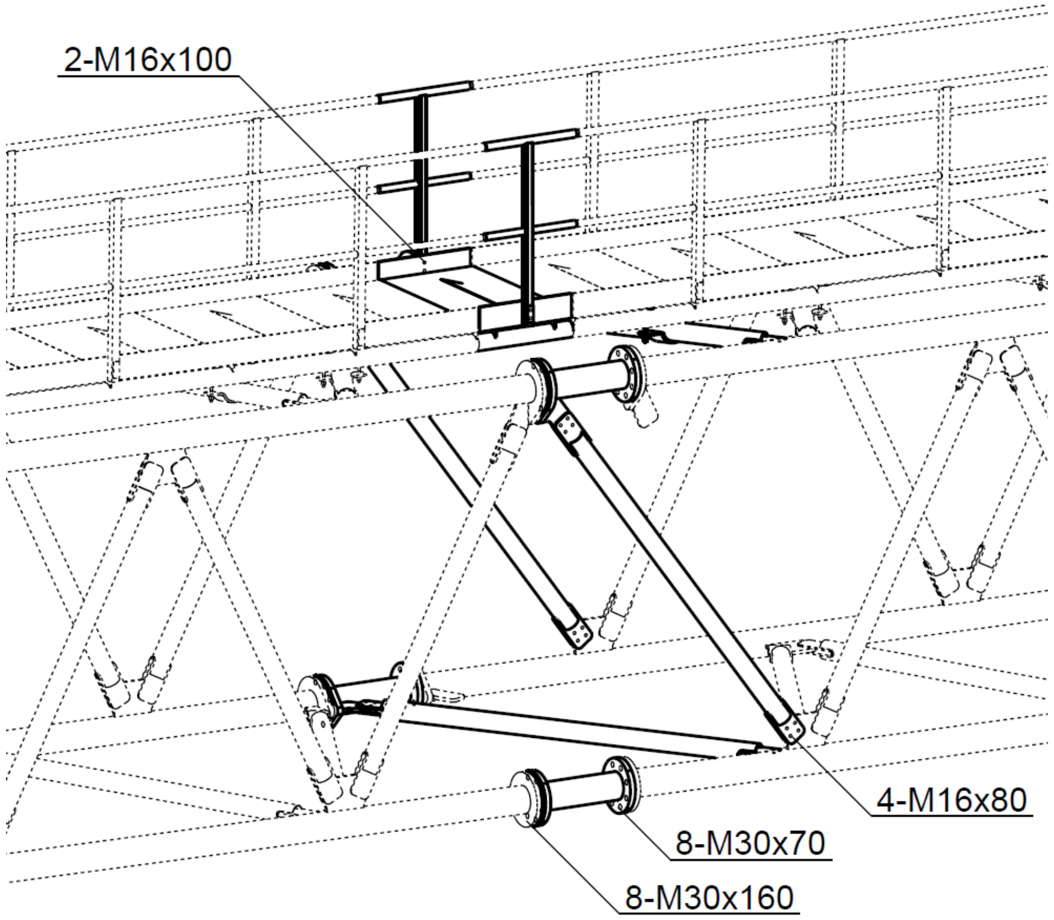
- The start of the bridge is supported directly on the slope at the edge of the runway.
- Unfortunately, the foundation moved settlements of the slope – about 0.6m - due to lack of requirement from the Client
- This was solved by casting an additional support on top of the original foundation.





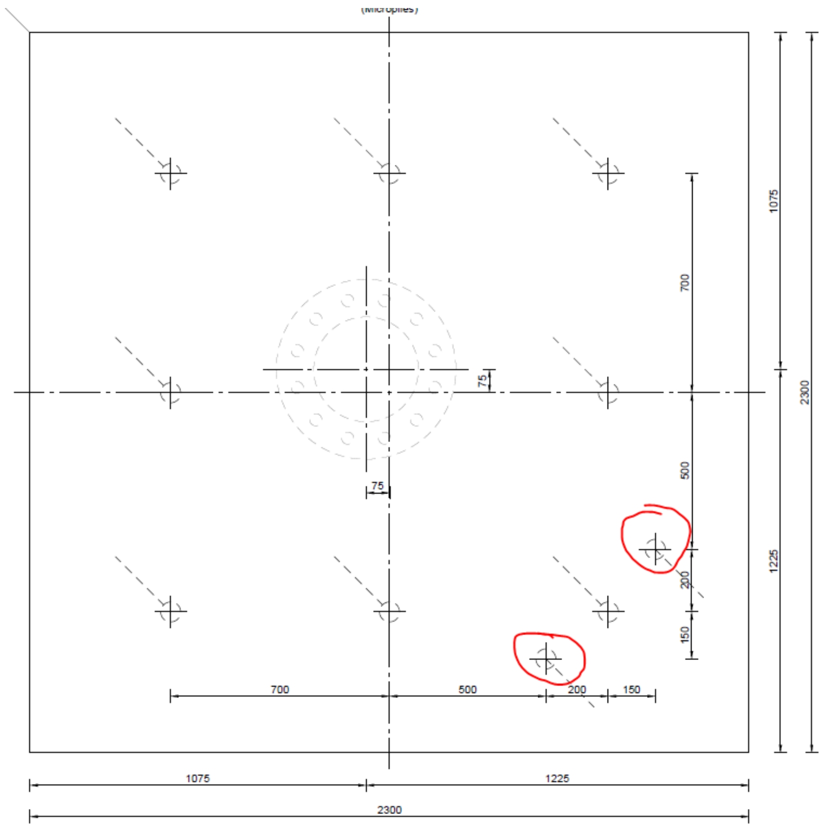
Misplacement of Foundations

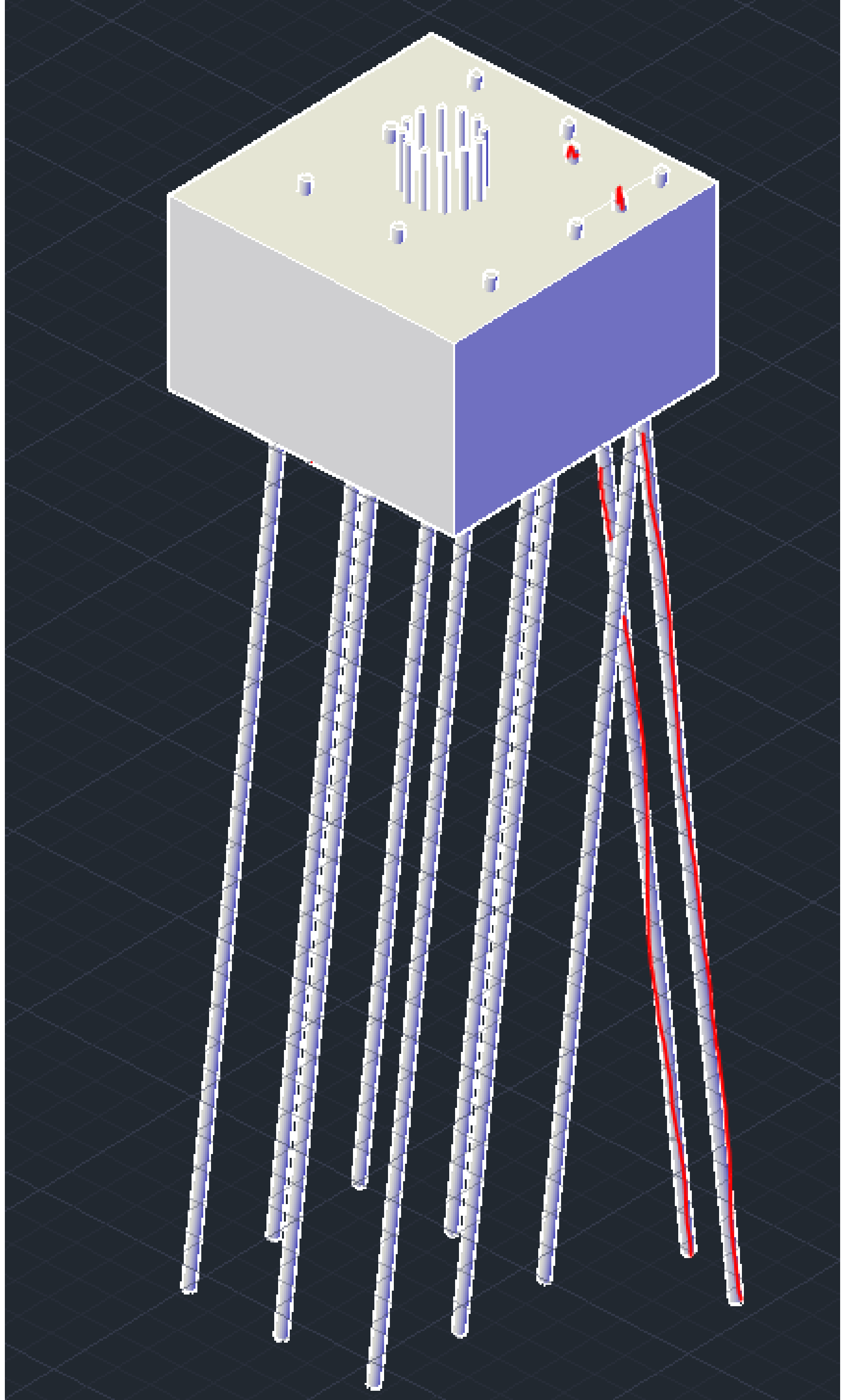
- The position of the foundations for two of the towers was not correct.
- The foundations were placed almost 600 mm further away from the correct position.
- Luckily, it could be fixed by include an extension piece between to of the towers which extents length of the bridge.
- The extension is barely visible from the ground.



Wrong direction of rock anchors

- Unfortunately, some of the anchors were installed in the wrong direction for 2 of the foundations. The angle between tower leg and anchors is ~10 degrees.
- The solution is to put 2 extra anchors in the "correct" direction.





Erection

Erection of the Bridge

Step 1 - Towers

Step 2 – Bridge deck

Step 3 – Lights

Material and CO_2 savings

Material and CO2 savings

Ways of reducing material and CO2 emission:

Change design basis:

- Svend Ole Hansen has prepared site specific wind and ice load
- Frangible light mast not necessary
- Rock anchors to be used
- Architects involved

Change in design

- Use of rock anchors instead of concrete gravity foundations
- Use of tubes instead of L-profiles
- A simpler design - Fewer towers
- No towers under cross bridge
- Utilising the cable tubes as a structural member

Improvements

- Reduce load

- Easier maintenance
- More optimised structure
- More aesthetic design

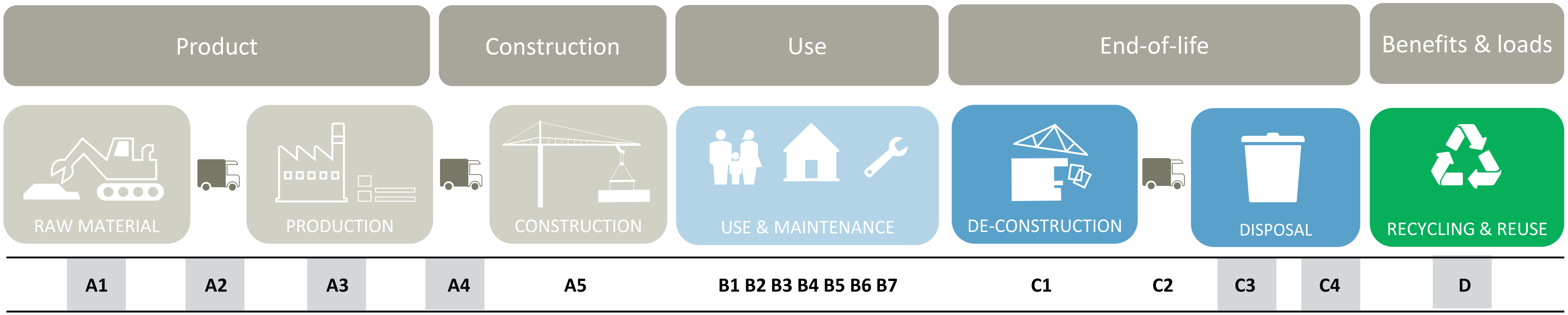
- Less Concrete
- Less steel
- Less steel and safety rails
- Less steel
- Less steel

Method and system boundaries

The calculation for this study includes the life cycle stages marked in grey in the figure below.
In accordance with EN 15978, the life cycle stages *A1-3*, *A4* and *C3-4* and *D* are assessed in this calculation, including extraction of raw materials, production and transport to construction site, end of life and the benefits and loads beyond the system boundaries. Excavation on the construction site is excluded along with maintenance/repairs and other processes that may occur during the use phase, as well as deconstruction/demolition at the end of life. The period of the life cycle analysis is set to 100 years assuming the standard life-time of a bridge as well as the expected life-time of the materials (concrete and steel) and in accordance with the (RSL) given in the EPDs.

Data for smaller components such as bolts, screws, coating for walkaway, railing etc. is included in the declared quantity for steel. Blasting of rock, fall arrest system, frangible towers, approach lights and cables are excluded from the study. As this applies to both footbridge scenarios and thus comparable, it is omitted. The study is therefore delimited to only the large components such as concrete, steel and reinforcement used for the footbridge.

Life cycle stages in accordance with European standard: EN 15978



Assumptions and reasoning

Transport at End-of-Life stage (C2) is not included in the study. Calculative, the software LCAbyg 5 supports a large part of a building’s life cycle according to EN15978, but not module C2.

At End-of Life stage (C3-4) and the Benefits and Loads stage (D), the steel and reinforcement is assumed to be sorted and separated and where most of the steel is assumed to be recycled and where the rest goes to landfilling or loss materials after sorting. At End-of Life stage (C3-4) most of the concrete is assumed to be recycled and the rest goes to landfill. The Benefits and Loads stage (D) of the concrete includes the recycling of crushed concrete as substitution of gravel in connection with the construction of roads.

Transport to construction site (A4) is included in the study.
The steel and reinforcement used for the two footbridges proposals is produced in Poland. The transport from production site in Poland to Nuuk is assumed to be carried out by Cargo Ship roughly estimated to 4000 km through Google Maps. The concrete used in the LCA variant study is produced in Denmark according to the EPD. The reason for this is the lack of availability of product specific EPD data for concrete on the market and more specific from Greenland. However, in a real-life scenario, the concrete is assumed to be produced in Greenland. The transport from production site (real-life scenario) in Greenland to the construction site is assumed to be carried out by lorry >26 t roughly estimated to 5 km through Google Maps.

For the reinforcement and concrete product-specific EPDs have been used and for the steel, generic data has been used, since the data is consistent with the steel used in the two footbridge scenarios, both in terms of e.g., production site (Poland) and steel type (hot rolled).The concrete used for the calculation, resp. C30/C35 have different class specifications (moderate and high strength). A difference between these two types of concrete, is e.g., the cement content, which e.g., leads to different results for GWP. However, this is not considered to have the decisive importance of the outcome of the overall results, but instead the large difference in the quantity of concrete for the two scenarios. However, the factor ratio is still worth having in mind.

The study is not a full LCA, but a screening assessment and the results are therefore preliminary and indicative and have not been review by a third party.

Material and CO2 savings

	Owner's design	New Design
Steel weight	750 t	521 t
Concrete volume	6300 m^3	433 m^3
Reinforcement	300 t	55 t
CO_2 emission	6194 t	1610 t
CO_2 reduction		74%

Conclusion

How to be more climate friendly:

- You can influence the CO_2 footprint on a project – even if you assist the contractor
- Think about how to improve by changing the project
- Make your solution as simple as possible – and make it flexible
- Using steel can reduce the CO_2 footprint